Offshore oil platform discharges to the pacific outer continental shelf along the coast of southern California in 1996 and 2000

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ABSTRACT - The 23 oil platforms currently operating offshore of southern California are a potential source of contaminant inputs to the Southern California Bight (SCB) from discharges associated with drilling and production activities. Data regarding oil platform discharges were obtained from Discharge Monitoring Reports submitted by oil platform operators to the U.S. Environmental Protection Agency. These data were used to quantify oil platform discharges to the SCB in 1996 and 2000 in terms of total volumes discharged, contaminant loading, and average discharge constituent concentrations. Results of this evaluation were compared with an earlier assessment conducted in 1990. Results were also compared to discharges from large and small wastewater treatment facilities (publicly owned treatment works, or POTWs) to gauge the relative contribution of oil platform discharges to the SCB. Oil platforms discharged 5,374 and 5,638 million liters of produced water and 12,128 and 2,955 metric tons (mt) of solids to the SCB in 1996 and 2000, respectively. Oil platform discharges were minor compared to effluents from large and small POTWs in terms of both volume and constituent mass emissions.

INTRODUCTION

The Pacific Outer Continental Shelf (POCS), offshore of the states of California, Oregon, and Washington, has been a source of oil and gas since the late 1960s. As of December 1998, a cumulative 914 million barrels (Mbbl) of oil and 873 billion cubic feet (Bcf) of gas had been recovered from POCS fields, and an estimated 1,724 Mbbl of oil and 2,208 Bcf of gas were estimated to remain (Sorensen *et al.* 2000). The POCS includes 38 fields containing proved and unproved reserves of oil and gas, of which 3 fields have dominated production in the entire region, producing 100% of the total offshore oil and gas resources in the POCS (Figure 1) (Dunkel 2001). These three fields are the Santa Maria-Partington Basin, the Santa Barbara-Ventura Basin, and the Los Angeles Basin, which contain 23 oil platforms used to extract oil and gas from subsurface reservoirs offshore of southern California.

Activities associated with offshore oil and gas production result in the regular discharge of contaminants to the SCB, such as metals, nutrients, and petroleum hydrocarbons. These waste streams result from one of three types of activities: (1) well drilling and maintenance including drilled cuttings, drilling muds, and well completion and treatment fluids; (2) oil and gas production including produced water and cooling water; and (3) daily platform oper-

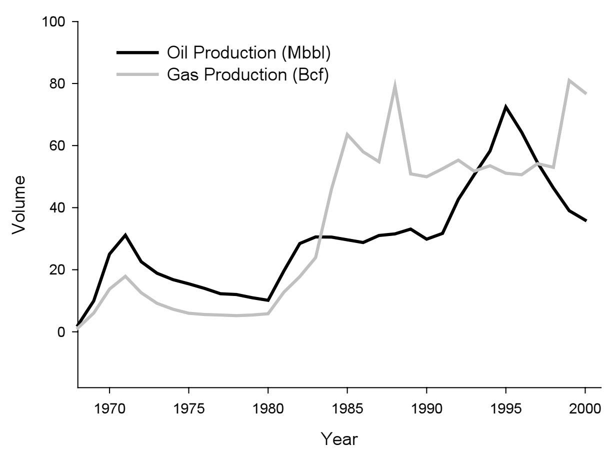

Figure 1. Annual oil and gas production from off shore oil platforms in the POCS from 1968 through 1998; Mbbl is millions of barrels, and Bcf is billions of cubic feet (source: Sorensen et al. 2000).

ations including sanitary and domestic wastes and fire control system test water.

Drilling discharges consist of muds and cuttings that are only generated during the drilling of a new well, and are consequently variable and intermittent. Drilling muds are a dynamic mixture of barites, lignosulfates, polymers, and other chemical compounds added to a borehole during drilling to lubricate the drill, ease the flow of drill cuttings to the surface for removal, and prevent collapse of the borehole during drilling. There are eight generic types of drilling muds; however, the actual composition of muds added to a well is adjusted during drilling to accommodate changing geological conditions.

Produced water is the primary discharge associated with oil and gas recovery, and is of the greatest concern to environmental managers. Produced water is one of the leading anthropogenic point sources of hydrocarbon pollution to the ocean in the U.S., and accounts for over 90% of the total contaminant input from all discharges associated with offshore oil and gas extraction (National Research Council 2003). Produced water is a high salinity brine that commingles with oil and gas in a reservoir (Menzie 1982). It is produced concurrently with the recovery of oil and gas from geologic formations, and must be separated from the oil and gas before they are processed for commercial use. Separation of produced water from the oil and gas mixture occurs on site at an offshore platform, or is sent via pipeline to an onshore processing facility. After separation, produced water is treated and discharged to the ocean. In the case of onshore processing, the produced water is usually transferred by pipeline back to the source platform for discharge to the ocean. The quantity of produced water extracted with oil and gas is known to increase over the life of a well as the amount of oil in the well decreases (Neff *et al.* 1987, National Research Council 2003). Recently, oil platform operators have begun re-injecting portions of the produced water generated back into wells to minimize the discharge of this waste stream to the ocean.

Well completion/treatment fluids are a combination of various fluids used prior to and during production of a well. Completion fluids are salt solutions, brines, polymers, and various additives used to control the pressure in the well once drilling is completed and to clean drilling muds and cuttings that could inhibit oil and gas production. Well treatment fluids are used to restore or improve productivity by chemically or physically altering the oil- or gas-bearing strata. These discharges are usually combined and analyzed together, and may also contain a discharge known as workover fluids. Workover fluids are used during the maintenance, repair, or abandonment of a well.

The remainder of oil platform discharges are derived from general activities associated with offshore platform operations. The most significant of these in terms of volume are sanitary/domestic waste, cooling water, and fire control system test water. Sanitary/domestic waste is generated by personnel operating and living on the platform and is treated on-site before discharge to the ocean. Cooling water is used to cool heat-generating components on an oil platform. Seawater is used for the cooling water system, and chlorine may be added to prevent bacterial growth and fouling of the system. Fire control system test water is seawater retained aboard the platform for emergency purposes. The system is tested regularly to ensure proper functioning, resulting in the discharge of the seawater. More seawater is then collected to replace the water that was discharged.

Discharges from oil platforms are regulated by a number of different state and federal agencies(Raco 1994) and the Minerals Management Service (1996). Monitoring and reporting of oil platform discharges is required by the Clean Water Act, Section 402 under the National Pollutant Discharge Elimination System (NPDES). Permit requirements include monitoring and reporting of discharges for a suite of contaminants such as metals, organics, and general constituents (i.e., suspended solids, oil, and grease). However, NPDES monitoring does not include an assessment of the annual and long-term contributions of contaminants from oil platforms, primarily in the form of produced water. For environmental managers to make sound decisions regarding southern California's coastal resources, it is important to quantify the contribution of oil platforms to overall contaminant loading in the region in relation to other discharges.

