Final Report

Environment and Sustainability Initiative
University of California, San Diego

Submitted to the
Metropolitan Wastewater Department
City of San Diego
October 1, 2007

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Final Report
Point Loma Outfall Review

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The City of San Diego operates a regional wastewater treatment plant located on the Point Loma Peninsula. Effluent from this facility is discharged approximately 4.5 miles offshore at a depth of 310 feet. The treatment plant has the physical facilities to handle 240 million gallons per day (mgd), and has been permitted for that capacity by the State Regional Water Quality Control Board. The effluent flow has averaged about 175 mgd in recent years. The City has monitored ocean water quality and biological parameters surrounding the outfall in compliance with the National Pollutant Discharge Elimination System permit issued by the San Diego Regional Water Quality Control Board.

The City requested a scientific review of the impact of the Point Loma Ocean Outfall (PLOO) as the City considers a request to the Environmental Protection Agency for a new modified permit for the facility. The Environment and Sustainability Initiative at the University of California, San Diego assembled a team to review data collected in the coastal and near-shore receiving water over the last five-to-ten years, focusing on benthic ecology, sediment chemistry, physical variables, and marine microbiology. The interdisciplinary scientific team included scientists who have worked on the Point Loma Outfall in the past, and several new experts who bring "fresh eyes" to the task, including UCSD Prof. Paul Linden and Dr. Richard M. Gersberg of the Graduate School of Public Health at San Diego State University.

This document provides preliminary findings in addressing the City's goal of identifying any significant observable impact of the Point Loma Outfall on receiving waters, based on a 3-month review of existing data and analyses already performed. The Principal Investigator, Prof. Paul Linden, and the Project Coordinator, Dr. Lisa Shaffer, participated with City staff and the Mayor in a public event announcing the start of the study, and provided information in response to media inquiries. Preliminary findings were reported to the Mayor and staff on September 25. This document serves as the final report for the project.

The team from Scripps Institution of Oceanography and the Jacobs School of Engineering consisted of experts in benthic ecology (Paul Dayton and Ed Parnell); physical oceanography and coastal and nearshore transport (Linda Rasmussen and Ed Parnell); and molecular marine microbiology and microbial human pathogens present in the marine environment (Douglas Bartlett, assisted by one of his graduate students), as well as Dr. Kathleen Dohan, a post-doctoral fellow at Scripps who worked closely with Prof. Linden. The UCSD Environment and Sustainability Initiative provided

administrative support. Dr. Richard Gersberg from the Graduate School of Public Health, San Diego State University conducted the marine microbiology and public health assessment under a separate contract, but his results are included in this consensus report. The details of each team member's work are presented in the Background and Analysis section.

SUMMARY OF FINDINGS

The consensus conclusions of the team are summarized below. We found no evidence of significant adverse impacts of the PLOO. Following this summary, we have included the more detailed assessment of each area. In all cases, it is important to note that the scientific team did not conduct new, fundamental research and performed limited analysis of observational data. They reviewed existing analyses and reports, as requested by the City. Their conclusions are constrained by the limited time and scope of this project. In some cases, specific recommendations are presented that would enable further analysis to be conducted.

MICROBIOLOGY, SEDIMENT CHEMISTRY AND BIOACCUMULATION: We reviewed the existing information about the densities of total and fecal coliforms and enterococci as a function of source and time and provided an assessment based on evaluation of this microbiology data. We also conducted a review of the data on bioaccumulation of selected chemicals and levels of these chemicals in the sediments in the area of the PLOO.

Our primary conclusion is that after a careful review of the bacterial monitoring data and reports, there is little evidence that the wastewater plume is significantly impacting the shoreline or beaches in the region and adversely affecting human health. Even at densities below the California Ocean Plan [California State Water Resources Control Board (2001)] standards, there is no discernible connection between the wastewater plume and shoreline water quality. In terms of sediment chemistry, we concluded that, based on comparison of outfall versus reference sites, accumulation of the selected compounds (mercury, arsenic, selenium, zinc, PCBs, DDD, DDE, DDT, and chlordane) in the region around the outfall is not discernible.

With regard to bioaccumulation of chemicals in fish, a statistical analysis on total PCB levels showed rockfish fish liver levels in the zone near the PLOO were significantly higher than rockfish liver levels in the reference zone north of the PLOO. However, further investigations using trawl fishing data, which are collected over a larger area, suggest that the LA-5 dredge disposal site located south of the PLOO station could be the source. Unfortunately, currently it is impossible to know definitively whether the elevated levels are due to the PLOO or the LA-5 site. We recommend that the City of San Diego conduct a more detailed analysis of this finding and perhaps search for more suitable bioaccumulation reference sites, away from known sources of PCBs.

We also concluded that the PLOO has a minimal influence on its adjacent shoreline in terms of microbiology. More analyses of effluent tracking data and its relation to kelp

station and shore station indicator bacterial counts will be useful in making more definitive conclusions.

BENTHIC ECOLOGY: The benthic ecology team focused on benthic faunal components to assess benthic community patterns, processes, and responses to the outfall. With regard to the ability to evaluate the relative ecological impact of pollutants on the benthic community, all of the very different approaches described later in this report are strongly correlated, and there are no indications of significant impacts on the Point Loma benthic community. The benthic communities off Point Loma have remained fairly stable over the years in terms of species richness, density, biomass, and dominance, and these parameters have been consistent with Bight-wide trends. Comparisons of pre and post discharge data do show some trends. For example, there was an overall post-discharge increase in the number of species and infauna density and a decrease in dominance, the opposite of expectations of environmental degradation. There is no evidence that benthic communities off Point Loma outside the zone of initial dilution (ZID) (or San Diego in general) are dominated in any way by pollution tolerant species. If there are measurable impacts of the Point Loma outfall on the macrobenthos, they are subtle. There is also no indication that the Point Loma outfall significantly affects the community composition of megafauna off San Diego.

PHYSICAL OCEANOGRAPHY: We focused on the physical circulation and water mass properties of the receiving waters. We report that the complexity of the oceanographic conditions in the Point Loma area demands more observations before any conclusions can be made about the transport of the plume. Engineering model runs using recent stratification data are consistent with earlier predictions for dilution. While plume surfacing cannot be ruled out entirely, the probability is likely very low. The spatial distribution of bacteria also suggests that the plume is trapped at depth and does not reach the shore. However, more extensive data collection to analyze the shoreward plume transport is currently underway. Hydrographic work to track the plume and fine-scale modeling are both planned for the immediate future.

BACKGROUND INFORMATION AND ANALYSES

MICROBIOLOGY AND PUBLIC HEALTH (Rick Gersberg, Douglas Bartlett, Alexandra Purdy)

The following narrative is a summary of the findings of the Scientific Review Team that was organized to evaluate the impact of the Point Loma Ocean Outfall. In 2006 the average daily outfall from PLOO was 170 mgd (ranging from 162 to 180 mgd). PLOO discharges effluent from the Point Loma Wastewater Treatment Plant and has been in operation since 1963. It was extended to a length of approximately 7.2 km in November 1993. Weekly counts of total coliforms, fecal coliforms and enterocci are determined for many stations in order to evaluate compliance with California Ocean Plan standards. Many offshore locations are also sampled on a monthly or quarterly basis.

The present report includes an evaluation of the following aspects of the PLOO discharge:

1. MICROBIOLOGY-An assessment of data on marine microbiology, which includes data on the comprehensive monitoring of bacterial indicators, and allows an assessment of the possible impact of the PLOO on human health.

2. BIOACCUMULATION-An assessment of the monitoring data on selected toxic chemicals in the tissues of fish in the region of the PLOO in order to evaluate the potential for bioaccumulation of selected pollutants through the food chain.

3. SEDIMENT CHEMISTRY-An assessment of the sediment chemistry in the area of the PLOO discharge (as compared to the north reference sites) in order to evaluate the potential accumulation of selected toxic chemicals in the nearby sediments.

