STATE OF CALIFORNIA
CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL COAST REGION

STAFF REPORT FOR REGULAR MEETING OF MAY 15, 2003

Prepared on April 10, 2003

ITEM NUMBER:

SUBJECT: **Duke Energy Moss Landing Power Plant, Units 1 and 2, Review of Finding No. 48, NPDES Permit Order No. 00-041, Pursuant to Order of the Monterey County Superior Court**

KEY INFORMATION

Location:.......................... Highway 1 & Dolan Road, Moss Landing
Discharge Type:................ Cooling Water, Industrial Process Wastewater and Storm Water
Design Capacity:............... 890 MGD (Existing Plant) & 1.226 BGD (Modernized Plant)
Disposal: .... Pacific Ocean, Moss Landing Harbor, Elkhorn Slough, and Moro Cojo Slough
Existing Order:……… WDR Order No. 00-041 (NPDES Permit No. CA0006254); Finding 48 concerns alternatives to minimize entrainment impacts from the cooling water intake system

SUMMARY

On February 5, 2003, the Monterey County Superior Court remanded NPDES Permit Order No. 00-041 to the Regional Board for further proceedings in accordance with its Court Order. As directed by the Court Order, this staff report is a thorough and comprehensive analysis of the "best technology available" applicable to the Duke Energy Moss Landing Power Plant (MLPP).

Regional Board staff reviewed all known intake structure technologies, such as screening devices, filters, etc., and alternatives for reducing cooling water flow, such as seasonal flow limits, variable speed pumps, and closed cooling systems.

Intake structure technologies for minimizing entrainment, such as screening devices and filters, are experimental technologies at this time. Their use at MLPP would require site-specific research. As such, these alternatives are not demonstrated available technologies for MLPP.

Seasonal flow restrictions are not applicable to MLPP because larvae are available and are entrained year round, and there are no threatened, endangered, or otherwise critical species being entrained that would benefit from this alternative. Variable speed pumps would likely offer no increased benefit beyond the current NPDES permit requirement to minimize cooling water flows by shutting down circulating water pumps when possible.

Closed cooling systems, such as mechanical draft cooling towers or dry cooling would provide a significant reduction in entrainment, up to 100%. Staff considers these alternatives to be demonstrated available technologies, and has little evidence that they could not be installed at MLPP. However, the cost of these alternatives is estimated to be approximately $47 million to $124 million.

The estimated value of the entrainment losses is $1.2 to $9.7 million based on staff's habitat equivalency conversion method. Staff and the Regional Board's independent scientists believe that the habitat equivalency method is the best way to interpret and value the entrainment losses because it addresses the underlying basis of larval production—increased habitat quantity and quality over the long-term. Other methods are available, such as conversion of entrainment losses to commercial fishing values, but the result (thousands of dollars per year) only represents a utilitarian use. Another value to consider is the change that would occur in the

Elkhorn Slough area if closed cooling systems were installed. Staff assumes there would be a beneficial change, but believes that the benefit (biological change) could not be differentiated from changes caused by the many other factors acting on Elkhorn Slough.

Staff's conclusion is that intake structure alternatives (such as screens and filters) for reducing entrainment are experimental and therefore not demonstrated available technologies for MLPP, and that the cost of closed cooling systems is wholly disproportionate to their benefit.

Staff recommends the Regional Board determine that the weight of the evidence supports Finding No. 48 of the NPDES Permit for MLPP, which states that the costs of alternative cooling technologies are wholly disproportionate to the benefit to be gained.

DISCUSSION

The Regional Board adopted NPDES Permit Order No 00-041 On October 27, 2000. The Order was appealed to the State Board, which upheld the Order with minor additions. A lawsuit was subsequently filed in Monterey County Superior Court alleging the once-through cooling water system for Units 1 and 2 authorized by the NPDES Order did not comply with Section 316(b) of the Clean Water Act. On February 5, 2003, the Court remanded the NPDES Permit Order to the Regional Board for further proceedings. The Court found that a sentence in the NPDES Order: "…in this case the costs of alternatives to minimize entrainment impacts are wholly disproportionate to the environmental benefits…" was not supported by the weight of the evidence because of the lack of a "comprehensive, definitive, consideration of cooling water alternatives." The Court did not reject the Regional Board's wholly disproportionate cost test. Accordingly, this report is a comprehensive, definitive consideration of cooling water alternatives.

As described in previous staff reports to the Regional Board (September 2000, October 2000), staff formed a technical workgroup to oversee the biological studies related to Moss Landing Power Plant (MLPP). Staff also hired independent scientific experts familiar with Elkhorn Slough to participate in the technical workgroup and direct the biological studies. The Regional Board's independent scientists on this project are Dr. Greg Cailliet, Moss Landing Marine Laboratories, and Dr. Pete Raimondi, UC Santa Cruz. These scientists are independent from, and have never worked for, the discharger.

Dr. Cailliet is a professor of ichthyology, marine ecology, population biology, and fisheries biology, with main interests in community and population ecology, biological oceanography, marine plankton and nekton, and estuarine ecology. Dr. Cailliet has long-term, first hand knowledge of the Elkhorn Slough area and its biological and physical history.

Dr. Raimondi is a professor of ecology and evolutionary biology whose research emphasizes nearshore marine communities. He also has substantial experience on the design, evaluation and analysis of marine monitoring programs, with particular expertise on the evaluation of marine discharges. Dr. Raimondi is currently directing the largest intertidal monitoring program in the world (through the Partnership for Interdisciplinary Studies of Coastal Oceans, or PISCO).

Dr. Cailliet and Dr. Raimondi have extensive experience as independent scientists on several power plant projects in California. The technical workgroup also included California Energy Commission staff and their independent scientist, Dr. Michael Foster, Moss Landing Marine Labs. Dr. Foster is a professor of marine biology (retired), with expertise in kelp forest ecology and intertidal communities. The technical workgroup directed Duke Energy's entrainment study, including all aspects of the study design and implementation.

The results of the entrainment study indicate that the new power generation units at Moss Landing Power Plant (MLPP) will cause an estimated 13% loss of larvae (average loss for the taxa entrained) from the Elkhorn Slough/Moss Landing Harbor area. These results are reported in Duke Energy's *Moss Landing Power Plant Modernization Project 316(b) Demonstration Study*, 2000.

Cooling Water Alternatives Analysis

Regional Board staff relied on recent information from the U.S. Environmental Protection Agency (USEPA) to determine the availability of intake structure technologies, closed cooling alternatives, and costs. Many other references were also used, and a complete list of references is included at the end of this staff report. These references are part of the record for this case.