This study characterized discharges for the years 1996 and 2000 from 23 offshore oil platforms operating in federal waters off southern California (Figure 2; Table 1). An additional four platforms within the state water boundaries were not included in this report, since many have been decommissioned or do not directly discharge to the ocean. Comparisons were made among oil platforms for the two years of this study, and historical trends in oil platform emissions were established by comparing study results with those from a previous assessment

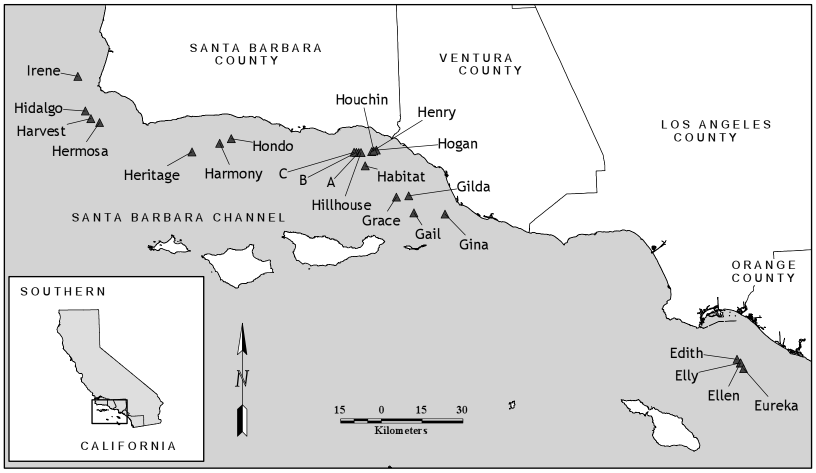

Figure 2. Locations of oil platforms in southern California.

conducted in 1990 (Raco 1994). Further, constituent mass emissions discharged by oil platforms were compared to discharges from large POTWs. Since large POTWs historically discharge the most constituent emissions to the SCB (Steinberger and Schiff 2003a), this latter assessment allowed us to gauge the relative significance of oil platform discharges to the SCB. Oil platforms discharges were compared to discharges from small POTWs, since these are the two primary point sources in the northern SCB region—the Santa Barbara Channel, where most of the oil platforms are located.

Methods

Data regarding oil platform discharges in 1996 and 2000 were obtained primarily from monthly, quarterly, and annual discharge monitoring reports (DMRs) submitted by the individual platforms, in compliance with NPDES permit requirements, to the U.S. Environmental Protection Agency (EPA) Region IX. Information was also obtained from the Minerals Management Service when it could not be found in the EPA files.

Non-drilling associated discharges were evaluated in terms of volume, constituent mass emissions (MEs), and annual average flow-weighted constituent concentrations (FWCs) for the most significant waste streams. These included produced water, cooling water, sanitary/domestic waste, fire control system test water, and well completion and treatment fluids. Drilling associated discharges, such as drilling muds and cuttings, were evaluated only in terms of total volumes. The water/solid content and the specific gravity of drill cuttings were taken into account when calculating the total volume of solids discharged via drill cuttings. To facilitate the comparison of our results to an assessment conducted in 1990, we used the same water/solids content (65% solids) and specific gravity (2.6 kg/L) used by Raco (1994), which were taken from Ayers (1983) and Runchal (1983), respectively.

Monthly discharge volumes from each oil platform and waste stream were calculated from monthly flow values then summed over all months in the year (i = 1-12) to obtain the total annual discharge volume (V):

$$V = \sum_{i=1}^{12} uFT$$

where, F was the monthly flow, T was the number of days in the given month, and u was the unit conversion factor for reporting discharge volumes in liters (L).

Annual constituent MEs were calculated from the reported monthly constituent concentrations and the average monthly flows for the given discharge type. Constituent concentrations in oil platform discharges were most often reported as post-dilution results in the DMRs. The actual end-of-pipe concentrations (Ce), however, were needed to calculate the annual mass emissions and flow-weighted concentrations. In a few cases, end-of-pipe results were obtained directly from laboratory reports. When they were not reported, the NPDES-mandated initial dilution equation was used to calculate these values:

$$Ce = Co + Dm(Co - Cs)$$

where, Ce was the end-of-pipe concentration, Co was the post-dilution constituent concentration, Dm was the minimum probable dilution (dilution factor), and Cs represented the background seawater concentration for the given constituent. Background seawater concentrations were obtained from the California Ocean Plan (SWRCB-Cal EPA 1997), which listed background concentrations for a limited selection of metals (As, Cu, Ag, Zn, and Hg). For the remainder of constituents, Cs was set to zero.

Table 1. Active offshore oil platforms in federal waters of the POCS southern California region.

Field	Platform	NPDES[a]	Lease	Operator[b]	Installation Date	First Production	Depth (m)	Well Slots
Beta	Edith	CA0110516	OCS-P 0296	Nuevo Energy Company	1/12/1983	1/21/1984	49	72
	Ellen	CA0110419	OCS-P 0300	Aera Energy	1/15/1980	1/13/1981	80	80
	Elly	CA0110419	OCS-P 0300	Aera Energy	3/12/1980	n/a	77	n/a
	Eureka	CA0110516	OCS-P 0301	Aera Energy	7/8/1984	3/17/1985	211	60
Carpinteria	Henry	CA0110516	OCS-P 0240	Nuevo Energy Company	8/31/1979	5/5/1980	52	24
	Hogan	CA0110020	OCS-P 0166	Pacific Offshore Operators, Inc.	1967	6/10/1968	47	66
	Houchin	CA0110028	OCS-P 0166	Pacific Offshore Operators, Inc.	7/1/1968	4/28/1969	49	60
Dos Cuadras	A	CA0110516	OCS-P 0241	Nuevo Energy Company	9/14/1968	3/3/1969	58	57
	B	CA0110516	OCS-P 0241	Nuevo Energy Company	11/8/1968	7/19/1969	58	63
	C	CA0110516	OCS-P 0241	Nuevo Energy Company	2/28/1977	8/1/1977	58	60
	Hillhouse	CA0110516	OCS-P 0240	Nuevo Energy Company	11/26/1969	7/21/1970	58	60
Hondo	Harmony	CA0110842	OCS-P 0190	Exxon Mobil Corporation	6/21/1989	12/30/1993	363	60
	Hondo	CA0110516	OCS-P 0188	Exxon Mobil Corporation	6/23/1976	4/2/1981	255	28
Hueneme	Gina	CA0110516	OCS-P 0202	Nuevo Energy Company	12/11/1980	2/11/1982	29	15
Pescado	Heritage	CA0110851	OCS-P 0182	Exxon Mobil Corporation	10/7/1989	12/18/1993	326	60
Pitas Point	Habitat	CA0110516	OCS-P 0234	Nuevo Energy Company	10/8/1981	12/15/1983	88	24
Point Arguello	Harvest	CA0110516	OCS-P 0315	Arguello, Inc.	6/12/1985	6/3/1991	205	50
	Hermosa	CA0110516	OCS-P 0316	Arguello, Inc.	10/5/1985	6/9/1991	184	48
	Hidalgo	CA0110516	OCS-P 0450	Arguello, Inc.	7/2/1986	5/27/1991	130	56
Point Pedernales	Irene	CA0110648	OCS-P 0441	Torch Operating Company	8/7/1985	4/13/1987	73	72
Santa Clara	Gilda	CA0110516	OCS-P 0216	Nuevo Energy Company	1/6/1981	12/19/1981	62	96
	Grace	CA0110397	OCS-P 0217	Venoco, Inc.	7/30/1979	7/25/1980	96	48
Sockeye	Gail	CA0110737	OCS-P 0205	Venoco, Inc.	4/5/1987	8/8/1988	224	36

[a] National Pollutant Discharge Elimination System (NPDES) permit number.