In addition to reviewing data from the Annual Reports for 2001-2006 and datasets listed in the Reference section below, some original data sorting and statistical analyses were carried out on selected pollutants and datasets, analyses that were above and beyond those that are presently available from the City of San Diego, Metropolitan Wastewater Division database and reports. However it is important to note here, that due to the limited timeframe and scope of the Scientific Review Panel, such original analyses as performed in this evaluation are necessarily selective and limited in scope.

MICROBIOLOGY: The City of San Diego performs shoreline and water column bacterial monitoring in the region surrounding the PLOO. This program is designed to assess the microbial quality of the regional marine waters, evaluate the movement and dispersal of the PLOO wastewater plume, and monitor compliance with the 2001 California Ocean Plan. Microbiology monitoring includes determination of the densities of the fecal indicator bacteria (FIB) including total and fecal coliforms and enterococci. These bacterial indicators are not generally pathogens themselves, but instead are

indicative of fecal contamination of marine waters and the possible presence of other microbial pathogens which may include viruses as well as bacteria and parasites. However, since the die-off of FIB (particularly total and fecal coliforms) may be more rapid than pathogenic viruses, these FIB may not always be conservative (the most protective) indicators of the degree of human health risk.

Despite the caveat above, after a careful review of the bacterial monitoring data and reports, Professor Gersberg's analysis finds that ***there is little evidence that the wastewater plume is significantly impacting the shoreline or beaches in the region and adversely affecting human health.*** This finding is based on the general conclusion from review of the 2001-2007 bacterial monitoring dataset, that elevated densities of bacteria in the region of the PLOO are generally limited to the stations in the vicinity of the PLOO and to waters deeper than 60m. Indeed, the absence of direct evidence for bacterial contamination in the surface waters in the winter months, when water column is well mixed (not stratified), suggests that stratification is not the only factor limiting the depth of the plume to deeper than 60m. Apparently, the depth of the discharge site (around 98m) may be the dominant factor keeping the PLOO wastewater from reaching the surface waters [City of San Diego (2005)].

In an attempt to further discern whether there was any relationship between water quality at the shore stations and the deeper waters offshore, Professor Gersberg conducted a Spearman correlational analysis for paired D (shoreline) and C (nearshore kelp, surface, mid and bottom depths) FIB densities for the dry season (May through October) for the period 2001-2007. In this case, analysis was restricted to the dry season since it was expected that during this period, not only is stratification well developed, but any confounding of the relationship by terrestrial sources of contamination at the shoreline is minimized. Results indicated that most, if not all, of the paired stations showed no statistically significant (p-value < 0.05) correlations, and for the very few paired stations that did, results became non-significant when the few statistical outliers were removed from the dataset. This suggests that even at densities below the Ocean Plan standards, ***there is no discernible connection between the wastewater plume and shoreline water quality.***

Indeed, the very high rate of compliance with the California Ocean plan FIB standards for both the shoreline and kelp stations reflects the fact that the public health risk posed by the PLOO at the shoreline stations is most probably not significant. For example, data presented in Appendix A, Table 1a, show that compliance at the shoreline (D4 –D12) stations within the period 1994-2007 for all FIB for both the geometric mean and the single-sample maximum standards range from 95-100%. For the kelp stations at the 10-20m contour (A1, A6, A7, C4-C8), compliance was even higher (Table 1b). Considering the directional gradient of possible impact of the PLOO wastewater plume, the fact that the water quality at the kelp stations was higher than at the shore stations, indicates that terrestrial sources of fecal contamination account for much (if not all) of the shoreline pollution, rather than the PLOO wastewater plume. However, because the FIB may arise from a variety of both point (like the PLOO plume) and non-point sources (incl. terrestrial sources such as urban runoff, warm-blooded animals especially shorebirds, and

leaking sewer systems), resolution of the specific source of contamination at shore stations, particularly at levels below ocean plan standards, is difficult to attain, short of a more robust statistical and spatial analysis as mentioned above. In spite of this, Prof. Gersberg concludes that ***the very high rates of compliance shown in Table 1a and b, coupled with the lack of a continuous gradient of contamination from the PLOO through to the kelp stations and the shoreline stations, indicate that the human health risk posed by the PLOO is most probably not significant.***

The Annual Receiving Waters Monitoring reports for 2005 and 2006, ocean monitoring bacteriological count data and total coliform data listed in the Reference section were examined by Dr. Bartlett along with Lindbergh Airport precipitation data (courtesy of Kayo Watanabe [NOAA (2007)]).

During the 27 month pre-extension period from August 1991 to Oct. 1993 there were 169 shoreline total coliform counts equal to or greater than 1,000 CFU/100 ml sample (mean of these samples ~ 23,000, high ~ 300,000). In contrast during the 142 month period between Feb 1994 and Nov. 2006 there were only 76 such samples (mean of these samples ~ 3,000, high =16,000). ***This represents a change in the frequency of such high counts from 15.6 to 1.3%, clearly a dramatic result.***

If one discounts as possible runoff-related events those counts that were recorded within a 7 day period of measurable rainfall (recorded at Lindberg Field) then the 76 high coliform count samples obtained since 1994 drop down to 22. In a few of these cases some of the kelp stations also have high total coliform counts within a week of the shoreline counts. In none of these cases does an analysis of the offshore station counts and kelp station counts lead to the impression that the plume is reaching the shoreline. However, such counts are rarely within a day or two of the shore sampling dates, and so it is not possible to conclude unambiguously that none of these high counts are related to the PLOO effluent plume. The high counts which occasionally occur at shore station D11 may result from contaminated San Diego River or Mission Bay waters.

The distribution of mean coliform plots presented in the Annual Receiving Waters Monitoring Reports for 2005 and 2006 are extremely useful. The April 2005 and 2006 plots in particular indicate that the plume may have moved towards the shoreline at that time to at least the 60m depth contour. If kelp and shore station data were obtained at the same time as that of the offshore locations (obviously not a trivial additional undertaking) the possibility of plume impact to the shoreline could be addressed more directly. However, although not taken on the same day, the shore and kelp and stations sampled near the same times showed no indication that the plume reached those areas. For example, the relatively high values indicated in the 2005 and 2006 plots were for station F8 sampled on 4/12/05 (Totals = 16,000 CFU/100 mL) and station F10 sampled on 4/12/06 (Totals = 9,400 CFU/100 mL). In 2005, kelp stations were sampled on 4/7 and 4/13, while shore stations were sampled on 4/9 and 4/15; all values were low with total coliforms <100 CFU/100 mL. In 2006, shore and kelp stations bracketing the F10 sampling date were also relatively low (i.e., <400).

The expanded array of PLOO offshore sampling sites begun in 2004 and MODIS satellite remote sensing data are being used for improved effluent tracking. In addition, the City's very recent Moored Observation System Pilot Study described in the Physical Oceanography section will also improve plume tracking. Correlating this information to the bacteriological counts is probably being done, but it is not described in the City of San Diego reports and would be useful to describe explicitly.

In summary, it is evident that ***the PLOO has a minimal influence on its adjacent shoreline***. More analyses of effluent tracking in relation to kelp station and shore station indicator bacterial counts will be useful.

BIOACCUMULATION: The bioaccumulation portion of the PLOO monitoring program is conducted in order to evaluate the potential for bioaccumulation of selected pollutants through the food chain. It consists of two components:

1. analysis of muscle (and liver) tissues from fishes collected by rig fishing
2. analysis of liver tissues from trawl-caught fishes.

In this regard, the analysis conducted by Dr. Gersberg consisted of a review of the bioaccumulation data in existing reports and databases of the City of San Diego, as well as some original data analyses on bioaccumulation data for 1995-2006 in which selected fish tissue contaminant levels for rig fishing stations and trawl fishing stations in the vicinity of the PLOO (RF1 and TF1) were compared statistically to comparable values at stations away from the PLOO (RF2 and TF2). However, given the limited scope and timeframe for the present Scientific Review Team assessment, this analysis is mostly focused on a select group of chemicals of concern (mercury, selenium, arsenic, zinc, total PCBs, and the pesticides DDE, DDD, DDT, and chlordane. Moreover, for the most part, this analysis focused on fish livers (except for total PCB levels for which both fish muscle and liver were analyzed), because the liver is the organ where chemical contaminants are typically concentrated, and as such, liver levels of contaminants of concern may be used to gauge the potential for these same contaminants to bioaccumulate in the food chain.