There are two potential ways of addressing entrainment losses:

1. Intake Structure Technologies
   a. Screening or filtering systems
2. Reduced Cooling Water Volume
   a. Variable speed pumps
   b. Seasonal flow limitations
   c. Closed cooling systems (cooling towers, dry cooling)

Only technologies that may reduce entrainment at MLPP are relevant to this analysis. It should be noted that Regional Board staff assumes 100% mortality of all organisms entrained in the once-through cooling water system at MLPP. This is a common assumption for entrainment studies (USEPA *Phase II Technical Development Document, Chapter A7: Entrainment Survival*, 2003), included here as Attachment 1. Utility companies have done several studies since the 1970's to determine if this general assumption is correct, and the results of these studies indicate that entrainment mortality is highly variable and can be low for some taxa (meaning the assumption of 100% mortality may be too conservative). However, the USEPA states, and Regional Board staff agrees, that data regarding survival of entrained taxa must be quite rigorous to be convincing. USEPA concludes that the entrainment survival studies done to date are <u>not</u> convincing, and that there is not enough evidence to assume less than 100% mortality of entrained organisms. USEPA states that data from a particular facility cannot be used to predict entrainment survival at another facility due to the many variables involved. Moreover, the number of variables involved are so numerous that the studies conducted to date should be viewed as a "provocative set of anecdotes that demonstrate the need for further study, but do not provide the basis for making predictions."

<u>This principle (the need for rigorous data) must be applied to studies that have been done on intake structure technologies as well, as discussed below. Without rigorous data to demonstrate the capability of various intake structure technologies to reduce entrainment mortality, we cannot conclude or predict that the technology will be successful at a specific site. This is a critical part of the analysis.</u> Note that intake technologies do not include closed cooling systems, such as cooling towers, which are discussed separately.

Intake Structure Technologies

Intake structure technologies are evaluated in detail in the report: *Preliminary Regulatory Development, Section 316(b) of the Clean Water Act, Background Paper Number 3: Cooling Water Intake Technologies,* 1994 (hereafter Background Paper No. 3). This report was prepared by Science Applications International Corporation (SAIC), an <u>independent consultant</u> to the USEPA, and is included here as Attachment 2 (that is, Background Paper No. 3 is included with this staff report as Attachment 2). The USEPA directs agencies to use Background Paper No. 3 when implementing section 316(b) of the Clean Water Act. Background Paper No. 3 describes all potential intake structure technologies, as follows:

1. Intake Screen Systems
   a. Single entry, single exit vertical traveling screens (conventional)
   b. Modified vertical traveling screens
   c. Inclined single entry, single exit traveling screens
   d. Single entry, double exit traveling screens
   e. Double entry, single exit traveling screens (dual flow)
   f. Horizontal traveling screens
   g. Fine mesh screens mounted on traveling screens
   h. Horizontal drum screens
   i. Vertical drum screens
   j. Rotating disk screens
   k. Fixed screens
2. Passive Intake Systems
   a. Wedge wire screens
   b. Perforated pipes

   c. Radial wells
   d. Porous dikes
   e. Artificial filter beds
3. Fish Diversion or Avoidance Systems (impingement only)
   a. Louver barriers
   b. Velocity cap
   c. Fish barrier nets
   d. Air bubble barriers
   e. Electrical barriers
   f. Light barriers
   g. Sound barriers
   h. Cable and chain barriers
   i. Water jet curtains

Background Paper No. 3 includes a description of each technology and corresponding Fact Sheets that describe where the technology is being used, advantages and disadvantages, research findings, and design considerations (Attachment 2). The conclusions are summarized below.

Regarding intake screen systems listed under Number 1 above, Background Paper No. 3 states: "The main finding with regard to intake screen systems is that they are limited in their ability to minimize adverse aquatic impacts." The report also states that "there has also been an interest in the use of fine-mesh mounted on traveling screens for the minimization of entrainment. However, the use of fine-mesh mounted on traveling screens has not been demonstrated as an effective technology for reducing mortality of entrainment losses." This is an important issue. Both once-through cooling <u>and screening technologies</u> cause mortality of organisms. The net benefit of a screening technology must be measured as a reduction in overall mortality. If the screening technology prevents entrainment of larvae and eggs, but simply replaces entrainment mortality with screening induced mortality, there is no benefit. The screening technologies are currently experimental. Site-specific and species specific research must be done to determine their potential effectiveness at a particular power plant.

With respect to passive screens listed in Number 2 above, Background Paper No. 3 concludes: "The main findings for passive intake systems are that available technologies that effectively reduce fish eggs and larvae entrainment are extremely limited." Radial wells and wedgewire screens are the only alternatives considered to have potential for reducing entrainment mortality, but they are not used on large scale systems such as MLPP. Radial wells are literally ground water wells, and are used on small-scale applications, not on facilities like MLPP Units 1 and 2, which require a total cooling capacity of 360 million gallons per day (mgd). Wedgewire screens are also limited in their application, as discussed later in this report.

With respect to fish diversion and avoidance systems listed in Number 3 above, Background Paper No. 3 concludes: "The main finding relative to fish diversion and/or avoidance systems is that none of the corresponding technologies protect organisms and/or fish that are non-motile or in early life stages." That is, these technologies do not reduce entrainment.

Regional Board staff agrees with the conclusions of Background Paper No. 3. The data collected on intake technologies to date are limited, highly variable, site-specific, and species-specific. The only technologies that <u>may</u> apply to MLPP for the purpose of reducing entrainment mortality are certain screening technologies, such as fine mesh screens, but they are considered experimental. The only way to determine the effectiveness of a screening technology at MLPP is to conduct site-specific research, with independent scientific experts overseeing all aspects of the work. Such research would likely take years to complete, and the total costs are unknown.

A comprehensive review of intake technologies is also provided in *Fish Protection at Cooling Water System Intakes: Status Report*, EPRI, 1999 (hereafter EPRI 1999). EPRI is the Electric Power Research Institute, Inc., of Palo Alto, California. Utility companies fund EPRI, which in turn sponsors research on utility industry issues. The EPRI report is not attached here due to its size (about 380 pages), but is available for review at the Regional Board office and is part of the record. The conclusions of EPRI 1999 are similar to the conclusions of Background paper No. 3, that is, more research is needed on the various intake structure technologies before their applicability can be determined. In addition, USEPA recently summarized information for the intake technologies considered to have *potential* for reducing entrainment and impingement in their *Phase II Technology Development Document, Chapter 3: Efficacy of Cooling Water intake Structure Technologies*, 2003 (hereafter TDD Chapter 3). Much of the language below is taken from TDD Chapter 3.

Description and Efficacy of Cooling Water Intake Screen Technologies with Potential to Reduce Entrainment

To support their draft Section 316(b) proposed rule for existing facilities, the USEPA compiled data on the performance of the screening technologies currently used to minimize impingement and entrainment at power plants nationwide. The goal of the USEPA's data collection and analysis effort has been to determine whether specific technologies can be demonstrated to provide a consistent level of proven performance. This is a critical point—technologies must be demonstrated to provide a consistent level of performance for them to be considered as available technologies. The USEPA used this information to compare specific regulatory options and their associated costs and benefits, and ultimately to support USEPA's draft 316(b) rule for existing facilities.

As mentioned above, the Electric Power Research Institute compiled the most recent national data on intake technologies (EPRI 1999). The findings of EPRI 1999 are cited by the USEPA in their work, and are therefore represented here. It is important to realize that studies done at various power plant facilities used different methodologies, were done at different times, and with different goals and objectives, and that there is significant variability in the information available from different sources. The following should be understood:

1. A compilation of data under these circumstances can only provide an indication of potential performance results for the various screening technologies. Actual performance results are entirely site-specific and species-specific.
2. Some facility data include all of the major species and associated life stages present at an individual facility. Other facilities only include data for selected species and/or life stages. Much of the data were collected in the 1970s and early 1980s, when existing facilities were required to complete their initial 316(b) demonstrations.
3. Some facility data includes only initial survival results, while other facilities have 48 to 96-hour survival data. These data are relevant because some taxa can exhibit significant latent mortality after initial survival.
4. The USEPA did not review data collection or reporting procedures, including quality assurance/quality control protocols. Some data come from laboratory and pilot-scale testing rather than full-scale evaluations.

