

# Table of Contents

---

<b>Production Credits and Acknowledgements .....</b>	<b>iii</b>
<b>Table and Figure Listing .....</b>	<b>iv</b>
<b>Acronyms and Abbreviations .....</b>	<b>xi</b>
<b>Executive Summary .....</b>	<b>1</b>
<i>T. Stebbins</i>	
<b>Chapter 1. General Introduction .....</b>	<b>7</b>
<i>T. Stebbins</i>	
Introduction .....	7
Regular Fixed-Grid Monitoring .....	8
Random Sample Regional Surveys .....	8
Literature Cited .....	9
<b>Chapter 2. Oceanographic Conditions .....</b>	<b>13</b>
<i>W. Enright, J. Pettis Schallert, G. Welch, M. Kasuya, A. Latker</i>	
Introduction .....	13
Materials and Methods .....	14
Results and Discussion .....	16
Summary and Conclusions .....	24
Literature Cited .....	26
<b>Chapter 3. Water Quality .....</b>	<b>31</b>
<i>M. Nelson, A. Latker, N. Haring, L. Othman, M. Kasuya, S. Romero</i>	
Introduction .....	31
Materials and Methods .....	31
Results .....	33
Discussion .....	38
Literature Cited .....	40
<b>Chapter 4. Sediment Conditions .....</b>	<b>45</b>
<i>A. Latker, P. Vroom, N. Haring</i>	
Introduction .....	45
Materials and Methods .....	46
Results .....	47
Discussion .....	55
Literature Cited .....	56
<b>Chapter 5. Macrobenthic Communities .....</b>	<b>61</b>
<i>P. Vroom, N. Haring, R. Velarde, T. Stebbins</i>	
Introduction .....	61
Materials and Methods .....	62
Results .....	63
Discussion .....	72
Literature Cited .....	75

# Table of Contents

---

<b>Chapter 6. Demersal Fishes and Megabenthic Invertebrates .....</b>	<b>79</b>
<i>P. Vroom, A. Latker, R. Gartman, M. Nelson, W. Enright</i>	
Introduction .....	79
Materials and Methods .....	80
Results .....	81
Discussion .....	88
Literature Cited .....	90
<b>Chapter 7. Bioaccumulation of Contaminants in Fish Tissues .....</b>	<b>95</b>
<i>A. Latker, P. Vroom, R. Gartman</i>	
Introduction .....	95
Materials and Methods .....	95
Results .....	98
Discussion .....	105
Literature Cited .....	109
<b>Chapter 8. San Diego Regional Survey — Sediment Conditions .....</b>	<b>115</b>
<i>A. Latker, P. Vroom, N. Haring</i>	
Introduction .....	115
Materials and Methods .....	115
Results .....	117
Discussion .....	126
Literature Cited .....	127
<b>Chapter 9. San Diego Regional Survey — Macrobenthic Communities .....</b>	<b>131</b>
<i>P. Vroom, N. Haring, R. Velarde, T. Stebbins</i>	
Introduction .....	131
Materials and Methods .....	132
Results .....	133
Discussion .....	146
Literature Cited .....	147
<b>Glossary .....</b>	<b>151</b>

## APPENDICES

- Appendix A: Supporting Data — Oceanographic Conditions*
- Appendix B: Supporting Data — Water Quality*
- Appendix C: Supporting Data — Sediment Conditions*
- Appendix D: Supporting Data — Macrobenthic Communities*
- Appendix E: Supporting Data — Demersal Fishes and Megabenthic Invertebrates*
- Appendix F: Supporting Data — Bioaccumulation of Contaminants in Fish Tissues*
- Appendix G: Supporting Data — San Diego Regional Survey — Sediment Conditions*
- Appendix H: Supporting Data — San Diego Regional Survey — Macrobenthic Communities*

# Table of Contents

---

## PRODUCTION CREDITS AND ACKNOWLEDGEMENTS

### **Technical Editors:**

*T. Stebbins, A. Latker*

### **Production Editors:**

*M. Nelson, N. Haring, P. Vroom, R. Gartman, M. Kasuya, J. Pettis-Schallert*

### **GIS Graphics:**

*M. Kasuya*

### **Acknowledgments:**

We are grateful to the personnel of the City's Marine Biology, Marine Microbiology, and Wastewater Chemistry Services Laboratories for their assistance in the collection and/or processing of all samples, and for discussions of the results. The completion of this report would not have been possible without their continued efforts and contributions. We would especially like to thank G. Daly, A. Davenport, A. Feit, M. Kelly, D. Olson, D. Silvaggio, R. Velarde, and L. Wiborg for their critical reviews of various chapters of this report. We would also like to thank Dr. E. Parnell of the Scripps Institution of Oceanography for his advice and assistance. Complete staff listings for the above labs and additional details concerning relevant QA/QC activities for the receiving waters monitoring data reported herein are available online in the 2011 Annual Receiving Waters Monitoring & Toxicity Testing Quality Assurance Report ([www.sandiego.gov/mwwd/environment/reports.shtml](http://www.sandiego.gov/mwwd/environment/reports.shtml)).