Results of the above analysis of the selected chemicals of concern at the RF1 and TF1 stations (close to the outfall) compared to away (north) of the outfall (RF2 and TF2) showed no clear and significant differences, except for total PCBs in fish livers at the RF stations (Appendix C, Table C1). Rockfish fish liver levels at RF1were significantly higher than rockfish liver levels for RF2. Details of the analyses are provided in Appendix C.

Dr. Parnell has performed additional robust analyses of the PCB data that include a) evaluating how the numerous nondetects in these data are handled and reanalyzing the data, b) looking at individual PCB congeners instead of total PCBs, and c) a more in depth comparison among sites that includes the southern farfield areas (i.e., near the LA5 disposal site and further south). Appendix C includes details of Dr. Parnell's work as well.

He found that the trawl fishing station near the LA-5 dredge disposal site (trawl fishing zone 3) has the highest concentrations for all PCB congeners and this difference is significant for most congeners. PCB concentrations decrease with increasing distance from the LA-5 site both to the north and to the south (*i.e.*, lower concentrations of PCBs at the outfall and even less further north off Mission Beach). In all cases, trawl fishing zone 3 (near LA-5) has the highest median values, upper quartiles, and outliers. The rig fishing results show that there are greater concentrations for most PCB congeners at the outfall site compared to the Mission Beach site.

The spatial patterns for the rig fishing and the trawl fishing stations are consistent at the two sites where both collections are performed. The trawl fishing provides the additional information that the centroid of PCB contamination on the shelf is likely the LA-5 disposal site. This suggests that the LA-5 dredge disposal site is the most likely source of significant PCB contamination in fish on the Point Loma shelf.

However, there currently is no way to know definitively whether the elevated levels in the rig fishing are due to the PLOO or the LA-5 site. We recommend that the City of San Diego conduct a more detailed analysis of this finding and perhaps search for more suitable bioaccumulation reference sites, away from known sources of PCBs.

SEDIMENT CHEMISTRY: Ocean outfalls are only one of many anthropogenic sources that may influence the chemical composition of the sediments through the discharge of wastewater and the subsequent deposition of a wide variety of organic and inorganic chemicals. Some of the most commonly detected chemicals in municipal wastewater discharge include various organic compounds, trace metals, and pesticides. The City of San Diego collects sediment samples at 22 stations in the region of the PLOO in order to assess the impact of wastewater discharge on sediment quality near the discharge site. For the present analysis, a comparison was conducted for a selected subset of chemicals of concern (mercury, arsenic, selenium, zinc, PCBs, DDD, DDE, DDT, and chlordane) between levels at the outfall stations (stations E14, E11, E15 and E17) and the north reference stations at similar depth contours (stations B9, B10, B12). The comparison with the north reference stations avoided possible confounding by the dredge disposal site LA5 which exists south of the PLOO. Overall, the data analysis conducted by Dr. Gersberg for this comparison of outfall versus reference sites, indicated that ***accumulation of the selected compounds above in the region around the outfall is not discernible***.

It should be noted here that it is also possible that contaminated sediments are accumulating downslope from the shelf. The City began some deep slope monitoring off San Diego in 2003 as part of the Bight'03 regional monitoring program and more specifically as a separate, more intensive "Deep Benthic Pilot Study" of sites 200-500m depth west of Pt Loma in 2005 [Stebbins and Parnell (2005)]. The latter is referred to briefly below in the Benthic Analysis section. Additionally, further work is planned for deep habitats in the upcoming Bight'08 regional program. As such, it is not known

presently if the effects of the PLOO or other sources of contaminants are accumulating in these areas [Scripps Institution of Oceanography (2004)].

BENTHIC ANALYSIS (Paul Dayton, Ed Parnell)

This analysis addresses benthic infauna, demersal fishes and large invertebrates as well as a brief description of ecological thresholds and indicators of ecological stress. The City has been working under the terms of their permit in which they need to maintain natural conditions in sediments and biota beyond the wastewater zone of initial dilution (ZID). In order to insure compliance they have carried out the standard EPA and State Regional Water Quality Control Board monitoring programs and analyses. These data provide the basis for this review. The Scripps report [Scripps Institution of Oceanography (2004)] found some concerns about other regional sources of contaminants and the City is studying them. When available, these extra data will be discussed as well.

BENTHIC INFAUNA: The benthic macrofauna community is extremely diverse and represents the best known and probably the most sensitive indicators of stress to this system. The reason that the infauna are particularly useful for monitoring benthic stress is that many species are sensitive to various environmental parameters that could be driven by pollution stress. These animals cannot escape stress because they are not very mobile, often respond quickly to adverse conditions, either natural or anthropogenic, and in most cases are relatively short-lived so that their populations depend on recruitment that is itself sensitive to many environmental factors including, especially, pollution. But the challenge with any such study is to evaluate natural variability in time and space from changes possibly induced by ocean outfalls or other pollutant sources. The infaunal community is composed of species that are sensitive to these factors and tend to have relatively fast turnover rates so that the populations respond quickly to changes of all sorts, natural and anthropogenic. Before treatment of sewage began, the impacts were obvious and virtually complete as entire benthic areas became anaerobic and covered with mats of bacteria or dominated by a handful of pollution tolerant species. As wastewater treatment improved, the level of degradation changed such that there was not a clear criterion of how much ecological change is too much. The fact that the changes induced by wastewater outfalls became almost impossible to measure coincided with an appreciation of the considerable background variation, which challenged regulators and ecologists to find ways of teasing apart natural and anthropogenic changes.

EPA waiver requirements are rigorous and allow virtually no change in the area beyond the ZID. Traditionally the natural background variation in benthic communities is monitored at distant reference stations, and they developed a format in which samples are taken from a grid designed to evaluate the community impacts of the outfall over a large spatial area. During the 1960s – 1980s most outfalls had significant effects on the benthic community, and ecologists developed a sophisticated understanding of species-specific responses. This understanding has been integrated into indices that are sensitive to small amounts of contamination because they select and emphasize those species known to be most sensitive.

San Diego has always complied with all waiver requirements for its discharge from Point Loma. Monitoring of the receiving waters environment is comprehensive and well conducted. The analytical problems discussed above are acute because there are thousands of infaunal species in local coastal waters and their patterns of distribution and abundance are highly variable over space and time. In order to evaluate possible impacts of the outfall, the City employs many different types of analyses to evaluate changes in critical community parameters, including species richness and abundance, species diversity, dominance, evenness, and populations of various indicator species. These are typical community analyses that are responsive to large changes. There are other more specialized pollution indices that have been developed over the last 50 years to be extremely sensitive to outfall perturbations. The Infaunal Trophic Index (ITI) was used for many years for assessments of southern California waters, while the more recently developed Benthic Response Index (BRI) has been shown to be a powerful tool for detecting impacts at continental shelf depths up to 200 m. The BRI is considered a more robust index than the ITI because the ITI does not necessarily account for differences in physical factors such as depth and grain size while the BRI does indirectly. Other successful indices include the Shannon diversity index (H'), Pielou's evenness index (J'), and the Swartz dominance index. One of the best analytical tools to examine possible outfall effects in the face of the extreme regional variability is to use powerful trend analysis statistics that evaluate localized changes in the area around the outfall. One of the most popular analyses is the BACIP (before-after-control-impact-paired) analysis. This analysis tests differences between control and impact sites before and after a possible impact event (e.g., initiation of wastewater discharge). Another interesting approach was published recently by the Southern California Coastal Water Research Project (SCCWRP) [Weisberg *et al.* (2006)]. Here, the authors independently asked a large number of the most experienced pollution benthic ecologists in the country to evaluate several large data sets and rank them from stressed to non-stressed. There was an almost perfect agreement on the relative abundance of a small number of indicator species. With regard to the ability to evaluate the relative ecological impact of pollutants on the benthic community, ***all of the very different approaches are strongly correlated, and there are no indications of significant impacts on the Point Loma bottom community.***

One problem for the Point Loma region, and for most other areas as well, is identifying appropriate reference or control sites. This relates to the fact that most of the benthic biota important for these analyses are extremely sensitive to their sedimentary habitat. For example, grain size and the amount of organic material present are critical. For the Point Loma monitoring program, the sediments of the northern stations originally chosen as reference stations include sites with both coarser and finer sediments than sites nearer the outfall. The composition of grain size in sediments so profoundly affects both the chemistry and the biological community within the sediments that natural differences would be expected between sites having different grain size compositions even without the presence of a sewage outfall. Additionally, several monitoring sites to the south of the outfall are likely impacted by a nearby toxic waste dump site (EPA's LA-5 dredge material disposal site) or outflow from the mouth of San Diego Bay. It is important to note that the prevalence of coarse sediments in the outfall area indicates that it is in an

erosive environment in which currents will disperse flocculent material. In summary, ***there are complications with any analysis of the Point Loma Outfall because there are such large amounts of spatial and temporal variation in the background parameters.*** Addressing such concerns was a major recommendation of the previous Scripps Point Loma Outfall Project report.