The intake structure technologies discussed below are those that USEPA considers as *potentially* capable of reducing entrainment. Regional Board staff also evaluated these technologies with respect to MLPP.

Cylindrical Wedgewire Screens: Wedgewire screens are designed to reduce entrainment by physical exclusion and by exploiting hydrodynamics. Physical exclusion occurs when the mesh size of the screen is smaller than the organisms susceptible to entrainment. The screen mesh ranges from 0.5 to 10 mm. Hydrodynamic exclusion results from maintenance of a low through-slot velocity, which, because of the screen's cylindrical configuration, is quickly dissipated, thereby allowing organisms to escape the flow field. Adequate countercurrent flow is needed to transport organisms away from the screens (such as in a river system). Wedgewire screens may also be referred to as profile screens or Johnson screens.

Wide mesh wedgewire screens have been used at two "high flow" power plants: J.H. Campbell Unit 3 (770 MW) and Eddystone Units 1 and 2 (approximately 700 MW combined). At Campbell, Unit 3 withdraws 400 mgd of water from Lake Michigan approximately 1,000 feet from shore, but uses a 10-mm wedgewire screen, which addresses impingement, not entrainment (a fine mesh screen of 0.5-mm or less is necessary to reduce entrainment). Eddystone Units 1 and 2 withdraw over 500 mgd of water from the Delaware River. However, Eddystone uses a wedgewire screen mesh size of 6.4-mm, which is also too large to address most of the entrained organisms.

Other plants with lower intake flows have installed wedgewire screens but there are limited biological performance data for these facilities. The Logan Generating Station in New Jersey withdraws 19 MGD from the Delaware River through a 1-mm wedgewire screen. Entrainment data show 90 percent less entrainment of larvae and eggs then conventional screens. No impingement data are available. Unit 1 at the Cope Generating Station in South Carolina is a closed cycle unit that withdraws about 6 MGD through a 2-mm wedgewire screen, however, no biological data are available. Performance data are also unavailable for the Jeffrey Energy Center, which withdraws about 56 MGD through a 10-mm screen from the Kansas River in Kansas. The system at the Jeffrey Plant has operated since 1982 with no operational difficulties. Finally, the American Electric Power Corporation has installed wedgewire screens at the Big Sandy (2 MGD) and Mountaineer (22 MGD) Power Plants, which withdraw water from the Big Sandy and Ohio River respectively. Again, no biological test data are available for these facilities.

The USEPA concludes that wedgewire screen technology has not been widely applied in the power plant industry to date. It has only been installed at a handful of power plant facilities nationwide. The lack of more representative full-scale plant data makes it impossible to conclude that wedgewire screens can be used in all environmental conditions. There are no full-scale data specifically for marine environments where biofouling and clogging are significant concerns, as would be the case at MLPP. In addition, a crosscurrent flow, such as would be present in a river, is imperative for organisms to move or be carried away from the screens. Most of the wedgewire screens installed to date are in river systems, where cross current flow is natural.

Regional Board staff agrees with USEPA's conclusion regarding the limited data available for wedgewire screen technology. There are no data for sites similar to MLPP, where biofouling is a major concern, and cross current flows (as found in a river system) are not present. Also, Regional Board staff does not accept the entrainment reduction numbers above from EPRI 1999. There is no context for these values, that is, how the studies were done, how mortality was determined, the number of taxa considered, independent review, etc. Accordingly, the results only provide an indication that wedgewire screens may be effective in some applications. There is no evidence that the screens could function in a marine environment, using 0.5-mm mesh, on a large volume facility. Therefore, wedgewire screens are not a demonstrated available technology for an environment such as Moss Landing, or for a facility like MLPP.

Fine-Mesh Screens: Fine-mesh screens are typically mounted on conventional traveling screens in an attempt to exclude eggs, larvae, and juvenile forms of fish from intakes. The excluded organisms are impinged on the fine mesh screen, and must be rinsed of the screen and returned to the source water body. Fine mesh screens generally include those with mesh sizes of 5-mm or less. As noted above, staff believes a minimum mesh screen size of 0.5-mm is necessary to address entrainment unless site-specific research demonstrates otherwise.

USEPA states that fine mesh screens with fish return systems show promise for controlling entrainment and impingement. However, they have not been installed, maintained, and optimized at many facilities. The most significant example of long-term fine mesh screen use has been at the Big Bend Power Plant in the Tampa Bay area. The facility has an intake canal with 0.5-mm mesh Ristroph screens that are used seasonally on the intakes for Units 3 and 4. During the mid-1980s when the screens were initially installed, their efficiency in reducing entrainment and impingement was highly variable. The operator, Florida Power & Light (FPL), evaluated different approach velocities and screen rotational speeds. In addition, FPL recognized that frequent maintenance (manual cleaning) was necessary to avoid biofouling. By 1988, system performance had apparently improved. <u>The available biological data for this case is limited, and the thoroughness and efficacy of the studies are unknown (as with other mortality studies for intake technologies)</u>. The system's efficiency in screening fish eggs (primarily drums and bay anchovy) reportedly exceeded 95 percent with

80 percent latent survival for drum and 93 percent for bay anchovy. For larvae (primarily drums, bay anchovies, blennies, and gobies), screening efficiency was 86 percent with 65 percent latent survival for drum and 66 percent for bay anchovy (an overall effectiveness of 0.86 x 0.66 = 0.57 for bay anchovy). Latent survival in control samples was also approximately 60 percent. More recent data are not available for this facility.

Additional full-scale performance data for fine mesh screens at large power stations (>100 mgd) are not available. Background paper No. 3, Fact Sheet 7, Attachment 2, illustrates the high variability of effectiveness for this technology, and states: "Generally, the use of fine mesh on conventional traveling screens has not been demonstrated as an effective technology for reducing mortality or entrainment losses." This statement is referenced to EPRI, 1989. A more recent conclusion regarding fine mesh screens in EPRI 1999 states: "While survival of some aquatic organisms has been shown to be high, fragile species and life stages exhibit low survival, and may actually survive better with course mesh screens that allow them to pass through the cooling water system..." Regional Board staff conclude that fine mesh screen technology has *potential* for reducing entrainment, but the alternative is not a demonstrated available technology for reducing entrainment at MLPP. The effectiveness of the screens at reducing entrainment mortality could only be determined through testing and research at MLPP.

Tetra Tech's *Evaluation Of Cooling System Alternatives, Proposed Morro Bay Power Plant*, 2002, report to the Regional Board estimates the cost of fine mesh screens for the proposed Morro Bay Power Plant at $8 million. This report is included here as Attachment 3. The proposed Morro Bay Power plant is very similar to the MLPP Units 1 and 2, so the costs estimate is a valid comparison here. This cost estimate does not reflect the experimental nature of the technology because it does not include pilot and full-scale testing, comprehensive mortality studies, oversight by independent scientists, and downtime for the Power Plant.