[b] Platform operators as of December 2000.

n/a = Not applicable (Elly is a processing platform for oil/gas produced at platform Ellen).

End-of-pipe results then were used to calculate monthly constituent MEs per discharge type per oil platform, and summed over all months to obtain the annual constituent MEs:

$$ME = \sum_{i=1}^{12} yCeFT$$

where, F was the monthly flow for a given discharge type, Ce was the end-of-pipe constituent concentration, T was the number of days in the given month, and y was the unit conversion factor for reporting the estimated MEs in metric tons (mt). For ME calculations, non-detectable values were assigned a value of zero.

The FWCs were calculated using the estimated annual MEs normalized by the annual discharge volumes from each oil platform:

$$FWC = \frac{ME}{V}$$

Total discharge volumes, MEs, and FWCs calculated for the years 1996 and 2000 were compared to a previous assessment conducted in 1990 (Raco 1994) to assess trends in oil platform discharges between 1990 and 2000.

Total volumes and MEs from all oil platforms combined were compared to total discharges from large POTWs (discharge >100 mgd) in 1990, 1996, and 2000, to assess the relative contribution of oil platform discharges to overall emissions in the SCB. Annual volumes and MEs for large POTWs in 1990, 1996, and 2000 were taken from Steinberger and Schiff (2003a), Cross and Raco (1992), and Raco-Rands (1999). Discharge volumes and constituent MEs from the two sources were compared in terms of the relative percent difference (RPD) between estimates for each of the sources:

$$RPD = \frac{(LP - OP)}{(LP + OP)/2}(100)$$

where LP was the estimate under comparison for large POTWs, and OP was respective estimate for oil platforms. As written, a positive value for the RPD in this comparison would indicate that the estimate for large POTWs was higher. Constituent mass emissions for oil platforms and large POTWs in 2000 were also calculated at the full detection level and compared to determine whether differing detection limits used by the facilities would influence comparison of these two point sources.

Fifteen of the twenty-three platforms in the POCS discharge to the Santa Barbara Channel, twelve of which discharge in the same vicinity of the channel as the only other significant point source in this region—small wastewater treatment facilities (discharge < 25 mgd) (Steinberger and Schiff 2003b; Figure 2). Total volumes and MEs for oil platforms also were compared to total discharges from small POTWs for 1990, 1996, and 2000, to assess the relative significance of these two point sources in the Santa Barbara Channel. Assessments of small POTW discharges conducted in 1989 and 1995 were used for comparison to the 1990 and 1996 information for oil platforms, respectively, since small POTW assessments for 1990 and 1996 were not available. Data from small POTWs were taken from Steinberger and Schiff (2003b) and Raco-Rands (1997). The RPDs were used to compare discharges from small POTWs and oil platforms using the equation above, where values for small POTWs were substituted for the variable LP. In this comparison, a positive value for the RPD would indicate that discharges from small POTWs were higher.

In many cases, constituents were not detected in oil platform discharges. The effect of non-detectable values on conclusions about the importance of oil platform discharges relative to large POTWs to total Bight-wide emissions was investigated by calculating mass emission estimates using the full detection level instead of a zero value. The revised estimates of mass emissions using full detection levels for both POTWs and oil platforms were compared to determine whether conclusions about relative importance changed.

Results

Oil Platform Discharges in 1996 and 2000

Drilling associated discharges were intermittent during 1996 and 2000, and varied widely in overall quantity between the two years. In 1996, 31 new wells were drilled (spudded) at offshore oil platforms in southern California, while in 2000, only 13 new wells were spudded. Consequently, total discharge volumes of drill cuttings were over four times greater in 1996 than in 2000, and discharges of drilling muds were five times greater in 1996 than 2000 (Table 2). The contaminant content of drilling associated discharges were not explicitly quantifiable since the composition of the drilling muds varies during the drilling of a well, and accurate monitoring of the changing composition is not conducted.

In 1996, offshore oil platforms discharged over 56 billion liters of liquid (non-drilling associated) effluent (Table 2). Almost 90% of this discharge was originally seawater used for various purposes on the platforms (i.e., cooling water, fire control system water) then discharged back to the ocean. In 2000, the total volume of liquid discharges decreased slightly to just over 48 billion liters, of which 88% was originally seawater.

Cooling water discharges comprised the largest volume of non-drilling associated discharges from offshore oil platforms, but, along with sanitary/domestic waste, this discharge was only a source of residual chlorine. Cooling water discharges contributed the greatest loads of residual chlorine as a result of the larger volumes of this discharge relative to the other liquid discharges (Table 3); but, when compared in terms of the FWCs, sanitary/domestic waste discharges consistently had higher concentrations of residual chlorine. FWCs for sanitary/domestic waste, however, had more variability in residual chlorine concentrations (Table 4).

Produced water discharges were the second largest non-drilling associated discharge in terms of volume (Table 2). Produced water was the primary source of most constituent discharges from oil platforms in 1996 and 2000 (Table 5). Mass emissions of nearly all produced water constituents were greater in 2000, with the exception of nickel, total PAHs, toluene, and benzene. Constituent FWCs for all liquid effluent discharges were highly variable, with coefficients of variation (CVs) well over 100% for most constituents, especially in produced water discharges (Table 6). The lowest variability (24%) was observed for ethylbenzene in produced water in 2000.

It was difficult to attribute the majority of produced water discharges to any one platform, since several platforms intermittently commingled, or discontinued, their discharges in any given year. For example, in March of 2000, Platform Edith temporarily discontinued discharges of produced water; Platform Elly has not discharged produced water since 1991; platforms Ellen and Eureka discharged produced water (deck drainage was included in this discharge at these platforms) at Platform Elly in 2000; Platform Henry discharged produced water at Platform Hillhouse during both years; platforms Heritage and Hondo discharged produced water through Platform Harmony during both years; and, Platform C discharged produced water at Platform B until it discontinued discharge in July 1996. The combined discharge of produced water from Platforms Harmony, Hondo, and Heritage composed over 36% of the total discharge of produced water in 2000, up from a contribution of 21% in 1996 (Table 7). Platform A, which did not commingle its discharge with any other platform, discharged 13% and 15% of the total produced water from all platforms combined in 1996 and 2000, respectively.

Comparison of Discharges 1990, 1996, and 2000

Discharges of produced water were 2.3% higher in 1996 than in 1990, and 7.3% higher in 2000 than in 1990 (Table 8). Liquid discharge volumes for all waste streams, with the exception of fire control system test water, were fairly consistent across each of the three years of assessment. Drilling associated discharges, in contrast, were highly variable owing to the fact that well development, was intermittent.

Constituent mass emissions in produced water discharges were highly variable for 1990, 1996, and 2000, and a temporal trend in this discharge was not discernable from the data (Table 8).

Oil Platforms vs. Large and Small POTWs

When compared to large POTWs, oil platform discharges were found to be a minor source of contaminant loading to the SCB (Table 9). Only mass emissions of naphthalene in 1996 exceeded those from large POTWs. In 1990, 1996, and 2000, the RPDs between oil platform and large POTW discharges ranged from 141% to 200%, with discharges from large POTWs being considerably higher than those from oil platforms. The average RPD for all constituents and years evaluated, excluding the anomalous value for naphthalene, ranged from 194% to 196%, indicating that the magnitude of these discharges relative to each other remained fairly constant across the three years compared.