In response to the above and related issues and to recommendations of the Model Monitoring Program for large ocean discharges developed by SCCWRP for the State Water Quality Control Board, the City is actively involved in several relevant benthic-monitoring projects. These include a large comprehensive Sediment Mapping Project of both the Point Loma and South Bay outfall regions as well as pilot study of deeper habitats (200-500m) west of the Point Loma outfall [Stebbins, Schiff and Ritter (2004); Stebbins and Parnell (2005)]. Reports from the first phases of both projects are expected to be completed by the end of 2007. The purpose of the Sediment Mapping Project is to determine more meaningful spatial scales of sediment monitoring thereby increasing the sensitivity of monitoring. The purpose of the deeper sediment-sampling program is to determine whether there is any accumulation of pollutants further offshore from the outfall where natural sediment processes are most likely to transport sediment-associated pollutants. Additionally, the City has conducted summer benthic surveys of randomly selected sites of the San Diego coast from Mexico to Del Mar since 1994. The information from all of these surveys combined will be useful in evaluating the effectiveness of the current Point Loma monitoring grid, and if necessary, determining the appropriate locations for additional reference and/or monitoring sites.

An ophiuoid-polychaete assemblage that is common in the Southern California Bight (SCB) characterizes the infaunal communities off Point Loma. Changes in community composition at Point Loma probably reflect the general patterns of variation around the SCB related to oceanographic forcing such as El Niños or simple stochastic changes in populations relating to all sorts of natural ecological interactions. The benthic communities off Point Loma have remained fairly stable over the years in terms of species richness, density, biomass, and dominance, and these parameters have been consistent with Bight-wide trends. Comparisons of pre and post discharge data do show some trends. For example, there was an overall post-discharge increase in the number of species and infauna density and a decrease in dominance, the opposite of expectations of environmental degradation. ***There is no evidence that benthic communities off Point Loma outside the ZID (or San Diego in general) are dominated in any way by pollution tolerant species. If there are measurable impacts of the Point Loma outfall on the benthos, they are subtle.***

The outfall depth stations are located along the 98-m depth contour and span the terminus of the Point Loma outfall. Station E14 is located nearest the outfall, approximately 111 meters north and 256 meters west of the center of the diffuser "Y." This station is considered the Near-ZID or ZID boundary station and is the site most likely to be impacted by the outfall. Stations E11 and E17 are the closest near field stations, located approximately 204 m from the south and north ends of the respective diffuser legs. The remaining "E" stations are considered far field sites. The "B" stations are located >11 km

from the outfall and were originally selected to represent reference or control sites. However, benthic communities differed between the "B" and "E" stations prior to operation of the outfall [Smith and Riege (1994); City of San Diego (1995a)] most likely because these areas have different grain size compositions and therefore represent different habitats. Thus, station E26 was chosen to represent an additional control or reference site. This station is located ~8 km from the outfall and is considered the least likely "E" station to be impacted.

The City analyzed the reference stations and found that E26 and B9 were the most appropriate stations. BACIP analysis showed significant trends in which E14 differed from the control sites for species richness and abundance. Interestingly, the changes were opposite from what one would expect of a stressed community. There were no differences in the pollution indicators *Ampelisca spp* and *Rhepoxynius spp.* The most famous pollution indicator is the polychaete worm *Capitella capitata* that can reach densities >500/0.1 m^2 but only 6 individuals were found in 2006 in the stations near the outfall (E17, E14, and E11). Certainly these data are strong indication that there is no important benthic impact of the outfall. However, there were some changes that might reflect outfall impacts around E14. These include a modest but significant increase in the BRI index as well as significantly reduced densities of *Amphiodia spp.* and a small shift in the ITI index. None of these results indicate that the Point Loma benthic community is altered to the extent that it would serve as a warning about significant outfall impacts on the benthos. One consistent change relates to a small decrease in the density of *Amphioda urtica*, a small white brittle star that universally decreases after a pipe is installed. Because *Amphiodia urtica* is preyed upon by fish and crabs attracted to the structural habitat of outfalls, populations of this brittle star have been observed to be equally reduced along pipes that have long transported secondarily treated sewage. Therefore, it seems likely that the decreased abundance of this species near the Point Loma outfall is also due to the predation of fish and crabs attracted to the structure of the discharge pipe and mixing box and is not, as often claimed, caused by sewage discharge.

Unlike the infauna, megafauna species tend to be more long-lived but are much more mobile and can respond to environmental changes simply by moving into more appropriate environments. While their natural history is poorly studied, many are known to move a great deal; for example, some move seasonally following seasonal shifts in food or often to form breeding aggregations. There is little evidence that they have strong site fidelity so that the movements are probably sufficient to mask possible bioaccumulation. That is, bioaccumulation might occur from pollutants at one site but the fish may move to clean sites, so bioaccumulation is not a sensitive indicator unless it is pronounced and occurs in a large number of individuals. ***There is no indication that the Point Loma outfall significantly affects the community composition of megafauna off San Diego.***

PHYSICAL OCEANOGRAPHY (Linda Rasmussen, Kathleen Dohan, Ed Parnell, Paul Linden)

The City of San Diego has performed an extensive monitoring program throughout the area surrounding the Point Loma outfall, with approximately bi-weekly CTD (conductivity, temperature, depth) casts near the shore and CTD casts throughout the entire area four times a year. The City report for 2006 gives an overview of the mean hydrographic conditions in the area of the Point Loma outfall with a comparison to decadal patterns. They found no connections between the outfall and the distributions of pH, chlorophyll A, transmissivity and dissolved oxygen.

What the annual reports do not include is an analysis of episodic events that could lead to shoreward transport of the plume. The complexity of the oceanographic conditions in the Point Loma area demands more observations on a continuous basis before any conclusions can be made about the transport of the plume.

The City of San Diego, together with Ed Parnell and Linda Rasmussen from Scripps, has recently implemented a series of thermistor chains and ADCP (Acoustic Doppler Current Profiler) moorings [Storms, Stebbins and Parnell (2006)]. The first batch of data available for study is from two thermistor chains: one chain at the Y of the outfall, the other at the 60m isobath along the outfall pipe. The temperature data was collected every 10 minutes from June 2006 - April 2007. The ADCP data available is from two moorings: one at the Y, one south of the Y. The velocity data was collected every 3 minutes from September 2006 - the middle of December 2006. Five more thermistor chains are in place with data to be collected in the fall of 2007.

These high-resolution data sets clearly exhibit the variability in the coastal waters near the outfall. For example, at the Y the 12°C isotherm fluctuates about its average depth by 11.5 m, with many extreme events such as a change in mean location from 30m to 50m in 5 days. Internal tides, bottom currents, and diurnal currents can all contribute to these fluctuations and a "sloshing" of the colder underlying waters onshore, with potential for onshore transport of the plume. Two thermistor chains are insufficient to capture the full spatial extent of the significant fluctuations for this report, but the additional data being collected will be used in the future to study these events.