### **How to cite this document:**

City of San Diego. (2012). Annual Receiving Waters Monitoring Report for the South Bay Ocean Outfall (International Wastewater Treatment Plant), 2011. City of San Diego Ocean Monitoring Program, Public Utilities Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

# Table of Contents

---

## LIST OF TABLES

### Chapter 1: General Introduction

No Tables.

### Chapter 2: Oceanographic Conditions

2.1 Sample dates for oceanographic surveys conducted during 2011 ..... 15

### Chapter 3: Water Quality

3.1 Rainfall and bacteria levels at shore stations during 2011 ..... 34

3.2 Elevated bacteria at shore stations during 2011 ..... 35

3.3 Bacteria levels at kelp bed and other offshore stations during 2011 ..... 37

3.4 Elevated bacteria at kelp bed and other offshore stations during 2011 ..... 38

3.5 Total suspended solid concentrations from the kelp bed and other offshore stations during 2011 ..... 40

### Chapter 4: Sediment Conditions

4.1 Particle size and sediment chemistry parameters at benthic stations during 2011 ..... 48

### Chapter 5: Macrobenthic Communities

5.1 Macrofaunal community parameters for 2011 ..... 64

5.2 Percent composition of species and abundance by major taxonomic group for 2011 ..... 69

5.3 Ten most abundant macroinvertebrates collected at benthic stations during 2011 ..... 70

5.4 Mean abundance of the most common species found in cluster groups A–I defined in Figure 5.4 ..... 74

### Chapter 6: Demersal Fishes and Megabenthic Invertebrates

6.1 Demersal fish species collected in 28 trawls during 2011 ..... 81

6.2 Demersal fish community parameters for 2011 ..... 82

6.3 Description of demersal fish cluster groups A–E defined in Figure 6.4 ..... 86

6.4 Species of megabenthic invertebrates collected in 28 trawls during 2011 ..... 88

6.5 Megabenthic invertebrate community parameters for 2011 ..... 89

### Chapter 7: Bioaccumulation of Contaminants in Fish Tissues

7.1 Species of fish collected at each trawl and rig fishing station during 2011 ..... 97

7.2 Metals in liver tissues of fishes collected at trawl stations during 2011 ..... 99

7.3 Pesticides, total PCB, and lipids in liver tissues of fishes collected at trawl stations during 2011 ..... 102

7.4 Metals in muscle tissues of fishes at rig fishing stations during 2011 ..... 104

7.5 Pesticides, total PCB, and lipids in muscle tissues of fishes collected at rig fishing stations during 2011 ..... 106

7.6 Contaminant loads in liver tissues of fishes collected between 2009 and 2011 ..... 107

7.7 Contaminant loads in muscle tissues of fishes collected between 2009 and 2011 ..... 109

# Table of Contents

---

## LIST OF TABLES *(continued)*

### **Chapter 8: San Diego Regional Survey – Sediment Conditions**

8.1	Sediment grain size and chemistry parameters at regional benthic stations during 2011 .....	118
8.2	Spearman rank correlation analyses of percent fines and sediment chemistry parameters from regional benthic samples in 2011 .....	120

### **Chapter 9: San Diego Regional Survey – Macrobenthic Communities**

9.1	Macrofaunal community parameters for regional stations during 2011 .....	134
9.2	Percent composition of species and abundance by major taxonomic group for regional stations during 2011 .....	136
9.3	Ten most abundant macroinvertebrate taxa at regional benthic stations during 2011 .....	138
9.4	Most abundant taxa from each sediment type/depth stratum combination between 2009–2011 .....	142
9.5	Abundance of the most common species found in cluster groups A–O defined in Figure 9.4 .....	144

## LIST OF FIGURES

### **Chapter 1: General Introduction**

1.1	Receiving waters monitoring stations sampled around the South Bay Ocean Outfall .....	8
1.2	Regional benthic survey stations sampled during July 2011 .....	9