Small POTW and oil platform discharges are the two most prevalent point sources in the northern SCB, and this study found that oil platforms still constitute a minor source relative to the POTWs (Table 9). The RPDs between small POTWs and oil platforms ranged from 10% to 200% for most constituents, with a median RPD of about 188%, indicating that small POTW effluents contributed greater contaminants to the Santa Barbara Channel than oil platforms (Table 9). However, discharges of solids and total phenols from oil platforms were consistent-

Table 2. Volumes of liquid and solid discharges from offshore oil platforms in 1996 and 2000. Volumes are in units of L x 10^6, unless otherwise noted.

1966 Oil Platform	Cooling Water	Produced Water	Sanitary/ Domestic Waste	Fire Control System Test Water	Well Completion/ Treatment Fluids	Other Liquid[a]	**Total (non-drilling discharges)**	Drill Cuttings (mt)	Drilling Muds
A	--	791	0.21	--	--	--	**791**	--	--
B	--	296	0.23	--	--	--	**297**	--	--
C	--	42	0.28	--	--	--	**42**	418	3.5
Edith	--	47	0.22	--	--	--	**48**	--	--
Ellen	6,092	--	13	--	--	--	**6,105**	--	--
Elly[b]	--	--	--	--	--	3,640	**3,640**	--	--
Eureka	--	--	11	--	--	--	**11**	1,547	6.9
Gail	9,392	61	3.7	41	4.4	83	**9,585**	2,532	2.6
Gilda	--	680	1.1	--	--	1.64	**683**	1,476	16
Gina	--	41	0.24	--	--	--	**41**	--	--
Grace	2,123		1.5	2.4	0.001	1.2	**2,128**	--	0.0005
Habitat	--	38	0.28	--	--	0.29	**38**	--	--
Harmony	13,874	1,142	11	4.6	--	55	**15,079**	3,165	13
Harvest	--	637	0.69	--	--	0.69	**638**	--	--
Henry	--	--	0.20	--	--	--	**0.20**	--	--
Heritage	14,171	--	11	42	--	77	**14,295**	2,875	10
Hermosa	--	709	2.7	--	15	7.7	**734**	114	2.1
Hidalgo	--	343	1.7	--	0.58	1.4	**347**	--	--
Hillhouse	--	423	0.44	--	--	2.6	**426**	--	--
Hogan	--	124	--	--	--	--	**124**	--	--
Hondo	--	--	21	--	--	0.01	**21**	--	--
Houchin	--	--	--	--	--	--	**--**	--	--
Irene	399	--	7.9	902	--	--	**1,309**	--	--
1996 TOTAL	**46,050**	**5,374**	**89**	**992**	**20**	**3,871**	**56,383**	**12,128**	**55**
2000									
A	--	709	0.17	--	--	0.51	**710**	--	--
B	--	398	0.35	--	--	0.51	**399**	--	--
C	--	--	0.23	--	--	0.51	**0.74**	--	--
Edith	--	9.4	0.18	--	--	--	**10**	--	--
Ellen	4,778	--	12	--	--	--	**4,791**	--	--
Elly[b]	--	0.02	--	--	--	1,301	**1,301**	--	--
Eureka	--	--	10	--	--	--	**10**	--	--
Gail	9,697	140	2.7	10	--	100	**9,949**	--	--
Gilda	--	144	0.70	--	--	1.2	**146**	--	--
Gina	--	192	0.23	--	--	0.89	**193**	--	--
Grace	1,194		0.23	2.4	--	1.5	**1,199**	--	--
Habitat	--	35	0.41		--	0.99	**36**	--	--
Harmony	12,931	2,044	3.9	2.5	--	17	**14,998**	--	--
Harvest	--	445	2.4	--	--	0.67	**448**	62	0.38
Henry	--	--	0.26	--	--	0.53	**0.79**	--	--
Heritage	10,285	--	6.0	0.19	--	55	**10,343**	1,192	4.7
Hermosa	--	339	0.84	--	--	1.3	**341**	146	1.0
Hidalgo	--	308	2.6	--	1.1	1.2	**313**	42	0.43
Hillhouse	--	556	0.62	--	--	1.6	**558**	26	0.15
Hogan	--	294	--	--	--	--	**294**	--	--
Hondo	165	--	21	--	--	213	**186**	1,488	4.0
Houchin	--	--	--	--	--	--	**--**	--	--
Irene	--	--	6.6	1,993	--	--	**1,999**	--	--
2000 TOTAL	**39,051**	**5,612**	**73**	**2,008**	**1.1**	**1,697**	**48,226**	**2,955**	**11**

[a]Other liquids include cement wash seawater, excess cement slurry, blowout preventer fluids, desalination unit fluids, deck drainage, fugitive paint processing water, and H_2S gas processing water.
[b]Other liquid discharge type for platform Elly is composed of only seawater/seawater filter backwash water.
Dash = No discharge, or information not reported/found.

Table 3. Estimated constituent mass emissions in selected non-drilling associated waste streams discharged from oil platforms in 1996 and 2000.

Year	Constituent	Units	Cooling Water	Sanitary/ Domestic Waste	Fire Control System Test Water	Well Completion/ Treatment Fluids[a]	TOTAL
1996	Volume	L x 10^6	46,050	89	992	20	**47,151**
	Oil/Grease	mt	--	--	--	0.08	**0.08**
	Ammonia-N	mt	--	--	--	0.13	**0.13**
	Residual Chlorine	mt	3.9	0.20	1.4	--	**5.6**
2000	Volume	L x 10^6	39,050	73	2,008	1.1	**41,132**
	Oil/grease	mt	--	--	--	--	**--**
	Ammonia-N	mt	--	--	--	--	**--**
	Residual Chlorine	mt	2.1	0.35	1.2	--	**3.7**

[a] Ammonia-N and oil/grease not analyzed in 2000 for well completion/treatment fluids.

ly higher than those from small POTWs, as indicated by the negative RPD values. There was little difference in RPD values among years, signifying that discharges from small POTWs and oil platforms have been constantly relative to each other over time.

The issue of non-detectable values was investigated to determine whether the importance of oil platforms discharges relative to large POTWs might increase if mass emission estimates were calculated using the full detection level instead of a zero value. Using the full detection limit in mass emission estimates resulted in increases in oil platform emissions, but also caused increases in large POTW emissions. As a result, the overall comparison of the two sources was not affected, with the exception of a few individual constituents. For example, mercury and zinc loads from oil platforms became slightly more important in comparison to large POTWs when the full detection level was used for mass emission estimates.

Discussion

Oil platforms contributed relatively minimal contaminant loadings to the SCB on both a regional scale and a local scale. With a few minor exceptions, constituent loads from large and small POTWs far exceeded those from oil platforms. Though detection levels used by oil platforms for constituent analyses were an average of 60 times higher than those used by large POTWs, changing the treatment of non-detectable values in mass emission estimates to equal the detection limit (vs. zero) did not alter the conclusions about the relative contribution of oil platforms to total Bight-wide emissions; oil platforms are not an important source of contaminants to the SCB relative to other point sources in the Bight.