The velocities also exhibit short timescale variability. The mean across-shore velocity is 0.3cm/s onshore at the bottom, but is predominantly offshore above 10m at approximately 4cm/s amplitude. As an illustration, this average speed of 0.3cm/s means water could reach the shore in 3 days. This is unlikely because the change in temperature as the seafloor depth rises towards shore impedes shoreward currents, but without more observations across-shore such transport cannot be eliminated. The mean along-shore velocity ranges from 0cm/s at the bottom to 5cm/s in the middle of the column back to 0cm/s at the top. The standard deviation of the currents at all levels is 10cm/s. The range in bottom across-shore velocities during a three-month period was from 47cm/s offshore to 33 cm/s onshore.

Most of the energy is in mean, diurnal and tidal fluctuations. Most of the variability, at approximately 75%, is in the barotropic mode (i.e., the velocity is constant with depth). The next significant mode is the first baroclinic mode, capturing approximately 20% of the variability in the currents. In this mode currents are in different directions with depth with a reversal in direction between the surface and the bottom. This results in shear, which could contribute to mixing of the water column. This behavior is consistent with other coastal studies. These types of currents are probably forced by large-scale remote winds with local winds affecting the top few meters of the water column only. The tidal currents have approximately 5cm/s cross-shore amplitudes with no consistent alignment in time or between depths.

A plume mixing and dilution model (RSB [Frick *et al.* (2003)]) was run as part of the 1994 waiver application to determine the initial volumetric dilution of the plume and its variability throughout the year. The waiver presented average monthly dilution factors, as well as some model results from individual days, using the annual average daily flow rate of 205 mgd and zero ambient current (per California Ocean Plan regulatory guidelines). The model was replicated using a more recent version of RSB (Visual Plumes NRFLD model [Frick *et al.* (2003)]) and comparable results were obtained. Temperature profiles were selected from recent thermistor string data to represent weak winter stratification (19 February 2007), strong summer stratification (27 July 2006) and summer upwelling conditions (28 August 2006). The winter and upwelling profiles were chosen to represent potential `worst case' scenarios in which the subsurface density gradient is weak and thus more likely to allow the plume to rise higher. Previous model results have shown that a well-mixed bottom to mid-depth water column is most likely to allow surfacing of the outfall plume.

The predicted volumetric dilution at mid-plume was within or slightly higher than the range of average monthly values given in the waiver application (December-February dilution ratio of 200-250:1, June-August 320-360:1) As with results shown in the waiver application, maximum plume height in winter was deepest (58 m depth), though dilution is somewhat lower because of earlier trapping (263:1). The shallowest plume height occurred during the summer upwelling simulation (42 m depth) but with a correspondingly higher dilution factor (411:1).

It is possible that conditions may occur that allow a greater plume rise, given the extreme temporal variability of the temperature and currents in this region. However, the weakest density gradients appear to be associated with upwelling events that also provide cold, dense water that mixes with the plume to neutralize buoyancy sooner. ***So while plume surfacing cannot be ruled out entirely, the probability is likely very low.***

The variability seen in the thermistor and ADCP data illustrates the uncertainty in using only snapshots from intermittent CTD profiles to describe complex local hydrography. However, the combination of time series from CTD, thermistor and ADCP data will be useful in initializing and validating a high-resolution numerical simulation of the currents and plume transport. The *in situ* data, plus output from the plume model described above, will eventually be used by Linda Rasmussen to seed a small-scale Regional Ocean Model (ROMS [Moore *et al.* (2004)]) simulation for the area. Such a model would be

invaluable for understanding the structure of the circulation in the region and the patterns of plume transport. In addition to this future phase of the detailed regional oceanographic study, tow-yos with plume tracers will be deployed.

The physical oceanographic data at present is inadequate to predict with certainty either the location or the dilution rate of the plume. The best indicator of the plume location at present is the distribution of high bacterial counts in the weekly surveys, which do not show any significant transport above 40m depth with most of the higher counts confined to 80m depth. The bacteria data does show transport of the plume north and south along the 100m isobath, occasionally out of range of the sampling stations, but predominantly northward. This is consistent with the results from the extreme test-case plume runs and the preliminary ADCP data and suggests that the plume is trapped at depth.

The next two stages of further study will provide more insight into the oceanographic conditions near the Point Loma outfall. Although the ADCP and thermistor data will soon be available, presently we do not have enough data to definitively rule out transport of the plume to shore.

CONCLUSIONS

In the case where sufficient data is available, there is no discernible evidence of significant adverse impacts of the PLOO. In the case where more data is required, initial results suggest no adverse environmental impacts except for one concern with elevated PCBs in fish livers closer to the outfall, although this is possibly due to the LA5 dredge site. The City is currently involved with several projects to address the various data collection needs at which point proper assessments can be made.

This overall conclusion is based on the following specific conclusions. In terms of microbiology, there is no discernible connection between the wastewater plume and shoreline water quality. Regarding sediment chemistry, there is no discernible accumulation of the selected compounds in the region around the outfall. Other than the PCB issue, there is no significant elevation of chemical levels near outfall.

The benthic analysis concludes that there are no indications of significant impacts on the Point Loma bottom community (infaunal, macrobenthos, or megafauna). All of several very different approaches to evaluate the ecological impacts of pollutants on the benthic community are strongly correlated. There are complications with analysis due to the large spatial and temporal variation in the background parameters. The City is actively involved in several benthic-monitoring projects with reports from the first phases expected by the end of 2007, which should provide important new understanding.

In the analysis of physical oceanography, the complexity of the oceanographic conditions in the Point Loma area demands more observations before any conclusions can be made about the transport of the plume. Engineering model runs and bacteria distributions

suggest that the plume is trapped at depth and does not reach the shore. More extensive data collection to analyze the shoreward plume transport is currently underway, with plume tracking and fine-scale modeling of the currents in the region both planned for the immediate future.

The final bottom line is that where data were sufficient to support conclusions, no areas of concern were identified. We did identify several areas where further observations and analysis may be warranted, and it appears that work is already underway to address these needs.

APPENDIX A

Table 1a. Summary of compliance with bacteria standards (single-sample maximum) for PLOO shore stations between 1994 and 2007

10000 Total Coliform Standard 1994-2007

Shore Stations	# of times exceeded	N (# of observations)	% of exceedance	% Compliance
D1	14	386	3.6	96.4
D2	10	353	2.8	97.2
D3	1	344	0.3	99.7
D4	0	579	0.0	100.0
D5	0	588	0.0	100.0
D6	0	340	0.0	100.0
D7	0	583	0.0	100.0
D8	0	595	0.0	100.0
D9	0	583	0.0	100.0

400 Fecal Coliform Standard 1994-2007

Shore Stations	# of times exceeded	N (# of observations)	% of exceedance	% Compliance
D1	17	386	4.4	95.6
D2	10	353	2.8	97.2
D3	3	344	0.9	99.1
D4	0	579	0.0	100.0
D5	0	588	0.0	100.0
D6	0	340	0.0	100.0
D7	1	583	0.2	99.8
D8	8	595	1.3	98.7
D9	2	583	0.3	99.7
D10	1	239	0.4	99.6
D11	11	239	4.6	95.4

104 Enterococcus Standard 1994-2007

Shore Stations	# of times exceeded	N (# of observations)	% of exceedance	% Compliance
D1	25	386	6.5	93.5
D2	15	353	4.2	95.8
D3	3	344	0.9	99.1
D4	2	579	0.3	99.7
D5	4	588	0.7	99.3
D6	1	340	0.3	99.7
D7	2	583	0.3	99.7
D8	11	595	1.8	98.2
D9	6	583	1.0	99.0
D10	9	239	3.8	96.2
D11	13	239	5.4	94.6
D12	5	239	2.1	97.9

Table 1a (continued). Summary of compliance with bacteria geometric mean standards for PLOO shore stations