Aquatic Microfiltration Barriers: Aquatic microfiltration barrier systems are barriers that employ a filter fabric designed to allow for passage of water into a cooling water intake structure, but exclude aquatic organisms. The Regional Board's Technical Workgroup for MLPP and the Morro Bay Power Plant projects spent considerable time considering this technology. These systems are designed to be placed in front of the intake structure, and because of the fine mesh size and very low through-filter velocity, a huge surface area is needed. These systems may be floating, flexible, or fixed. Since these systems generally have such a large surface area, the velocities that are maintained at the face of the permeable curtain are very low. One company, Gunderboom, Inc., has a patented full-water-depth filter curtain comprised of polyethylene or polypropylene fabric that is suspended by flotation billets at the surface of the water and anchored to the substrate below. The curtain fabric is manufactured as a matting of minute unwoven fibers with an apparent opening size of 20 microns. Gunderboom systems also employ an automated "air burst" system to periodically shake the material and pass air bubbles through the curtain system to clean it of sediment buildup and release any other material back into the water column. Regional Board staff and the Board's independent scientists have major concerns about biofouling and long-term performance of this system.

USEPA concludes that microfiltration barriers, including the Gunderboom, show potential for minimizing entrainment, but that the technology is currently "experimental in nature." Currently, the only power plant where the Gunderboom has been used at a full-scale level (but seasonal) is the Lovett Generating Station along the Hudson River in New York, where pilot testing began in the mid-1990s. Initial testing at this facility showed significant potential for reducing entrainment. Entrainment reductions up to 82 percent were observed for eggs and larvae and these levels have been maintained for extended month-to-month periods during 1999 through 2001. There have been operational difficulties that have affected long-term performance, including tearing, overtopping, and plugging/clogging, which were addressed to a large extent through subsequent design modifications. Gunderboom, Inc. specifically designed and installed a "microburst" cleaning system to remove particulates. Each of the problems at Lovett could be a significantly greater concern at marine sites with higher debris flows. More information of filter systems is available in USEPA's TDD Chapter 3, 2003.

A major problem with this system is the surface area needed to maintain very low through-filter velocities. With a 20-micron mesh, and a flow rate of 250,000 gpm, the filter system for MLPP would be 1,250 feet long (assuming 20 foot depth). It is highly unlikely that a structure of this size could be placed in Moss Landing Harbor due to navigation issues. Regional Board staff concludes that these filter systems have *potential* for addressing entrainment at appropriate locations, but there are very little data available, and therefore these systems are not a demonstrated available technology for MLPP.

Porous Dikes: Porous dikes, also known as leaky dams, are filters resembling a breakwater surrounding a cooling water intake. The core of the dike consists of cobble or gravel that permits free passage of water. The dike acts both as a physical and behavioral barrier to aquatic organisms. Tests conducted to date have indicated that the technology is effective in excluding juvenile and adult fish. The major problems associated with porous dikes come from clogging by debris and silt, ice build-up, and by colonization of fish and plant life. EPRI 1999 concludes: "No recent research has been performed with porous dikes, sand filters, and infiltration intakes. While these fish protection concepts are often discussed, no practical way to apply them to CWIS (cooling water intake systems) has been identified." Staff agrees.

Variable Speed Pumps: In theory**,** variable speed pumps may reduce entrainment rates in some cases by decreasing cooling water flows relative to fixed speed pumps. At MLLP Units 1 and 2, there are three pumps per Unit, or a total of six pumps, rated at 42,000 gpm each. The existing NPDES permit for MLPP requires the discharger to minimize cooling water flows by shutting down cooling water pumps when possible. Staff is not aware of any research comparing variable speed pumps to a group of single speed pumps that can be individually shut down when power demand decreases. Staff has no evidence to support the use of variable speed as a method for reducing entrainment at MLPP. USEPA's *Technical Development Document, Chapter 2: Costing Methodology for Model Plants*, which includes *Appendix B: Technology Cost Curves*, 2003, is included here as Attachment 4. From USEPA's Cost Curves, variable speed pumps for MLPP would be approximately $1 million based on a flow rate of 250,000 gpm.

Seasonal Flow Limitations: Seasonal flow limitations are applicable in cases where one or more particularly important species (such as endangered or threatened species) are present and being entrained. This is not the case at MLPP, where no such species were identified in the entrainment sampling program (*Moss Landing Power Plant Modernization Project, 316(b) Resource Assessment*, Duke Energy, 2000). At MLPP, larvae are available and entrained throughout different seasons, and seasonal flow limits would require choosing some species over others for protection. This alternative is not recommended at MLPP as there is no practical way to choose certain taxa as being more important than others unless there are threatened or endangered species present. The cost (lost revenue) of seasonal flow restrictions depends on the duration and magnitude of the seasonal limitation and energy prices. The costs could range into the tens of millions depending on these factors. Duke Energy estimated the cost of an assumed seasonal flow limit scenario in its 316(b) Resource Assessment. For the scenario assumed, Duke Energy estimated the cost at approximately $58 million. This value is valid only for the assumed scenario and the assumptions made for the variables involved. Nevertheless, the cost of any significant flow limitation would likely be in the tens of millions per year range simply based on the size of the Power Plant (1060 MW) and the value of the power generated.

Tetra Tech included total revenue estimates for various power plants in their *Evaluation of Cooling System Alternatives, Proposed Morro Bay Power Plant, M*ay 2002, report to the Regional Board (Attachment 3 to this staff report). Their independent calculations estimate total revenue at approximately $250,000 per MW of generating capacity in the California market. MLPP Units 1 and 2 produce 1060 MW, which equates to approximately $290 million per year in total revenue based on Tetra Tech's estimates. Therefore, any significant reduction in cooling water flows (such as 10% annual reduction) will result in a cost in the tens of millions of dollars per year. As noted above, staff can make no biological argument for seasonal flow limitations based on the species entrained. Therefore, this alternative is not reasonable or defensible at MLPP.

Intake Location: Shoreline intake structures, such as those at MLPP, can be moved offshore to minimize entrainment and impingement of estuarine taxa. However, the USEPA acknowledges that "the ability of existing facilities to do so may be quite limited," and "as such, this discussion is of limited applicability to the majority of existing facilities, but is included to complete the discussion." Staff presented an analysis of this option to the Regional Board in its October 27, 2000 staff report. The Regional Board's independent scientists also submitted a letter to the Regional Board regarding this alternative, which was attached to the October 27, 2000 staff report.

Theoretically, an offshore intake system could reduce entrainment impacts if it were located in the ocean at a depth where concentrations of entrainable organisms are less than at other depths. However, the area of Monterey Bay adjacent to the Moss Landing Power Plant has a fairly even distribution of entrainable organisms throughout the ocean water column due to strong tidal effects, wind mixing and shallow depths. These environmental settings make it impossible to select an ideal offshore intake location to reduce the entrainment. Entrainable organisms in the nearshore of Monterey Bay include the planktonic larvae of flatfishes, rockfishes, white croaker, smelts, and northern anchovy and entrainable organisms in the harbor-slough include the planktonic larvae of gobies and Pacific herring. An offshore intake system would change composition of entrained taxa, but there is no evidence that it would reduce the amount of entrainment.