### **Chapter 2: Oceanographic Conditions**

2.1	Water quality monitoring stations sampled around the South Bay Ocean Outfall.....	14
2.2	Temperature, salinity, dissolved oxygen, pH, transmissivity, and chlorophyll a recorded at 28-m stations during 2011 .....	16
2.3	Ocean temperatures recorded in 2011 .....	18
2.4	Rapid Eye images of the SBOO and coastal regions on October 26 and December 21, 2011.....	19
2.5	Ocean salinity recorded in 2011 .....	20
2.6	Relative CDOM values recorded in 2011 .....	22
2.7	Rapid Eye images of the SBOO and coastal regions following storm events on January 1 and February 21, 2011 .....	23
2.8	MODIS image of widespread plankton blooms in San Diego’s nearshore waters on September 8, 2011 .....	24
2.9	Time series of temperature, salinity, transmissivity, pH, dissolved oxygen, and chlorophyll a anomalies between 1995–2011 .....	25

### **Chapter 3: Water Quality**

3.1	Water quality monitoring stations sampled around the South Bay Ocean Outfall.....	32
-----	---	----

# Table of Contents

---

## LIST OF FIGURES *(continued)*

3.2	Comparison of bacteriological data from shore stations to rainfall between 1996 and 2011.....	35
3.3	Rapid Eye satellite image taken on March 24, 2011 combined with bacteria levels at shore stations on March 22, 2011 .....	36
3.4	Comparison of bacteriological data from kelp bed stations to rainfall between 1996 and 2011.....	39
3.5	Rapid Eye satellite image taken on January 1, 2011 combined with bacteria levels at kelp bed and other offshore stations from January 1 to February 1, 2011 .....	41
3.6	Distribution of seawater samples with elevated FIBs at kelp bed and other offshore stations during 2011 .....	41
3.7	Percent of samples collected from offshore stations with elevated bacterial densities between 1995–2011 .....	42

### Chapter 4: Sediment Conditions

4.1	Benthic stations sampled around the South Bay Ocean Outfall.....	46
4.2	Distribution of sediment types at benthic stations during 2011 .....	49
4.3	Grain size and organic indicator data from stations between 1995–2011 .....	50
4.4	Scatterplot of percent fines versus concentration of total nitrogen, total volatile solids, and nickel within sediments in 2011 .....	53
4.5	Cluster analysis of sediment chemistry at benthic stations between 2007–2011 .....	54

### Chapter 5: Macrobenthic Communities

5.1	Benthic stations sampled around the South Bay Ocean Outfall.....	62
5.2	Macrofaunal community parameters 1995–2011 .....	66
5.3	Abundance per survey for the five most abundant taxa between 1995–2011 .....	68
5.4	Cluster analysis of macrofaunal assemblages at benthic stations during 2011 .....	72
5.5	Spatial distribution of cluster groups .....	73

### Chapter 6: Demersal Fishes and Megabenthic Invertebrates

6.1	Otter trawl station locations around the South Bay Ocean Outfall.....	80
6.2	Species richness and abundance of demersal fish collected between 1995–2011 .....	83
6.3	The eight most abundant fish species collected between 1995–2011 .....	84
6.4	Cluster analysis of demersal fish assemblages between 1995–2011.....	85
6.5	Species richness and abundance of megabenthic invertebrates collected between 1995–2011.....	90
6.6	The four most abundant megabenthic invertebrate species collected between 1995–2011.....	91

### Chapter 7: Bioaccumulation of Contaminants in Fish Tissues

7.1	Otter trawl and rig fishing station locations around the South Bay Ocean Outfall.....	96
7.2	Concentrations of metals detected frequently in the liver tissues of fishes from each trawl station during 2011 .....	100

# Table of Contents

---

## LIST OF FIGURES *(continued)*

7.3	Concentrations of pesticides and total PCBs in liver tissues of fishes from trawl stations during 2011 .....	103
7.4	Concentrations of frequently detected contaminants in muscle tissues of fishes from rig fishing stations during 2011 .....	105
7.5	Concentrations of select parameters in liver tissues of fishes collected between 2009 and 2011 .....	108
7.6	Concentrations of select parameters in muscle tissues of fishes collected between 2009 and 2011 .....	110

## Chapter 8: San Diego Regional Survey – Sediment Conditions

8.1	Regional benthic survey stations sampled during July 2011 .....	116
8.2	Distribution of sediment types at regional benthic stations during July 2011 .....	119
8.3	Scatterplot of percent fines versus depth, total volatile solids, and copper for regional benthic stations in 2011 .....	121
8.4	Comparison of representative grain size and chemistry parameters in sediments from the four major depth strata sampled between 2009–2011 .....	122
8.5	Cluster analysis of sediment chemistry at regional stations between 2009–2011 .....	124
8.6	Spatial distribution of cluster groups .....	125