Geometric Mean Total Coliform Standard

Shore Stations	# of times exceeded	N (# of observations)	% of exceedance	% Compliance	Year
D1	22	380	5.8	94.2	1994-2003
D2	3	353	0.8	99.2	1994-2003
D3	0	343	0.0	100.0	1994-2003
D4	0	574	0.0	100.0	1994-2007
D5	0	584	0.0	100.0	1994-2007
D6	0	334	0.0	100.0	1994-2003
D7	0	547	0.0	100.0	1994-2007
D8	1	588	0.2	99.8	1994-2007
D9	0	581	0.0	100.0	1994-2007
D10	0	233	0.0	100.0	2003-2007
D11	0	234	0.0	100.0	2003-2007
D12	0	234	0.0	100.0	2003-2007

Geometric Mean Fecal Coliform Standard

Shore Stations	# of times exceeded	N (# of observations)	% of exceedance	% Compliance	Year
D1	3	382	0.8	99.2	1994-2003
D2	2	353	0.6	99.4	1994-2003
D3	0	344	0.0	100.0	1994-2003
D4	0	574	0.0	100.0	1994-2007
D5	0	584	0.0	100.0	1994-2007
D6	0	334	0.0	100.0	1994-2003
D7	0	549	0.0	100.0	1994-2007
D8	1	594	0.2	99.8	1994-2007
D9	0	581	0.0	100.0	1994-2007
D10	0	234	0.0	100.0	2003-2007
D11	0	234	0.0	100.0	2003-2007
D12	0	234	0.0	100.0	2003-2007

Geometric Mean Enterococcus Standard

Shore Stations	# of times exceeded	N (# of observations)	% of exceedance	% Compliance	Year
D1	56	381	14.7	85.3	1994-2003
D2	12	353	3.4	96.6	1994-2003
D3	0	343	0.0	100.0	1994-2003
D4	0	574	0.0	100.0	1994-2007
D5	1	584	0.2	99.8	1994-2007
D6	0	334	0.0	100.0	1994-2003
D7	0	549	0.0	100.0	1994-2007
D8	39	594	6.6	93.4	1994-2007
D9	3	581	0.5	99.5	1994-2007
D10	2	234	0.9	99.1	2003-2007
D11	3	234	1.3	98.7	2003-2007
D12	0	234	0.0	100.0	2003-2007

Table 1b. Summary of compliance with bacteria standards (single-sample maximum) for PLOO kelp stations (1994-2007).

10000 Total Coliform Standard (1994~)

Stations	Depth	# of times exceeded	N (# of observations)	% of exceedance	% Compliance
C4	Surface	2	840	0.002	99.998
	Mid	2	1679	0.001	99.999
	Bottom	0	0	NA	NA
C5	Surface	2	839	0.002	99.998
	Mid	2	1677	0.001	99.999
	Bottom	0	0	NA	NA
C6	Surface	0	838	0.0	100.0
	Mid	0	1676	0.0	100.0
	Bottom	0	0	NA	NA
C7	Surface	0	837	0.0	100.0
	Mid	0	212	0.0	100.0
	Bottom	0	1674	0.0	100.0
C8	Surface	0	837	0.0	100.0
	Mid	0	212	0.0	100.0
	Bottom	0	1674	0.0	100.0
A1	Surface	1	840	0.001	99.999
	Mid	0	214	0.0	100.0
	Bottom	0	1680	0.0	100.0
A6	Surface	0	839	0.0	100.0
	Mid	0	214	0.0	100.0
	Bottom	0	1678	0.0	100.0
A7	Surface	1	839	0.001	99.999
	Mid	0	214	0.0	100.0
	Bottom	0	1678	0.0	100.0

400 Fecal Coliform Standard (1994~)

Stations	Depth	# of times exceeded	N (# of observations)	% of exceedance	% Compliance
C4	Surface	2	840	0.002	99.998
	Mid	2	1679	0.001	99.999
	Bottom	0	0	NA	NA
C5	Surface	1	839	0.001	99.999
	Mid	2	1677	0.001	99.999
	Bottom	0	0	NA	NA
C6	Surface	0	838	0.0	100
	Mid	0	1676	0.0	100
	Bottom	0	0	NA	NA
C7	Surface	0	837	0.0	100
	Mid	0	212	0.0	100
	Bottom	0	1674	0.0	100
C8	Surface	0	837	0.0	100
	Mid	0	212	0.0	100

	Bottom	0	1674	0.0	100
A1	Surface	1	840	0.001	99.999
	Mid	0	214	0.0	100
	Bottom	0	1680	0.0	100
A6	Surface	0	839	0.0	100
	Mid	0	214	0.0	100
	Bottom	0	1678	0.0	100
A7	Surface	1	839	0.001	99.999
	Mid	0	214	0.0	100
	Bottom	0	1678	0.0	100

104 Enterococcus Standard (1994)

Stations	Depth	# of times exceeded	N (# of observations)	% of exceedance	% Compliance
C4	Surface	3	840	0.004	99.996
	Mid	3	1679	0.002	99.998
	Bottom	0	0	NA	NA
C5	Surface	4	839	0.005	99.995
	Mid	6	1677	0.004	99.996
	Bottom	0	0	NA	NA
C6	Surface	1	838	0.001	99.999
	Mid	1	1676	0.001	99.999
	Bottom	0	0	NA	NA
C7	Surface	4	837	0.005	99.995
	Mid	1	212	0.005	99.995
	Bottom	3	1674	0.002	99.998
C8	Surface	2	837	0.002	99.998
	Mid	0	212	0.0	100
	Bottom	4	1674	0.002	99.998
A1	Surface	2	840	0.002	99.998
	Mid	0	214	0.0	100
	Bottom	2	1680	0.001	99.999
A6	Surface	1	839	0.001	99.999
	Mid	0	214	0.0	100
	Bottom	0	1678	0.0	100
A7	Surface	5	839	0.006	99.994
	Mid	0	214	0.0	100
	Bottom	3	1678	0.002	99.998

Table 1b (continued). Summary of compliance with bacteria geometric mean standards for PLOO kelp stations

Geometric Mean Total Coliform Standard (1994-2007)

Stations	Depth	# of times exceeded	% Compliance
C4	Surface*	0	100
	Mid**	0	100
	Bottom†	NA	NA
C5	Surface	0	100
	Mid	0	100
	Bottom	NA	NA
C6	Surface	0	100
	Mid	0	100
	Bottom	NA	NA
C7	Surface	0	100
	Mid	0	100
	Bottom	0	100
C8	Surface	0	100
	Mid	0	100
	Bottom	0	100
A1	Surface	0	100
	Mid	0	100
	Bottom	0	100
A6	Surface	0	100
	Mid	0	100
	Bottom	0	100
A7	Surface	0	100
	Mid	0	100
	Bottom	0	100

Geometric Mean Fecal Coliform Standard (1994~)

Stations	Depth	# of times exceeded	% Compliance
C4	Surface	0	100
	Mid	0	100
	Bottom	NA	NA
C5	Surface	0	100
	Mid	0	100
	Bottom	NA	NA
C6	Surface	0	100
	Mid	0	100
	Bottom	NA	NA
C7	Surface	0	100
	Mid	0	100
	Bottom	0	100
C8	Surface	0	100
	Mid	0	100
	Bottom	0	100

A1	Surface	0	100
	Mid	0	100
	Bottom	0	100
A6	Surface	0	100
	Mid	0	100
	Bottom	0	100
A7	Surface	0	100
	Mid	0	100
	Bottom	0	100

Geometric Mean Enterococcus Standard (1994~)

Stations	Depth	# of times exceeded	% Compliance
C4	Surface	3	99.996
	Mid	3	99.996
	Bottom	NA	NA
C5	Surface	2	99.998
	Mid	2	99.998
	Bottom	NA	NA
C6	Surface	0	100
	Mid	0	100
	Bottom	NA	NA
C7	Surface	0	100
	Mid	0	100
	Bottom	0	100
C8	Surface	0	100
	Mid	0	100
	Bottom	0	100
A1	Surface	0	100
	Mid	0	100
	Bottom	0	100
A6	Surface	0	100
	Mid	0	100
	Bottom	0	100
A7	Surface	0	100
	Mid	0	100
	Bottom	0	100

Note:* Surface: calculated by taking mean value of depth (1.0, 1.5, 2.0M) and comparing this value to geometric criteria.
** Mid: calculated by taking mean value of depth (3, 6.0. 6.1, 9.0M) and comparing this value to geometric criteria.
† Bottom: calculated by taking mean value of depth (12, 12.2, 18.0, 18.3M) and comparing this value to geometric criteria.