Staff's October 27, 2000 report to the Regional Board estimated the costs of an offshore intake structure at \$20-\$30 million. This estimate is consistent with estimates described in Tetra Tech's *Evaluation Of Cooling System Alternatives, Proposed Morro Bay Power Plant*, May 2002, for the Regional Board (Attachment 3 to this staff report). Tetra Tech used USEPA's *Economic and Engineering Analyses of the Proposed Section 316(b) New Facility Rule* and estimates from construction contractors. Tetra Tech's estimates for an intake structure located 3,500 feet offshore, which includes 2,000 feet of onshore pipeline (two 96" pipelines), at \$23 million.

In summary, staff and the Regional Board's independent scientists believe that an offshore intake system at the Moss Landing Power Plant would not provide a reduction in entrainment losses, and would increase impingement losses. Therefore, there is no benefit from this alternative.

Summary Regarding Intake Technologies Discussed Above: Staff considered all known intake technologies as described in the references above, and evaluated in detail those technologies that show *potential* for reducing entrainment mortality based on the limited available data. USEPA concludes that the available data for the technologies discussed above are problematic largely because there are relatively few fully successful examples of full-scale systems being deployed and tested. Regional Board staff agrees. Given that there are few full scale applications of these screening technologies, the lack of context for the studies that have been done (validity of the data), and the lack of independent studies to verify their effectiveness, staff concludes that these technologies have the *potential* to reduce entrainment, and that no generalizations should be made about the degree of effectiveness. Applying one of these technologies at a specific site would be experimental, and should be overseen by independent scientists. <u>The studies must carefully define the "effectiveness" or net benefit of the technology. That is, simply reducing entrainment rates is not the objective. The objective is to reduce mortality.</u>

Estimated Costs for Intake Structure Technologies

Some costs are estimated above where possible. However, information on costs for experimental technologies such as screening devices is not provided. In addition, no benefits (decreased mortality) can be predicted for these experimental technologies as applied to MLLP. The costs and benefits could only be determined through on-site research. Therefore, the "wholly disproportionate" cost test, discussed later in this report, cannot be applied to these technologies.

Description and Efficacy of Closed Cooling Systems

There is no question that closed cooling systems are demonstrated available technologies for reducing entrainment. Regional Board staff currently have little evidence that closed cooling systems could not be installed at MLLP; therefore, staff considers closed cooling systems to be available technologies for MLPP (with the exception of freshwater cooling towers as noted below). A general description of these systems, and estimated costs, are presented below.

Closed cooling systems are of two main types: wet and dry. Wet cooling systems recirculate freshwater or saltwater through towers. Make-up water is needed to replace losses due to evaporation. Dry cooling systems recirculate fresh water in a truly closed system (like the radiator in an automobile); no evaporation occurs and therefore no makeup water is needed. These systems follow the general hierarchy below:

Closed Cooling Systems

- I. Wet Cooling (saltwater or freshwater)
  - a. Mechanical Draft Cooling Towers
- II. Dry Cooling
  - a. Air Condensers
- III. Hybrid Cooling (saltwater or freshwater)
  - a. Mechanical Draft Towers and Air Condensers Combined

Wet Cooling: In a "wet" or mechanical draft cooling system, heated water from the power plant is pumped to the top of cooling towers where it is then sprayed downward inside the towers. Air is forced upward through the towers by large fans (this makes them "mechanical draft"). The forced air transmits heat from the water to the atmosphere. The cooled water collects at the bottom of the tower where it is recirculated back to the power plant. Some water is lost to evaporation, and "make-up" water is needed to keep the volume constant. Mechanical draft towers using <u>freshwater</u> are common closed cooling systems (California Energy Commission 2002). Mechanical draft cooling towers can be designed to handle all or part of the cooling load.

Mechanical draft towers using <u>freshwater</u> could theoretically reduce cooling water withdrawal from the Moss Landing Harbor area to zero, however, there is very little fresh water available in the Moss Landing area. Approximately 8 to 10 MGD of make-up water would be needed (Tetra Tech, 2002). This very large quantity of fresh water is not available in Moss Landing. Major saltwater intrusion problems exist in the area, which precludes the use of groundwater as a source of make-up water for the towers. Accordingly, freshwater cooling towers are unavailable for MLPP. Therefore, saltwater cooling towers would have to be used.

Staff considers saltwater mechanical draft towers to be an available technology for effectively reducing entrainment losses at MLPP by up to approximately 90%. There is an issue with "salt drift" from saltwater cooling towers, as described in Tetra Tech's *Evaluation of Cooling System Alternatives, Proposed Morro Bay Power Plant,* 2002 (Attachment 3 to the staff report). Salt drift is an issue in some locations, such as Morro Bay where the power plant is located directly upwind and adjacent to the local community. However, the issue at Moss Landing may be the affect of salt drift on agriculture. Staff acknowledges that salt drift may be an important issue at MLPP, but nevertheless considers mechanical draft cooling towers using saltwater to be an available technology at this time.

Dry cooling: Dry cooling technology is similar to the cooling system in an automobile. Heated water is pumped from the power plant to a large external "'radiator" or condenser. Large fans force air over the condensers and heat is thereby transferred from the condenser to the atmosphere. Dry cooling systems can be totally closed, requiring no make-up water. Dry cooling systems are currently in use at several power plants in the United States and are being included in plans for future power plant projects. In California and elsewhere, dry cooling is used where fresh water supplies are very limited. Staff considers dry cooling to be an available technology for effectively reducing entrainment losses at MLPP up to 100%.

Hybrid Systems: Hybrid systems are simply a combination of dry and wet cooling technologies. The proportion of cooling assigned to each technology depends on site-specific conditions, such as the amount of make-up water available. A hybrid system that uses both dry cooling and saltwater mechanical draft towers would reduce cooling water withdrawals from the Moss Landing Harbor by 95% or greater. Staff considers a hybrid system to be an available technology for effectively reducing entrainment losses at MLPP.

Estimated Costs for Closed Cooling Systems: Cooling system costs vary greatly depending on the type of system used (wet, dry, hybrid), the materials used, extra components needed to deal with specific issues such as plume abatement, and site-specific construction issues (Tetra Tech, 2002; USEPA 2003; Argonne National Laboratory, 1993). Costs vary greatly among sites, and within a given site depending on the assumptions made. One cannot accurately predict how much a closed cooling systems will actually cost because the site-specific issues associated with their construction and use (such as seismic requirements, mitigation for additional impacts, compliance with local ordinances, value of power lost due to efficiency losses, cost of money, etc.) are variable. Therefore, cost estimates for such systems are inherently speculative.

The cost estimates below for wet cooling towers and hybrid systems are from USEPA's TTD, *Chapter 2: Costing Methodology for Model Plants*, which includes *Appendix B: Technology Cost Curves*, 2003, included here as Attachment 4. The *Costing Methodologies for Model Plants* report describes USEPA's approach and assumptions for estimating cooling tower costs.

USEPA's TDD, *Chapter D: Dry Cooling*, 2003, included here as Attachment 5, describes USEPA's approach and assumptions for estimating dry cooling costs. Note that costs are based on a cooling water flow rate of 250,000 gpm.