## Chapter 9: San Diego Regional Survey – Macrobenthic Communities

9.1	Regional benthic survey stations sampled during July 2011 .....	132
9.2	Macrofaunal community structure metrics for the four major depth strata sampled during regional surveys between 2009–2011 .....	135
9.3	Percent composition of species and abundance by major phyla for each depth stratum at the regional stations during 2011 .....	137
9.4	Cluster analysis of macrofaunal data at regional stations between 2009–2011 .....	140
9.5	Spatial distribution of cluster groups .....	141

## LIST OF BOXES

### Chapter 3: Water Quality

3.1	Bacteriological compliance standards for water contact areas .....	33
-----	--	----

## LIST OF APPENDICES

### Appendix A: Oceanographic Conditions

A.1	Temperature, salinity, dissolved oxygen, pH, transmissivity, and chlorophyll a for surface and bottom waters in 2011	
A.2	Dissolved oxygen recorded in 2011	
A.3	Measurements pH recorded in 2011	
A.4	Transmissivity recorded in 2011	
A.5	Concentrations of chlorophyll a recorded in 2011	

# Table of Contents

---

## LIST OF APPENDICES *(continued)*

### **Appendix B: Water Quality**

- B.1 Elevated bacteria densities collected at shore stations during 2011
- B.2 Elevated bacteria densities collected at kelp bed stations during 2011
- B.3 Elevated bacteria densities collected at non-kelp bed offshore stations during 2011
- B.4 Samples with elevated FIB densities at shore stations during wet and dry seasons between 1995–2011
- B.5 Samples with elevated FIB densities at kelp bed stations during wet and dry seasons between 1995–2011
- B.6 Compliance with the 2005 California Ocean Plan water contact standards for shore and kelp bed stations during 2011

### **Appendix C: Sediment Conditions**

- C.1 Subset of the Wentworth scale and modifications used in the analysis of sediments in 2011
- C.2 Classification of sediment types
- C.3 Constituents and method detection limits for sediment samples between 2007–2011
- C.4 Constituents that make up total DDT and total PCB in each sediments collected in 2011
- C.5 Sediment grain size parameters for the January and July 2011 surveys
- C.6 Selected plots illustrating particle size distributions of sediments samples between 2003–2011
- C.7 Organic loading indicators at benthic stations for the January and July 2011 surveys
- C.8 Concentrations of trace metals for the January and July 2011 surveys
- C.9 Concentrations of total DDT, HCB, and total PCB for the January and July 2011 surveys
- C.10 Description of cluster groups A–F as defined in Figure 4.5
- C.11 Particle size and sediment chemistry parameters by cluster group

### **Appendix D: Macrobenthic Communities**

- D.1 Two-way crossed ANOSIM results for benthic infauna
- D.2 Delineation of cluster groups from Figure 5.4 by species exclusivity

### **Appendix E: Demersal Fishes and Megabenthic Invertebrates**

- E.1 Demersal fish species captured during 2011
- E.2 Total abundance by species and station for demersal fish during 2011
- E.3 Biomass by species and station for demersal fish during 2011
- E.4 Two-way crossed ANOSIM results for fish
- E.5 Megabenthic invertebrate taxa captured during 2011
- E.9 Total abundance by species and station for megabenthic invertebrates during 2011

# Table of Contents

---

## LIST OF APPENDICES *(continued)*

### **Appendix F: Bioaccumulation of Contaminants in Fish Tissues**

- F.1 Lengths and weights of fishes used for each composite sample during 2011
- F.2 Constituents and method detection limits for fish tissue samples analyzed between 2009–2011
- F.3 Constituents that make up total DDT, total chlordane, and total PCB in each composite sample during 2011
- F.4 Species of fish collected from each trawl and rig fishing station between 2009–2011
- F.5 Three-way PERMANOVA results for liver tissue
- F.6 Two-way crossed ANOSIM results for muscle tissue

### **Appendix G: San Diego Regional Survey – Sediment Conditions**

- G.1 Constituents and method detection limits for sediment samples collected as part of the 2009–2011 regional surveys
- G.2 Constituents that make up total DDT, total PCB and total PAH in each sediment sample collected as part of the 2011 regional survey
- G.3 Particle size parameters for the 2011 regional stations
- G.4 Plots illustrating sediment grain size composition for the 2011 regional stations
- G.5 Concentrations of chemical analytes in sediments from the 2011 regional stations
- G.6 Description of cluster groups A–O as defined in figure 8.5
- G.7 Particle size and chemistry parameters by cluster group