APPENDIX B

SOUTH BAY MICROBIOLOGY

The following summarizes the findings of Doug Bartlett and Alexandra Purdy on the impact of the South Bay Ocean Outfall (SBOO) which treats effluent to the full secondary/tertiary level. This study was performed in conjunction with analysis of the Point Loma Ocean Outfall and serves as an interesting contrast to the Point Loma findings.

In 2006 the average daily outfall from the South Bay Ocean Outfall (SBOO) was 24.5 mgd with about 5 mgd secondary effluent from San Diego's South Bay Reclamation Plant, the rest coming from the International Wastewater Treatment Plant operated by the IBWC. SBOO discharges treated effluent from both the South Bay Reclamation Plant (SBWRP) and the International Wastewater Treatment Plant (IWTP) and is about 5.6 km in length. Discharge from IWTP began in January 1999 and from SBWRP in May 2002.

The South Bay region is a much greater problem than the Point Loma region. In the 138-month period from July, 1995 to December, 2006 the shoreline stations along the South Bay contained 1,465 samples with coliform counts equal to or greater than 1,000 CFU/100 ml (mean = 10,700; high = 38,000). During a 130 month period from 1996 through 2006 the 3 kelp stations had 392 samples with total coliform counts equal to or exceeding 1,000 CFU/100 ml (mean ~8,300; high = ~18,000). This overall frequency of these high counts is similar among the two types of locations, but for those shore sites near the Tijuana River the maxima can be approximately twice as high. To put this into greater perspective some of the SBOO region shore stations are 30-40 times more likely to have high coliform counts compared to their counterparts in the PLOO region.

Shoreline contamination sources (such as the Tijuana River and the Los Buenos Creek) are a major problem. In 2006 the kelp stations had no periods in which they were out of compliance with the California Ocean Plan total coliform levels, whereas two of the shoreline stations near the Tijuana River were out of compliance about 50% of the time. Excessive coliform counts in the South Bay very clearly correlate with rainfall. In contrast to the PLOO data, total and fecal coliform levels have only slightly decreased at the shore stations since the initiation of outfall discharge. This modest decrease appears to be due in part to diverting discharge once destined for the Tijuana River to the SBOO.

A description of the plumes associated with the SBOO, the Tijuana River and the Los Buenos Creek in relation to other existing water quality assays derived from the MODIS satellite data should be included in the reports.

In summary, while it is evident that the PLOO and SBOO have a minimal influence on their adjacent shorelines, it is unclear why the South Bay shoreline indicator bacteria counts have not gone down more since the operation of the IWTP began in 1999. It is also not clear what fraction of the sewage flowing through the Tijuana River has been diverted thus far to the IWTP.

APPENDIX C

PCB BIOACCUMULATION

The bioaccumulation portion of the PLOO monitoring program is conducted in order to evaluate the potential for bioaccumulation of selected pollutants through the food chain. It consists of two components:

3. analysis of muscle (and liver) tissues from fishes collected by rig fishing
4. analysis of liver tissues from trawl-caught fishes.

This appendix describes the details of the PCB bioaccumulation analyses performed by Rick Gersberg and Ed Parnell.

The analysis conducted by Dr. Gersberg consisted of a review of the bioaccumulation data in existing reports and databases of the City of San Diego, as well as some original data analyses on bioaccumulation data for 1995-2006 in which selected fish tissue contaminant levels for rig fishing stations and trawl fishing stations in the vicinity of the PLOO (RF1 and TF1) were compared statistically to comparable values at stations away from the PLOO (RF2 and TF2). For the total PCB level analysis described here, both fish muscle and liver were analyzed.

A Mann-Whitney U-test conducted on total PCB levels for the dataset for 1995-2003, showed rockfish fish liver levels at RF1(median = 189; mean = 332.2 μg/kg) were significantly (p-value = 0.002) higher than rockfish liver levels for RF2 (median = 73; mean = 177 μg /kg). On the other hand, statistical comparison of total PCB in rockfish muscle at the RF1 and RF2 stations showed no significant (p-value = 0.828) difference. Although it is important to note here that a comparison between RF1 and RF2 stations should be considered with caution because different species of fish may have been collected at these two sites, and the liver is not consumed by most humans, the results regarding the highly bioaccumulative (and cancer-causing) PCBs may be suggestive of underlying bioaccumulative effects which deserves further scrutiny.

However, the significance of this finding is unclear, since the area located just south of the PLOO (zone 3) is near the LA-5 dredge disposal site, and elevated levels of PCBs in various fish species have been demonstrated at this location. Resuspension of fines from the dredged materials, or migration of fish into this zone south of the PLOO, could then account for the differences in total PCB levels observed at RF1 (near the PLOO) as compared to RF2 (north of the PLOO).

To investigate these elevated levels at the outfall site further, Ed Parnell has used robust regression of ordered statistics to develop probability distributions of the individual PCB congeners for liver tissue for all rig fishing and trawl fishing stations. This analysis deals with non-detects in the most robust manner available (state of the art for this field [Helsel (2005)]). Non-detects mean that the concentration of the analyte of interest is below the detection limits of the method/machine. It does not mean the concentration is zero. Assuming zero or a constant number can bias the results of any subsequent statistical analysis. Because there are so many non-detects among the various PCBs 27,897 out of

38,063 (~73%), each PCB (the City analyzed for 50 PCBs) needs to be compared using methods that are robust to censored data. Due to time constraints he focused on liver tissue because that is where the significant results described above were found and where PCBs are in much higher concentrations than in the muscle.

The trawl fishing station near the LA-5 dredge disposal site (trawl fishing zone 3) has the highest concentrations for all PCB congeners and this difference is significant for most congeners. PCB concentrations decrease with increasing distance from the LA-5 site both to the north and to the south (*i.e.*, lower concentrations of PCBs at the outfall and even less further north off Mission Beach). In all cases trawl fishing zone 3 has the highest median values, upper quartiles, and outliers. The results are shown in the boxplot of Figure 1. The rig fishing results show that there are greater concentrations for most PCB congeners at the outfall site compared to the Mission Beach site, shown in Figure 2.

The spatial patterns for the rig fishing and the trawl fishing stations are consistent at the two sites where both are done. The trawl fishing provides the added piece of information that the centroid of PCB contamination on the shelf is likely the LA-5 disposal site.

A straightforward interpretation of these results (based on the spatial patterns observed) is that the LA-5 dredge disposal site is the most likely source of significant PCB contamination in fish on the Point Loma shelf. The rig fishing results suffer from not having stations further south toward LA-5.

In conclusion, there is currently no way to definitively know whether the elevated levels in the rig fishing are due to the PLOO or the LA-5 site. It is recommended that the City of San Diego conduct a more detailed analysis of this finding and perhaps search for more suitable bioaccumulation reference sites, away from known sources of PCBs. A similar analysis could be performed for fish tissue samples, as well as for PCBs and metals in sediment samples. Additional rig fishing sampling south of the PLOO would further test the hypothesis that the source is LA-5.