The contribution of contaminants from oil platforms is likely exceeded by contributions from other sources in the SCB, in addition to those considered in this report. Sources such as natural oil seeps present a potentially greater source of petroleum hydrocarbons to the SCB. Natural seeps contribute almost ten times more hydrocarbons to coastal waters than produced water discharges. In southern California, an estimated 20,000 mt of crude oil are released per year to the coastal environment from terrestrial and sub-surface sources (National Research Council 2003) compared to 80 to 140 mt released per year from produced water discharges. Additionally, contributions from the transportation sector, including atmospheric deposition and ocean-going two-stroke engines, contribute about twice as much hydrocarbon pollution to the coastal ocean than do offshore oil and gas activities (National Research Council 2003). Consequently, emissions from oil platforms are not expected to be a major contributing factor to contamination in the SCB.

Literature Cited

Ayers, R.C. 1983. Characteristics of drilling discharges. In: An Evaluation of Effluent Dispersion and Fate Model for OCS Platforms. Contract No. 14-12-0001-29122. U.S. Department of the Interior, Minerals Management Service.

Cross, J. and V. Raco. 1992. Characteristics of effluents from large municipal wastewater treatment facilities in 1990 and 1991. pp. 8-18 *in*: J.N. Cross (ed.) Southern California Coastal Water Research Project Biennial Report 1990-1991 and 1991-1992 8-18. Southern California Coastal Water Research Project, Long Beach, CA.

Dunkel, C.A. 2001. Oil and gas resources in the Pacific Outer Continental Shelf as of January 1, 1999; An expanded update to the 1995 National Assessment of United States Oil and Gas Resources. OCS Report MMS 2001-014. U.S. Department of the Interior, Minerals Management Service. Camarillo, CA.

Menzie, C.A. 1982. The environmental implications of offshore oil and gas activities. *Environmental Science and Technology* 16: 454A-472A.

MMS (Minerals Management Service). 1996. Regulatory compliance for OCS oil and gas operations. OCS Report MMS 96-0039. U.S. Department of the Interior, Minerals Management Service. Camarillo, CA.

National Research Council. 2003. Oil in the Sea III: Inputs, Fates, and Effects. The National Academies Press. Washington, D.C.

Neff, J.M., N.N. Rabalais and D.F. Boesch. 1987. Offshore oil and gas development activities potentially causing long-term environmental effects. pp. 149-173 *in*: D. Boesch and N. Rabalais (eds.), Long-term environmental effects of offshore oil and gas development. Elsevier Applied Science. London, UK.

Raco, V. 1999. Characteristics of effluents from large municipal wastewater treatment facilities in 1996. pp. 2-17 *in:* S.B. Weisberg and D. Hallock (eds.), Southern California Coastal Water Research Project Annual Report 1997-1998. Southern California Coastal Water Research Project, Westminster, CA.

Raco, V. 1994. Estimated discharges from offshore oil platforms in the Southern California Bight in 1990. pp. 20-34 *in:* J.N. Cross (ed.), Southern California Coastal Water Research Project Annual Report 1992-1993. Southern California Coastal Water Research Project, Westminster, CA.

Raco-Rands, V. 1997. Characteristics of effluents from small municipal wastewater treatment facilities in 1995. pp. 17-31 *in*: S.B. Weisberg and D. Elmore (eds.), Southern California Coastal Water Research Project Annual Report 1996. Southern California Coastal Water Research Project. Westminster, CA.

Raco-Rands, V.E. 1999. Characteristics of effluents from large municipal wastewater treatment facilities in 1996. pp. 2-17 *in*: S.B. Weisberg and D. Elmore (eds.), Southern California Coastal Water Research Project Annual Report 1997-1998. Southern California Coastal Water Research Project. Westminster, CA.

Runchal, A. 1983. The drift model theory. In: An Evaluation of Effluent Dispersion and Fate Models for OCS Platforms. Contract No. 14-12-0001-29122. U.S. Department of the Interior, Minerals Management Service.

Sorensen, S.B., H.E. Syms and A. Voskanian. 2000. Estimated Oil and Gas Reserves: Pacific Outer Continental Shelf as of December 31, 1998. OCS Report MMS 2000-063. U.S. Department of the Interior, Minerals Management Service, Pacific OCS Region. Camarillo, CA.

Steinberger, A. and K. Schiff. 2003a. Characteristics of effluents from large municipal wastewater treatment facilities between 1998 and 2000. pp. 2-13 *in:* S.B. Weisberg and D. Elmore (eds.), Southern California Coastal Water Research Project Annual Report 2001-2002. Southern California Coastal Water Research Project, Westminster, CA.

Steinberger, A. and K. Schiff. 2003b. Characteristics of effluents from small municipal wastewater treatment facilities in 2000. pp. 15-30 *in:* S.B. Weisberg and D. Elmore (eds.), Southern California Coastal Water Research Project Annual Report 2001-2002. Southern California Coastal Water Research Project, Westminster, CA.

Stephenson, M.T. 1992. A survey of produced water studies. pp. 1-21 *in*: J.P. Ray and F.R. Engelhardt (eds.), Produced Water: Technological/ Environmental Issues and Solutions, Vol. 46. Plenum Press. New York.

SWRCB-Cal EPA. 1997. California ocean plan: water quality control plan, ocean waters of California, *Code of Federal Regulations*, Vol. 40 part 136.

Acknowledgements

The authors would like to thank D. Panzer, M. Brickey, and E. Bromley for courteously providing the data for this assessment. Special thanks to D. Panzer for answering numerous questions, reviewing preliminary data for this report, and providing the opportunity to tour an onshore processing facility and an offshore oil platform. Thanks also to S. Romp and the employees of Pacific Offshore Operators for providing gracious and educational tours through their respective facilities.

Table 4. Flow-weighted constituent concentrations (FWC), coefficients of variation (CV; in percent units), and number of samples (N) for select discharges in 1996 and 2000.

		1996												2000											
		Cooling Water			Sanitary/ Domestic Waste			Fire Control System Test Water			Well Competion/ Treatment Fluids			Cooling Water			Sanitary/ Domestic Waste			Fire Control System Test Water			Drill Muds		
Constituent	Units	FWC	CV	N	FWC	CV	N	FWC	CV	N	FWC	CV	N	FWC	CV	N	FWC	CV	N	FWC	CV	N	FWC	CV	N
Ammonia-N	mg/L	--	--	--	--	--	--	--	--	--	6.3	18	3	--	--	--	--	--	--	--	--	--	--	--	--
Oil/Grease	mg/L	--	--	--	--	--	--	--	--	--	3.9	55	5	--	--	--	--	--	--	--	--	--	--	--	--
Residual Chlorine	mg/L	0.09	114	36	2.24	150	164	1.46	81	12	--	--	--	0.05	38	24	4.84	94	155	0.59	36	12	--	--	--
Mysidopsis bahia (survival)	TUa	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.19	123	10

Table 5. Estimated constituent mass emissions in produced water discharges from oil platforms in 1996 and 2000.