Table 1 summarizes these costs. Note that where USEPA Cost Curves presented a wide range of costs, staff used the middle value. These costs are based on a cooling water flow rate of 250,000 gpm.

Table 2: USEPA cost Estimates for Closed Cooling Systems. USEPA, 2003.

Technology	USEPA Capital Cost[1]	USEPA Operation and Maintenance Cost	RWQCB Total Present Value[2]
Wet Cooling: Mechanical Draft Towers	$15.6 million	$2.5 million/year PV = $31 million	$47 million
Dry Cooling	$60 million to $100 million[3]	$1.9 million PV = $23.6 million	$84 million to $124 million
Hybrid (dry/wet)	$40 million	$6 million PV = $74 million	$114 million

[1]The capital costs for cooling towers above include a retrofit factor of 1.3, per USEPA
[2]Total present value (PV) calculated by RWQCB staff using USEPA values and assuming 30 year project life at 7%.
[3]Cost estimate depends on temperature design parameters.

Conclusion Regarding Estimated Costs of Applicable Alternatives

The USEPA cost estimates for the alternatives listed above are in the range of estimates from other sources, including:

1. *Moss Landing Power Plant Modernization Project, 316(b) Resource Assessment,* Duke Energy, 2000.
2. *Impact on the Steam Electric Power Industry of Deleting Section 316(a) of the Clean*

Water Act, Argonne National Laboratory, 1994 (estimates the cost of cooling towers at several power plants in the United States).

3. *Evaluation Of Cooling System Alternatives, Proposed Morro Bay Power Plant*, Tetra Tech, 2002. The proposed Morro Bay Power Plant is very similar to the new Power Plant Units at Moss Landing. Tetra Tech is an independent consultant to the Regional Board.

Tetra Tech's *Evaluation Of Cooling System Alternatives, Proposed Morro Bay Power Plant*, 2002, report to the Regional Board (Attachment 3) estimates the cost range for closed cooling systems for a facility like MLPP. The proposed Morro Bay Power Plant is very similar to MLPP Units 1 and 2. Both are combined cycle units, in a similar location with similar climates. The proposed Morro Bay Power Plant would produce 1200 MW, while MLPP Units 1 and 2 produce 1060 MW. Therefore, Tetra Tech's independent cost estimates for the proposed Morro Bay Power Plant are a good reference for MLPP. Tetra Tech's report illustrates the wide range of costs associated with a single facility, and verifies that costs for closed cooling systems at a facility like MLPP would range from about $30 million to over $100 million.

Argonne National Laboratory's report: *Impact on the Steam Electric Power Industry of Deleting Section 316(a) of the Clean Water Act*, 1994, also illustrates the wide range of industry cost estimates for retrofitting thirty-one existing power plants with cooling towers. The U.S. Department of Energy sponsored this report. For power plants with a similar capacity to MLPP (1060 MW), the report lists cooling tower costs (not dry cooling) ranging from $70 to $260 million in 1992 dollars. Since these are industry estimates, staff considers them to be possibly overestimated. This report is included here as Attachment 6.

Duke Energy's estimated costs for closed cooling systems in their *Moss Landing Power Plant Modernization Project, 316(b) Resource Assessment*, 2000. The cost ranges in this report are $60 million for cooling towers and $114 million for dry cooling, which are in the range of the cost estimates listed above.

In conclusion, staff considers USEPA's cost estimate range of $47 million to $124 million to be a reasonable cost estimate for closed cooling systems, with cooling towers being at the lower end and dry cooling being at the upper end. We acknowledge that the cost estimates are highly variable, and depend on assumptions made and site-specific conditions, and could be higher than this range.

Wholly Disproportionate Cost Evaluation

The cost of the various technologies listed above must be compared to the benefit that would be derived from implementing the technologies. Few cost estimates were provided for intake structure technologies (screens, filters, etc.) because they are not demonstrated available technologies, and the costs and benefits of such experimental technologies are largely unknown. Since the true cost and the benefit to be derived from experimental technologies are unknown, there is no way of determining if the cost is wholly disproportionate to the benefit to be gained.

Closed cooling systems would provide a definite reduction in entrainment mortality (up to 100% reduction). The cost range of these alternatives must be compared to the benefits that they would provide. There are a number of methods (and many variations of methods) to determine the value of eliminating the larval losses, including:

1. Measuring beneficial changes in Elkhorn Slough.
2. Converting the larval losses to a dollar value based on habitat equivalency.
3. Converting the larval loss to a dollar value based on commercial fishery values.

Measuring or estimating changes in the Elkhorn Slough area with respect to installation of closed cooling is problematic because of the many changes that have occurred, and continue to occur, in the area. The changes that have occurred over the past several decades are described in *Changes in a California Estuary, A Profile of Elkhorn Slough*, in press. Two chapters from this publication are included here as:

Attachment 7: *Changes in a California Estuary, A Profile of Elkhorn Slough, Chapter 11, Birds and Mammals*, in press.

Attachment 8: *Changes in a California Estuary, A Profile of Elkhorn Slough, Chapter 9: Invertebrates of Elkhorn Slough*, in press.

In addition, Dr. Cailliet, one of the Regional Board's independent consultants, provided a paper on changes in fish and fish larvae in Elkhorn Slough over time:

Attachment 9: *Status of Fish Assemblages of Elkhorn Slough over three decades from 1974-2000,* Greg Cailliet, Ph.D., April, 2003.

These papers illustrate the many changes that have occurred in Elkhorn Slough and the status of many taxa with respect to their abundance and diversity. The many changes that have occurred in the Elkhorn Slough area between the 1920s and the 1970s include development of the boat harbor, creation of a new entrance to Monterey Bay, continual dredging for navigation, major increases in erosion and scour and subsequent habitat changes, increases in pollutant loading, introduction of exotic species, and construction of MLPP. Habitat changes continue to occur as a result of significant erosion and scour. Under these conditions, where many factors are affecting the physical and biological parameters of the Slough, it is difficult or impossible to detect changes due to a particular variable, such as MLPP. There have been biological changes, as Dr. Cailliet points out in his Abstract:

> *The fish fauna in Elkhorn Slough is abundant, diverse, and dominated by both marine and estuarine species. The slough provides critical habitat not only for year-round residents, but also for marine species from near-shore waters that enter sloughs to feed, mate, and spawn. Many marine fishes, including a number of economically important species, inhabit the slough's relatively warmer, calmer waters as juveniles before moving to near-shore coastal waters. Detailed ecological studies of juvenile and adult fish assemblages in Elkhorn Slough began in the mid-1970s and continue today. In addition, studies of seasonal and spatial patterns of distribution and abundance have been done on larval stages of slough fishes.*
>
> *Since the 1970s, the abundance of both juvenile and adult fishes in Elkhorn Slough has decreased somewhat. However, in general, the species composition and overall densities of the dominant fish larvae appear to have remained fairly similar, with some species of fish larvae being considerably more abundant in 1999-2000 than in previous decades. The main categories of fish larvae exhibiting higher densities were gobies, the Pacific herring, Pacific sand lance, staghorn sculpin, white croaker, true smelts, and blennies. Only two larval species appear to have decreased densities over the past three decades, the longjaw mudsucker and northern anchovy.*
>
> *Several possible factors have been proposed that might be causing these changes in the distribution, abundance, and trophic patterns of the slough's fishes. Among these factors was impingement or entrainment of the Moss Landing Power plant. However, the intakes for that plant are in Moss Landing Harbor, and there is no evidence that water from Elkhorn Slough specifically was entrained in sufficient volume to cause these changes in the ichthyofauna. The other factors mainly include changes in the physical characteristics of these habitats, such as water depth, distance from the ocean, magnitude of tidal currents, temperature, and salinity. As the slough's habitats have been modified (e.g. through tidal scour and erosion, especially of the tidal creeks, but also the main channel), the fish assemblages and their use of these habitats also have changed. Thus, the main reason for these changes in the Elkhorn Slough fish assemblages is erosion and the subsequent shifting of sediment, which has influenced the ability of certain fishes to feed and successfully spawn and produce larvae or for immigrating larvae to survive in waters that may be increasingly turbid and fast moving.*

As Dr. Cailliet describes, two larval species appear to have decreased densities over the past three decades, the longjaw mudsucker and northern anchovy, while the majority of larval species have remained the same or increased. Dr. Cailliet's paper explains that habitat alteration is the most likely cause of the decline in longjaw mudsucker and northern anchovy larval species. Given the fact that many factors are acting on the Slough, especially changes in habitat, and the continuing abundance and diversity of taxa across trophic levels, staff does not believe it would be possible to differentiate changes caused by eliminating entrainment from changes caused by other factors. Even if one assumes that MLPP has contributed to the potential decline in longjaw mudsucker and northern anchovy larval species, the assumed benefit would then be an increase in these larval species if closed cooling were implemented. However, it is difficult to conceive a scenario in which potential increases in these two larval species could possibly justify the costs of closed cooling alternatives.

Differentiating changes caused by MLLP (or benefits caused by closed cooling) is highly problematic for the reasons noted above, but this does not mean there is no impact from MLPP. In fact, staff maintains the following:

1. Larvae are lost due to entrainment, and this itself is an impact
2. While the exact level of impact was not quantified (for example we did not determine the effect on adult populations or community effects, or effects outside Elkhorn slough) we do have a clear idea of the underlying cause (a good quantification of the loss of larvae) of any impact
3. We understand the factors affecting the production of larvae – habitat area, and quality of habitat
4. We can design programs to increase both the habitat area and the quality of habitat.

These facts led us to the habitat equivalency method, where the larval loss is converted to equivalent habitat acreage. Regional Board staff, the Regional Board's independent scientists, Energy Commission staff, and the Energy Commission's independent scientist all agreed that the best method for determining the "value" of entrainment losses was a habitat equivalency conversion. Staff used the 13% larval loss from Units 1 and 2, and an estimated area of 3000 acres for the Elkhorn Slough/Moss Landing complex, and calculated that it would take 0.13 x 3000 acres, or 390 equivalent habitat acres, to produce the larval loss. Based on actual, local values, the cost of purchasing and/or restoring this habitat was calculated as $1.2 million to $9.7 million. This approach more than compensates for impacts measured and not measured because it addresses the underlying basis of larval production, that is, habitat quantity and quality over the long-term.

Other valuation methods exist, such as calculating the entrainment losses based on commercial fish values. This value would be in the thousands of dollars per year, based on the valuation done in Duke Energy's *Morro Bay Power Plant Modernization Project 316(b) Resource Assessment,* 2001, in which the entrainment losses are similar to MLPP. Even if this value were multiplied by three orders of magnitude to account for any possible additional values, the cost for closed cooling would still be wholly disproportionate.

The value of the entrainment losses, $1.2 million to $9.7 million, should then be compared to the cost estimates for closed cooling systems, $47 million to $127 million. The costs of closed cooling systems are wholly disproportionate to the benefit to be gained.

CONCLUSION

Entrainment studies are characterized by uncertainty. It is difficult to identify and determine the number of organisms entrained, and more difficult to determine what the entrainment losses mean in terms of biological impacts. Proportional larval losses, such as the 13% proportional loss estimated for MLPP Units 1 and 2, have an unknown effect on the source water body. This uncertainty is common to all entrainment studies, and has caused major disagreements between agencies, utility groups, and environmental groups over the past several decades. There is also significant uncertainty regarding the effectiveness and cost of intake technologies such as screens and filters. These technologies are currently experimental.

However, there is no uncertainty regarding the effectiveness of closed cooling systems, such as cooling towers or dry cooling, which can reduce entrainment losses up to 100%. There is also no doubt that the costs for these systems are very high.

Staff concludes that the costs of the demonstrated available technologies ($47 to $128 million for closed cooling) are wholly disproportionate to the benefit to be gained by implementing them (eliminating larval losses valued at $1.7 to $9.8 million). Further, the habitat equivalency method used is the most appropriate valuation method because it addresses the underlying basis of larval production—increased habitat quantity and quality over the long-term.

Therefore, finding No. 48 in the NPDES permit for MLPP is supported by the weight of the evidence. The additional evidence presented only supports the finding, and there is no evidence that the finding is not adequate.

RECOMMENDATION

Staff recommends the Regional Board determine that Finding 48 in NPDES Order 00-041 is supported by the weight of the evidence.

ATTACHMENTS:

1. USEPA Phase II Technical Development Document, Chapter A7: Entrainment Survival http://www.epa.gov/waterscience/316b See Chapter A7 of USEPA's "Case Studies" Document
2. Preliminary Regulatory Development, Section 316(b) of the Clean Water Act, Background paper Number 3:" Cooling Water Intake Technologies, SAIC
3. Evaluation of Cooling System Alternatives, Proposed Morro Bay Power Plant, Tetra Tech
4. USEPA Phase II Technical Development Document, Chapter 2, Costing Technologies for Model Plant, and Appendix B: Technology Cost Curves http://www.epa.gov/waterscience/316b See Chapter 2 of USEPA's "Technical Development Document"
5. USEPA Phase II Technical Development Document, Chapter B: Dry Cooling http://www.epa.gov/waterscience/316b See Appendix D of USEPA's "Technical Development Document"
6. Impact on the Steam Electric Power Industry of Deleting Section 316(a) of the Clean Water Act, Argonne National Laboratory, 1994
7. Changes in a California Estuary, A Profile of Elkhorn Slough, Chapter 11: Birds and Mammals, in press
8. Changes in a California Estuary, Chapter 9: Invertebrates of Elkhorn Slough, in press
9. Status of Fish Assemblages of Elkhorn Slough Over Three Decades from 1974 – 2000.
10. Letter from Deborah Sivas, EarthJustice, March 24, 2003
11. Letter from Roger Briggs to Deborah Sivas, March 28, 2003
12. Letter from Sarah Flanagan, Pillsbury Winthrop, April 1, 2003
13. Letter from William Westerfield, California Energy Commission, April 2, 2003
14. Letter from Roger Briggs to Deborah Sivas, April 3, 2003

References used by staff during the permit process for Moss Landing Power Plant and this re-evaluation, which are part of the record:

1. USEPA 316(b) Phase II Technical Development Document for New Facilities, including all Chapters, Appendices, and supporting documentation, 2001.