Table C1. Mann-Whitney U-test for total PCBs at RF1, RF2, TFZONE1* and TFZZONE2**

Station	N	median	Year
RF1(fish liver)	41	189	1995-2003
RF2(fish liver)	40	73	1995-2003
***p*=0.002#**			
RF1(fish muscle)	53	1.5	1995-2003
RF2(fish muscle)	54	1.15	1995-2003
p=0.828			
TFZONE1	117	327	1995-2006
TFZONE2	118	234.2	1995-2006
p=0.220			

Note: Starting in August of 2003, stations changed to Zones 1 and 2.
* TFZONE1 consists of stations SD10 and SD12
** TFZONE2 consists of stations SD13 and SD14
 # Indicates significant result at p<0.05

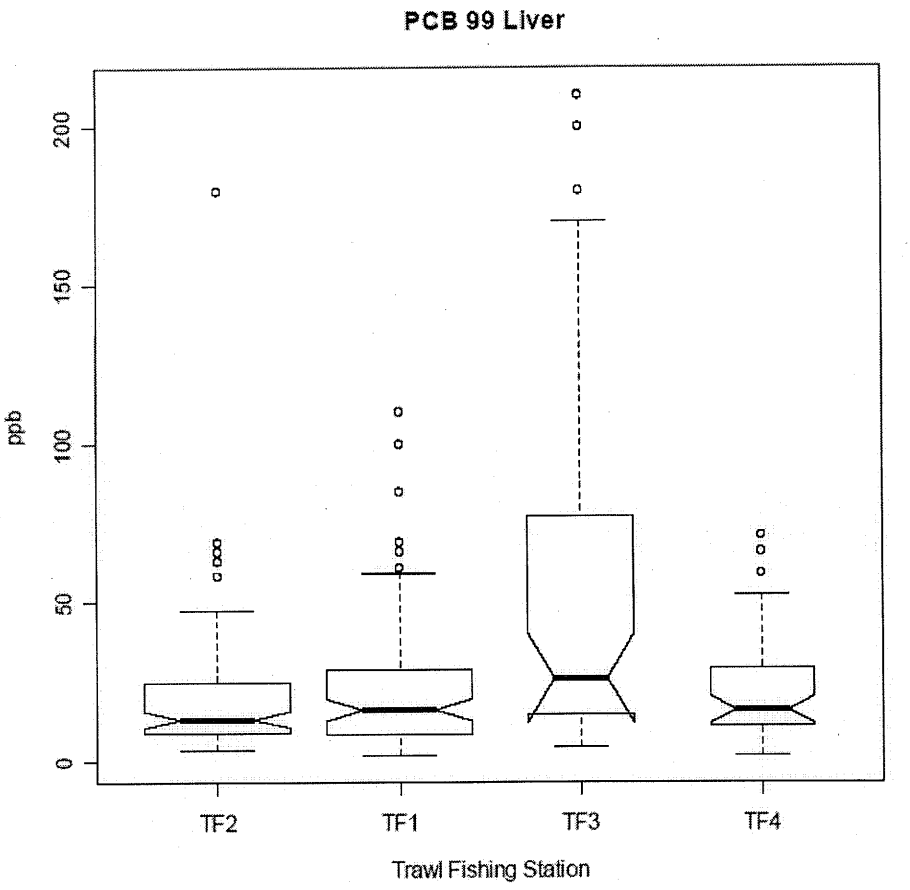

Figure 1: Trawl fishing boxplots showing frequency distributions of PCB congeners at each site. Depth=100m; Zone TF1=Outfall; Zone TF2=Mission Beach; Zone TF3=Near LA-5; Zone TF4=Silver Strand.

Boxplots show frequency distributions of PCB congeners at each site. Data are pooled over time at each site (1995-2006). Frequency plots include actual values for concentrations detected above method detection limits, and modeled concentrations (lognormal) for concentrations below detection limits using robust regression of ordered statistics (Helsel, 2005). Congeners were only analyzed if the sample size was >30 and the percentage of nondetects was <80%. Bold bars=median, boxes=quartiles, whiskers=smallest and largest non-outliers, circles=values for outliers, notches indicate 95% confidence limits (McGill et al., 1978), width of boxes is proportional to sample size ($n^{1/2}$) for each site.

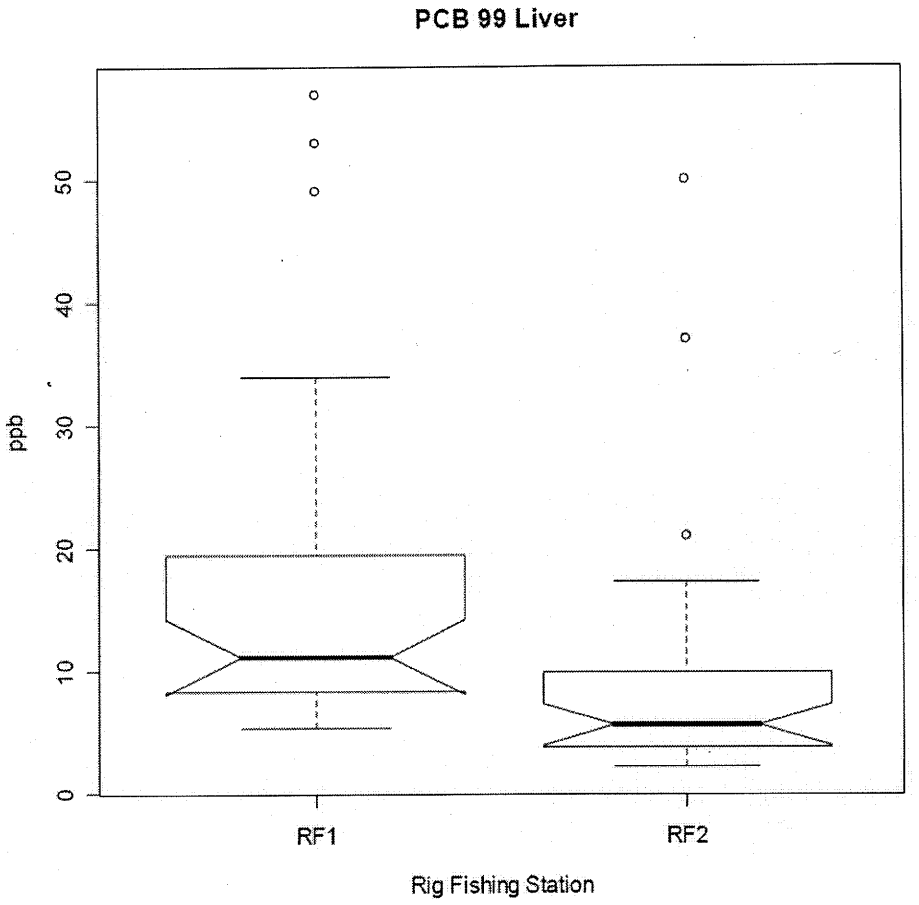

Figure 2: Rig fishing boxplots showing frequency distributions of PCB congeners at each site. Site RF1=Outfall; Site RF2=Mission Beach.

Acronyms

ADCP: Acoustic Doppler Current Profiler
BRI: Benthic Response Index
CTD: instrument to measure conductivity, temperature, and depth
EPA: Environmental Protection Agency
FIB: fecal indicator bacteria
ITI: Infaunal Trophic Index
IWTP: International Wastewater Treatment Plant
mgd: million gallons per day
MODIS: Moderate Resolution Imaging Spectroradiometer
PCBs: Polychlorinated Biphenyls
PLOO: Point Loma Ocean Outfall
SBOO: South Bay Ocean Outfall
SBWRP: South Bay Reclamation Plant
SCB: Southern California Bight
SCCWRP: Southern California Coastal Water Research Project
SWRCB: State Water Resources Control Board
tow-yo: a CTD that is towed behind a ship while being cycled through the water
ZID: zone of initial dilution

References

Databases

Ocean monitoring databases for 2001-2007 used in this review are publicly available on the City of San Diego website (http://www.sandiego.gov/mwwd/environment/data/). The available data is for bacteriology, fish trawls, benthic invertebrates, invertebrate trawls, and water quality. Additional data was provided by the City which was not available online:

1. ocean monitoring databases for 1991-2000

2. bacterial indicator monitoring data: PLOOWQ_Kelp_Micro_1994_2001.xls; PLOOWQ_Shore_Micro_1994_2001.xls; PLOOWQ_Mon_Micro_1994_2001.xls

3. data on bioaccumulation of toxic chemicals in fish tissue: PLOOBioaccum_1995_2006.xls

4. sediment chemistry data: PLOOSedChem_1996_2000.xls; PLOOSedChem_2001_2006.xls

5. total coliform counts equal to or greater than 1000 CFU/100 ml for a number of PLOO and SBOO locations going back to 1991

6. CTD casts from 1991-2006.

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