### **Appendix H: San Diego Regional Survey – Macrobenthic Communities**

- H.1 Regional three-way PERMANOVA results for benthic infauna
- H.2 Description of individual cluster groups A–O for regional samples collected between 2009–2011
- H.3 Delineation of cluster groups from Figure 9.4 by species exclusivity

This page intentionally left blank

## Acronyms and Abbreviations

---

ADCP	Acoustic Doppler Current Profiler
ANOSIM	Analysis of Similarity
APHA	American Public Health Association
APT	Advanced Primary Treatment
AUV	Automated Underwater Vehicle
BACIP	Before-After-Control-Impact-Paired
BOD	Biochemical Oxygen Demand
BRI	Benthic Response Index
CalCOFI	California Cooperative Fisheries Investigation
CCS	California Current System
CDIP	Coastal Data Information Program
CDOM	Colored Dissolved Organic Matter
CDPH	California Department of Public Health
CFU	Colony Forming Units
cm	centimeter
CSDMML	City of San Diego Marine Microbiology Laboratory
CTD	Conductivity, Temperature, Depth instrument
DDT	Dichlorodiphenyltrichloroethane
df	degrees of freedom
DO	Dissolved Oxygen
ELAP	Environmental Laboratory Accreditation Program
EMAP	Environmental Monitoring and Assessment Program
EMTS	Environmental Monitoring and Technical Services
ENSO	El Niño Southern Oscillation
ERL	Effects Range Low
ERM	Effects Range Mediam
F:T	Fecal to Total coliform ratio
FET	Fisher's Exact Test
FIB	Fecal Indicator Bacteria
ft	feet
FTR	Fecal to Total coliform Ratio criterion
g	gram
Global R	ANOSIM test value that examines for global differences within a factor
H'	Shannon diversity index
HCB	Hexachlorobenzene
HCH	Hexachlorocyclohexane
IGODS	Interactive Geographical Ocean Data System
in	inches
IR	Infrared
IWTP	International Wastewater Treatment Plant
J'	Pielou's evenness index
kg	kilogram
km	kilometer
km <sup>2</sup>	square kilometer
L	Liter

# Acronyms and Abbreviations

---

m	meter
m <sup>2</sup>	square meter
MDL	Method Detection Limit
mg	milligram
mgd	millions of gallons per day
ml	maximum length
mL	milliliter
mm	millimeter
MODIS	Moderate Resolution Imaging Spectroradiometer
MRP	Monitoring and Reporting Program
mt	metric ton
<i>n</i>	sample size
N	number of observations used in a Chi-square analysis
ng	nanograms
no.	number
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
NPGO	North Pacific Gyre Oscillation
NWS	National Weather Service
O&G	Oil and Grease
OCSD	Orange County Sanitation District
OEHHA	California Office of Environmental Health Hazard Assessment
OI	Ocean Imaging
<i>p</i>	probability
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyls
PDO	Pacific Decadal Oscillation
pH	Acidity/Alkalinity value
PLOO	Point Loma Ocean Outfall
PLWTP	Point Loma Wastewater Treatment Plant
ppb	parts per billion
ppm	parts per million
ppt	parts per trillion
PRIMER	Plymouth Routines in Multivariate Ecological Research
psu	practical salinity units
r	ANOSIM test value that examines for differences among levels within a factor
<i>r<sub>s</sub></i>	Spearman rank correlation coefficient
ROV	Remotely Operated Vehicle
SABWTP	San Antonio de los Buenos Wastewater Treatment Plant
SBOO	South Bay Ocean Outfall
SBWRP	South Bay Water Reclamation Plant
SCB	Southern California Bight
SCBPP	Southern California Bight Pilot Project
SD	Standard Deviation
SDRWQCB	San Diego Regional Water Quality Control Board

## Acronyms and Abbreviations

---

SIMPER	Similarity Percentages Routine
SIMPROF	Similarity Profile Analysis
SIO	Scripps Institution of Oceanography
sp	species (singular)
spp	species (plural)
SSL	Sub-surface Low Salinity Layer
SSM	Single Sample Maximum
SWRCB	California State Water Resources Control Board
tDDT	total DDT
TN	Total Nitrogen
TOC	Total Organic Carbon
tPAH	total PAH
tPCB	total PCB
TSS	Total Suspended Solids
TVS	Total Volatile Solids
USEPA	United States Environmental Protection Agency
USFDA	United States Food and Drug Administration
USGS	United States Geological Survey
USIBWC	United States International Boundary and Water Commission
wt	weight
yr	year
ZID	Zone of Initial Dilution
$\alpha$	alpha, the probability of creating a type I error
$\mu\text{g}$	micrograms
$\pi$	summed absolute distances test statistic

This page intentionally left blank