Constituent	Units	1996	2000
Volume	L x 10^6	5,374	5,612
Oil/Grease	mt	76	100
Ammonia-N	mt	332	368
Residual Chlorine	mt	--	--
Total Sulfides	mt	--	75
Cyanide	kg	nd	4.0
Arsenic	kg	nd	5.3
Barium[a]	kg	1,734	--
Cadmium	kg	nd	0.56
Chromium	kg	11	83
Copper	kg	0.19	31
Lead	kg	nd	2.59
Mercury	kg	0.03	0.15
Nickel	kg	65	10
Selenium	kg	nd	nd
Silver	kg	nd	1.2
Zinc	kg	46	291
Total Phenols[b]	kg	0.45	1,401
Phenol	kg	1,271	787
2,4-Dimethylphenol	kg	316	nd
Total PAH[c]	kg	174	nd
Benzo(a)pyrene	kg	nd	nd
Naphthalene	kg	174	nd
Bis(2-ethylhexyl)phthalate	kg	nd	0.59
Toluene	kg	3,270	349
Benzene	kg	2,466	143
Ethylbenzene	kg	561	18,533

[a] Barium not analyzed/reported in 2000.

[b] Estimated mass emission for total phenols represents value for platforms that did not resolve individual phenols, but analyzed only for total phenols.

[c] Total PAH is sum of benzo(a)pyrene and naphthalene.

nd = Not detected.

Table 6. Flow-weighted constituent concentrations (FWC), coefficients of variation (CV; in percent units), and number of samples (N) for produced water discharges in 1996 and 2000. Toxicity was not included in 1996 assessment.

		1996			2000		
Constituent	Units	FWC	CV	N	FWC	CV	N
Ammonia-N	mg/L	62	158	37	66	81	10
Cyanide	ug/L	nd	na	68	0.71	436	19
Oil/Grease	mg/L	14	276	153	18	69	124
Total Sulfides	mg/L	--	--	--	13	89	27
Antimony	mg/L	nd	na	1	--	--	--
Arsenic	µg/L	nd	na	91	0.95	323	23
Barium	µg/L	323	nc	1	--	--	--
Cadmium	µg/L	nd	na	69	0.10	301	22
Chromium	µg/L	2.0	214	69	15	401	22
Copper	µg/L	0.04	472	69	5.5	183	22
Lead	µg/L	nd	na	69	0.46	379	22
Mercury	µg/L	0.006	831	69	0.03	469	22
Nickel	µg/L	12	243	68	1.8	434	22
Selenium	µg/L	nd	na	36	nd	na	17
Silver	µg/L	nd	na	69	0.21	335	22
Zinc	µg/L	8.6	403	69	52	184	22
Naphthalene	µg/L	32	162	38	nd	na	8
Benzene	µg/L	459	184	38	25	153	8
Benzo(a)pyrene	µg/L	nd	na	38	nd	na	8
Bis(2-ethylhexyl)phthalate	µg/L	nd	na	38	0.11	283	8
Total Phenols	µg/L	0.08	nc	1	250	91	7
Phenol	µg/L	236	119	79	140	167	14
2,4-Dimethylphenol	µg/L	59	173	38	nd	na	8
Toluene	µg/L	608	220	38	62	135	8
Ethylbenzene	µg/L	104	144	38	3308	26	4
Toxicity	TUc	--	--	--	65	76	12
Haliotis rufescens	TUc	--	--	--	11	nc	1
Mysidopsis bahia (survival)	TUa	--	--	--	1.41	123	10

na = Not applicable, FWC = 0 (nd).
nd = Not detected.
nc = Value not calculable, n = 1.

Table 7. Estimated constituent mass emissions per waste stream discharged from individual oil platforms to the southern California coastal ocean in 1996 and 2000.

1996

Waste stream Type Constituent	Units	A	B	C[a]	Edith[b]	Ellen	Elly	Eureka	Gail	Gilda	Gina	Grace[c]	Habitat	Harmony	Harvest	Henry	Heritage	Hermosa	Hidalgo	Hillhouse	Hogan[e]	Hondo	Irene[f]	TOTAL
Fire Control System Test Water																								
Volume	L x 10^6	--	--	--	--	--	--	--	41	--	--	2.4	--	4.6	--	--	42	--	--	--	--	--	902	**992**
Residual Chlorine	kg	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1,449	**1,449**
Cooling Water																								
Volume	L x 10^6	--	--	--	--	6092	--	--	9392	--	--	2123	--	13874	--	--	14171	--	--	--	--	--	399	**46,050**
Residual Chlorine	kg	--	--	--	--	--	--	--	2,506	--	--	881	--	--	--	--	--	--	--	--	--	--	537	**3,923**
Sanitary/Domestic Waste																								
Volume	L x 10^6	0.21	0.23	0.28	0.22	13	--	11	3.7	1.1	0.24	1.5	0.28	11	0.69	0.20	11	2.7	1.7	0.44	--	21	7.9	**89**
Residual Chlorine	kg	3.4	1.9	3.3	0.23	41	--	67	--	8.0	1.6	--	--	1.2	0.90	1.3	4.2	--	--	3.4	--	61	--	**198**
Well Completion/Treatment Fluids																								
Volume	L x 10^6	--	--	--	--	--	--	--	4.4	--	--	0.001	--	--	--	--	--	15	0.58	--	--	0.01	--	**20**
Ammonia-N	mt	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.13	--	--	--	--	**0.13**
Oil/Grease	mt	--	--	--	--	--	--	--	0.08		--	--	--	--	--	--	--	--	--	--	--	--	--	**0.08**
Produced Water																								
Volume	L x 10^6	791	296	42	47	--	--	--	61	680	41	--	38	1142	637	--	--	709	343	423	124	--	--	**5,374**
Ammonia-N	mt	190	13	--	--	--	--	--	1.4	29	14	--	--	68	--	--	--	--	--	17	--	--	--	**332**
Cyanide	mt	nd	nd	nd	--	--	--	--	nd	nd	nd	--	nd	nd	nd	--	--	nd	nd	nd	nd	--	--	**nd**
Oil/Grease	mt	14	5.3	0.37	3.6	--	--	--	0.43	11	0.08	--	0.44	9.1	5.6	--	--	12	6.4	6.3	2.3	--	--	**76**
Arsenic	kg	nd	nd	nd	nd	--	--	--	nd	nd	nd	--	nd	nd	nd	--	--	nd	nd	nd	nd	--	--	**nd**
Cadmium	kg	nd	nd	nd	nd	--	--	--	nd	nd	nd	--	nd	nd	nd	--	--	nd	nd	nd	nd	--	--	**nd**
Chromium	kg	nd	nd	nd	nd	--	--	--	0.05	nd	nd	--	nd	11	nd	--	--	nd	nd	nd	nd	--	--	**11**
Copper	kg	nd	nd	nd	nd	--	--	--	0.19	nd	nd	--	nd	nd	nd	--	--	nd	nd	nd	nd	--	--	**0.19**
Lead	kg	nd	nd	nd	nd	--	--	--	nd	nd	nd	--	nd	nd	nd	--	--	nd	nd	nd	nd	--	--	**nd**
Mercury	kg	nd	nd	nd	0.03	--	--	--	nd	nd	nd	--	nd	nd	nd	--	--	nd	nd	nd	nd	--	--	**0.03**
Nickel	kg	nd	nd	nd	nd	--	--	--	1.5	--	nd	--	nd	63	nd	--	--	nd	nd	nd	nd	--	--	**65**
Selenium	kg	nd	nd		nd	--	--	--	nd	nd	--	--	nd	nd	nd	--	--	--	--	nd	--	--	--	**nd**
Silver	kg	nd	nd	nd	nd	--	--	--	nd	nd	nd	--	nd	nd	nd	--	--	nd	nd	nd	nd	--	--	**nd**
Zinc	kg	nd	nd	nd	nd	--	--	--	46	nd	nd	--	nd	nd	nd	--	--	nd	nd	nd	nd	--	--	**46**
2,4-Dimethylphenol	kg	148	50	--	--	--	--	--	nd	50	0.61	--	--	nd	--	--	--	--	--	68	--	--	--	**316**
Phenol	kg	nd	nd	nd	9.9	--	--	--	5.0	nd	nd	--	--	nd	573	--	--	489	151	42	nd	--	--	**1,271**
Benzene	kg	1,776	45	--	--	--	--	--	59	522	6.1	--	--	nd	--	--	--	--	--	58	--	--	--	**2,466**
Ethylbenzene	kg	317	87	--	--	--	--	--	2.1	100	6.2	--	--	nd	--	--	--	--	--	48	--	--	--	**561**
Toluene	kg	2,366	172	--	--	--	--	--	20	513	2.0	--	--	nd	--	--	--	--	--	197	--	--	--	**3,270**
Total PAH	kg	96	24	--	--	--	--	--	0.56	31	nd	--	--	nd	--	--	--	--	--	22	--	--	--	**174**
Total Phenols	kg	--	--	--	--	--	--	--	--	--	--	--	0.45	--	--	--	--	--	--	--	--	--	--	**0.45**
Bis(2-ethylhexyl)phthalate	kg	nd	nd	--	--	--	--	--	nd	nd	nd	--	--	nd	--	--	--	--	--	nd	--	--	--	**nd**