2. USEPA 316(b) Phase II Technical Development Document for Existing Facilities, including all Chapters, Appendices, and supporting documentation, 2003.

3. *Moss Landing Power Plant Modernization Project 316b Resource Assessment*, Duke Energy, April 2000.

4. *Evaluation of Cooling System Alternatives, Proposed Morro Bay Power Plant*, Tetra Tech, May 2003.

5. *Morro Bay Modernization Project 316(b) Resource Assessment*, Duke Energy, 2001.

6. *Application for Certification, Moss Landing Power Plant Modernization Project. Application to the Energy Commission*.

7. USEPA *Guidance for Evaluating the Adverse impact of Cooling Water Intake Structures on the Aquatic Environment*, 1977. Discusses Section 316b requirements, study design, the degree of impact, etc.

8. USEPA *Guidance for Determining Best Technology Available for the Location, Design, Construction, and Capacity of Cooling Water Intake Structures for Minimizing Adverse Environmental Impact*, April 1976.

9. *Impact on the Steam Electric Power Industry of Deleting Section 316a of the Clean Water Act: Capital Costs;* Veil, J.A.; Argonne National Laboratory, 1993.

10. PG&E's *Moss Landing Power Plant Cooling Water Intake Structures 316b Demonstration*; Ecological Analysts, Inc; 1983. The original 316b report for Moss Landing Power Plant.

11. PG&E's *Assessment of Alternatives to the Existing Cooling Water System*, 1982, by Tera Corporation, for the Diablo Canyon Power Plant. Analyzes cooling system alternatives and cost estimates.

12. California Coastal Commission's *Adopted Coastal Commission Resolution to Further Condition Permit No. 183-73, San Onofre Nuclear Generating Station Units 2 and 3*, June 28, 1991. Discusses cooling system impacts, costs of alternatives, and why mitigation was chosen over closed cooling.

13. California Coastal Commission's *Staff Recommendation: Permit Application and Condition Compliance,* regarding SONGS. Discusses power plant impacts and mitigation costs.

14. *Fish Protection at Cooling Water Intakes,* Status Report; EPRI, 1999. Discusses the status of many fish protection systems.

15. Proceedings from EPRI's *Power Generation Impacts on Aquatic Resources Conference*. 1999. Many papers on all aspects of the CWA 316b process. Technology, biological studies, mitigation, etc.

16. *The Quick and the Dead: Fish Entrainment, Entrapment, and the Implementation and Application of Section 316b of the Clean Water Act*; May, James, R; Vermont Law Review, 1995. Discusses history of CWA 316b, application and results at several facilities, with some discussion of costs. Illustrates the many wide ranging solutions agreed to by agencies and utilities.

17. State of New Jersey's NJPDES/DSW Permit No. NJ0005622, PSE&G Salem Nuclear Generating Station. Discussion of legal basis for considering costs of cooling alternatives, recommended mitigation, responses to comments.

18. Section 8 of a report by the Marine Review Committee to the Coastal Commission regarding SONGS: *Potential Corrective Measures.* Considers closed cooling, moving the discharge, costs, mitigation. Recommends rejection of closed cooling and adoption of mitigation measures. Note that approved mitigation at SONGS does not "mitigate" entrainment impacts.

19. USEAP hired SAIC to produce three documents: *Preliminary Regulatory Development, Section 316b of the Clean Water Act*, 1994:

    Background Paper Number 1: *Legislative, Regulatory, and Legal History of Section 316b and Information on Federal and State Implementation of Cooling Water Intake Structure Technology Requirements.*

    Background Paper Number 2: *Cooling Water Use for Selected United States Industries.*

    Background paper Number 3: *Cooling Water Intake Technologies.*

20. USEPA Record of Decision on Tampa Electric Company Big Bend Unit 4, NPDES Permit No. FL0037044. 1982. Discusses impacts, and alternatives.

21. USEPA NPDES Permit Nos. FL000680 and FL001473, Indian River Power Plant and Cape Canaveral Power Plant. 1983. Discusses impacts and alternatives. Allows significant entrainment and impingement impacts because other alternatives would present different impacts, and the Florida manatee benefits from the thermal discharge.

22. USEPA Advanced Permit Writer's Course, Presentation Materials. June 1995. Discusses 316b, policy, intent, implementation, permitting procedures, alternatives, etc.

23. USEPA NPDES Permit No. FL000817, Tampa Electric Company. Discusses entrainment impacts and solutions. 1981.

24. USEPA Determination Regarding Issuance of Proposed NPDES Permit No. MA0025135 for Boston Edison Company's Pilgrim Power Plant. Discusses 316b process, impacts, alternatives, resolution. 1977.

25. Hudson River Settlement Agreement: Technical Rational and Cost Considerations; Barnthouse, Lawrence, et al.; American Fisheries Society Monograph, 1988. Discusses entrainment impacts, interpretations, alternatives, resolution.

26. State of New Jersey, Department of Environmental Protection and Energy, letter dated January 31, 1994, regarding PSE&G Salem Nuclear Generation Station, NPDES Draft Permit No. NJ0005622. Several attachments. Discusses alternatives analysis, costs, and "wholly disproportionate" test.

27. State of New Jersey, Department of Environmental Protection and Energy, Fact Sheet for NPDES Permit No. NJ0005622, 1993. As above.

28. State of New Jersey, Department of Environmental Protection and Energy, final NPDES Permit No. NJ0005622. 1994. As above.

Biology:

29. *Improvement of Environmental Impact Analysis by Application of Principles Derived from Manipulative Ecology: Lessons from Coastal Marine Histories*; Peterson, C.H.; Australian Journal of Ecology; 1992. Discusses studies of marine impacts, resolutions, regulatory process, with emphasis on how to do better. Excellent paper

30. *Detecting Ecological Impacts: Concepts and Applications in Coastal Habitats.* Schmitt and Osenberg, ed; 1996. Discusses monitoring, studies, ability to detect impacts, mitigation, biological impact predictions versus actual impacts.

31. *Relative Contributions of Hudson River and Chesapeake Bay Striped Bass Stocks to the Atlantic Coastal Population*; Van Winkle, W.; American Fisheries Society Monograph, 1988.

32. *Science in the Courtroom*; Yost, Thomas; American Fisheries Society Monograph, 1988. Discusses scientific arguments about entrainment impacts that occurred in the courtroom regarding Hudson River, including compensation. Suggests ways to improve the overall process.

33. *Comparison of Trends in the Finfish Assemblage of Mount Hope Bay and Narragansett in Relation to Operations at the New England Power Brayton Point Station;* Gibson, Mark; Rhode Island Division of Fish and Wildlife, 1996. Several comment letters also included.

34. California Coastal Commission, *Procedural Guidance for Evaluation of Wetland Mitigation Projects in California's Coastal Zone*, 1995.

Additional Documents in the Record:

35. Curriculum Vitae, Greg Cailliet, Ph.D., Moss Landing Marine Laboratories.

36. Curriculum Vitae, Pete Raimondi, Ph.D., UC Santa Cruz.

37. All correspondence, monitoring reports, engineering reports, and miscellaneous documents in the Regional Board file for MLPP.

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