[a] Platform C discharged produced water through platform B beginning in July 1996.
[b] Platform Edith discontinued produced water discharges after March 2000.
[c] Platform Grace did not discharge produced water in 1996 or 2000.
[d] Barium not analyzed/reported in 2000.
[e] Produced water data for 2000 includes discharges from both platforms Hogan and Houchin.
[f] Platform Irene did not discharge produced water in 1996 or 2000.
[g] No constituents analyzed in well completion/treatment discharges in 2000.
(a) Platforms Ellen and Eureka discharged produced water through platform Elly in 2000; see Elly produced water data. None of these platforms discharged produced water in 1996.
(b) Platform Henry discharged produced water through platform Hillhouse in 2000; see Hillhouse produced water data.
(c) Platforms Heritage and Hondo discharged produced water through platform Harmony in 2000; see Harmony produced water data.

Table 7. (Continued)

2000

Waste stream Type Constituent	Units	A	B	C[a]	Edith[b]	Ellen	Elly	Eureka	Gail	Gilda	Gina	Grace[c]	Habitat	Harmony	Harvest	Henry	Heritage	Hermosa	Hidalgo	Hillhouse	Hogan[e]	Hondo	Irene[f]	TOTAL
Fire Control System Test Water																								
Volume	L x 10^6	--	--	--	--	--	--	--	10	--	--	2.4	--	2.5	--	--	0.19	--	--	--	--	--	1,993	**2,008**
Residual Chlorine	kg	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1186.8	**1,187**
Sanitary/Domestic Waste																								
Volume	L x 10^6	0.17	0.35	0.23	0.18	12	--	10	2.7	0.70	0.23	0.23	0.41	3.9	2.4	0.26	6.0	0.84	2.6	0.62	--	21	6.6	**73**
Residual Chlorine	kg	0.935	1.7	1.6	1.1	64	--	59	--	5.8	1.3	--	1.9	0.12	--	0.91	1.8	1.8	9.9	3.2	--	196	--	**351**
Cooling Water																								
Volume	L x 10^6	--	--	--	--	4,778	--	--	9,697	--	--	1,194	--	12,931	--	--	10,285	--	--	--	--	165	--	**39,050**
Residual Chlorine	kg	--	--	--	--	--	--	--	1,957	--	--	176	--	--	--	--	--	--	--	--	--	--	--	**2,134**
Well Completion/ Treatment Fluids[g]																								
Volume	L x 10^6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.1	--	--	--	--	**1.1**
Produced Water																								
Volume	L x 10^6	709	398	--	9.4	(a)	0.02	(a)	140	144	192	--	35	2,044	445	(b)	(c)	339	308	556	294	(c)	--	**5,612**
Ammonia-N	mt	--	--	--	0.001	(a)	--	(a)	7.7	--	--	--	--	325	--	(b)	(c)	--	35	--	--	(c)	--	**368**
Cyanide	mt	nd	nd	--	nd	(a)	nd	(a)	nd	nd	nd	--	nd	nd	nd	(b)	(c)	nd	nd	nd	0.004	(c)	--	**0.004**
Oil/Grease	mt	16	7.8	--	0.24	(a)	0.0007	(a)	0.60	3.0	4.0	--	0.82	24	12	(b)	(c)	8.2	8.0	12	4.9	(c)	--	**100**
Total Sulfides	mt	0.06	0.02	--	--	(a)	--	(a)		2.3	9.0	--	0.001	--	40	(b)	(c)	--	24	0.03	--	(c)	--	**75**
Arsenic	kg	nd	nd	--	nd	(a)	nd	(a)	nd	nd	nd	--	nd	nd	nd	(b)	(c)	nd	nd	nd	5.3	(c)	--	**5.3**
Cadmium	kg	nd	nd	--	nd	(a)	nd	(a)	nd	nd	nd	--	0.09	0.18	nd	(b)	(c)	nd	nd	nd	0.29	(c)	--	**0.56**
Chromium	kg	nd	nd	--	nd	(a)	0.0001	(a)	0.41	2.0	nd	--	0.17	5.9	3.0	(b)	(c)	1.9	2.0	nd	68	(c)	--	**83**
Copper	kg	nd	nd	--	nd	(a)	0.0001	(a)	4.6	10	7.7	--	nd	nd	nd	(b)	(c)	nd	nd	nd	8.4	(c)	--	**31**
Lead	kg	nd	nd	--	nd	(a)	nd	(a)	nd	nd	nd	--	nd	1.3	nd	(b)	(c)	nd	nd	nd	1.3	(c)	--	**2.6**
Mercury	kg	nd	nd	--	nd	(a)	nd	(a)	nd	nd	nd	--	nd	nd	nd	(b)	(c)	nd	nd	nd	0.15	(c)	--	**0.15**
Nickel	kg	nd	nd	--	nd	(a)	0.00004	(a)	nd	nd	nd	--	nd	nd	nd	(b)	(c)	nd	nd	nd	10	(c)	--	**10**
Selenium	kg	nd	nd	--	nd	(a)	--	(a)	nd	nd	nd	--	nd	nd	nd	(b)	(c)	--	nd	nd	--	(c)	--	**nd**
Silver	kg	nd	nd	--	nd	(a)	nd	(a)	nd	nd	nd	--	nd	nd	nd	(b)	(c)	nd	nd	nd	1.2	(c)	--	**1.2**
Zinc	kg	nd	nd	--	0.001	(a)	0.0009	(a)	45	nd	nd	--	nd	nd	218	(b)	(c)	nd	nd	nd	28	(c)	--	**291**
2,4-Dimethylphenol	kg	--	--	--	--	(a)	--	(a)	nd	--	--	--	--	nd	--	(b)	(c)	--	--	--	--	(c)	--	**nd**
Phenol	kg	426	0.58	--	--	(a)	--	(a)	63	144	77	--	77	nd	--	(b)	(c)	--	--	0.33	--	(c)	--	**787**
Benzene	kg	--	--	--	--	(a)	--	(a)	86	--	--	--	--	57	--	(b)	(c)	--	--	--	--	(c)	--	**143**
Ethylbenzene	kg	--	--	--	--	(a)	--	(a)	--	--	--	--	--	18,533	--	(b)	(c)	--	--	--	--	(c)	--	**18,533**
Toluene	kg	--	--	--	--	(a)	--	(a)	58	--	--	--	--	291	--	(b)	(c)	--	--	--	--	(c)	--	**349**
Total PAH	kg	--	--	--	--	(a)	--	(a)	nd	--	--	--	--	nd	--	(b)	(c)	--	--	--	--	(c)	--	**nd**
Total Phenols	kg	--	--	--	--	(a)	0.006	(a)	--	--	--	--	--	--	844	(b)	(c)	211	35	--	311	(c)	--	**1,401**
Bis(2-ethylhexyl)phthalate	kg	--	--	--	--	(a)	--	(a)	0.59	--	--	--	--	nd	--	(b)	(c)	--	--	--	--	(c)	--	**0.59**

[a] Platform C discharged produced water through platform B beginning in July 1996.
[b] Platform Edith discontinued produced water discharges after March 2000.
[c] Platform Grace did not discharge produced water in 1996 or 2000.
[d] Barium not analyzed/reported in 2000.
[e] Produced water data for 2000 includes discharges from both platforms Hogan and Houchin.
[f] Platform Irene did not discharge produced water in 1996 or 2000.
[g] No constituents analyzed in well completion/treatment discharges in 2000.
(a) Platforms Ellen and Eureka discharged produced water through platform Elly in 2000; see Elly produced water data. None of these platforms discharged produced water in 1996.
(b) Platform Henry discharged produced water through platform Hillhouse in 2000; see Hillhouse produced water data.
(c) Platforms Heritage and Hondo discharged produced water through platform Harmony in 2000; see Harmony produced water data.

Table 8. Comparison of oil platform discharge volumes and constituent mass emissions in 1990, 1996, and 2000. Volume units are in millions of liters (L x 10^6) and mass emission units are in kilograms (kg), unless otherwise noted. Values noted in bold indicate the year with the greatest constituent discharge of the three years.

Waste Stream	Constituent	1990	1996	2000	Mean	CV (%)
Cooling Water	Volume	--	**46,050**	39,051	42,550	12
	Residual Chlorine	--	**3,923**	2,134	3,029	42
Produced Water	Volume	5,254	5,374	**5,638**	5,422	4
	Oil/Grease (mt)	**144**	76	101	107	32
	Ammonia-N (mt)	--	332	**368**	350	7
	Cyanide	**24**	nd	4.0	9.3	138
	Arsenic	0.48	nd	**5.3**	1.9	152
	Cadmium	--	nd	**0.56**	0.3	141
	Chromium	64	11	**83**	53	71
	Copper	6.4	0.19	**31**	12	130
	Lead	**2.7**	nd	2.6	1.8	87
	Mercury	**4.6**	0.03	0.15	1.6	163
	Nickel	**302**	65	10	126	124
	Selenium	--	nd	nd	nd	0
	Silver	**1.7**	nd	1.2	1.0	91
	Zinc	**605**	46	296	316	89
	Total Phenols[a]	**2,608**	0.45 (1,588)	1401 (2,188)	2,128	24
	Phenol	**--**	**1,271**	787	1,029	33
	2,4-Dimethylphenol	--	**316**	nd	158	141
	Naphthalene	--	**174**	nd	87	141
	Toluene	--	**3,270**	349	1,809	114
	Benzene	--	**2,466**	143	1,304	126
	Ethylbenzene	--	561	**18,533**	9,547	133
Sanitary/Domestic Waste	Volume	67	**89**	73	76	15
	Residual Chlorine	--	198	**350**	274	39
Fire Control System Test Water	Volume	--	992	**2,008**	1,500	48
Well Completion/ Treatment Fluids	Volume	--	**20**	1.1	11	126
Drill Cuttings	Volume (mt)	3,126	**12,128**	2,955	6,070	86
Drill Muds	Volume	6.8	**55**	11	24	110

[a] Estimated mass emissions for total phenols represents the value calculated from analysis of total phenols as opposed to individual phenols; number in parentheses for 1996 and 2000 is the sum of individually resolved phenols.
Dash = Assessment not conducted for the given constituent in the given year.
nd = Not detected.
nc = Not calculable.

Table 9. Total liquid effluent volumes and constituent MEs from offshore oil platforms, large POTWs, and small POTWs in 1990, 1996, and 2000; also, the relative percent difference (RPD) between estimates from oil platforms and large POTWs, and between estimates from oil platforms and small POTWs, where this calculation was applicable. Data for small and large POTWs taken from Steinberger and Schiff (2003) unless otherwise indicated.

	Large POTWs			Oil Platforms			Small POTWs			RPD between Large POTW and Oil Platform Discharges[d]			RPD between Small POTW and Oil Platform Discharges[e]		
	1990	1996	2000	1990	1996	2000	1990[c]	1996[c]	2000	1990	1996	2000	1990	1996	2000
Liquid Volume[a] (L x 10^9)	1,625	1,528	1,489	5.32[b] (5.25)	53 (5.4)	47 (5.6)	189	198	194	nc	187	188	nc	116	122
Solids (mt x 10^3)	80	70	65	3.1	12	3.0	3.0	1.9	1.8	185	141	183	-4.6	-145	-48
Oil/Grease (mt x 10^3)	21	18	15	0.14	0.08	0.10	0.46	0.46	0.68	197	198	197	105	144	148
Ammonia-N (mt x 10^3)	46	41	43	--	0.33	0.37	2.7	3.6	3.4	--	197	197	--	166	161
Cyanide (mt)	13	10	9.2	0.02	nd	0.004	0.67	1.5	0.35	199	200	200	186	200	196
Arsenic (mt)	8.2	4.2	3.4	0.0005	nd	0.004	0.84	0.38	0.17	200	200	200	200	200	191
Cadmium (mt)	1.4	0.42	0.08	--	nd	0.001	0.53	0.45	0.42	--	200	197	--	200	199
Chromium (mt)	14	6.5	4.8	0.06	0.01	0.08	0.84	1.4	0.09	198	199	193	172	197	10
Copper (mt)	59	49	51	0.01	0.0002	0.03	3.4	6.8	0.82	200	200	200	199	200	186
Lead (mt)	8.1	1.2	0.64	0.003	nd	0.003	2.9	2.4	0.09	200	200	198	200	200	189
Mercury (mt)	0.25	0.03	0.02	0.005	0.00003	0.0001	0.23	0.010	0.002	193	200	197	192	199	164
Nickel (mt)	40	33	32	0.30	0.06	0.01	2.8	2.7	0.52	197	199	200	161	191	192
Selenium (mt)	7.3	7.4	8.5	--	nd	nd	--	--	--	--	200	200	--	--	--
Silver (mt)	9.5	4.9	4.1	0.002	nd	0.001	0.58	0.63	0.09	200	200	200	199	200	195
Zinc (mt)	115	90	66	0.61	0.05	0.29	12	16	8.2	198	200	198	181	199	186
Total Phenols[f] (mt)	25	126	187	2.6	1.6	2.2	--	0.27	0.08	162	195	195	--	-143	-186
Naphthalene (mt)	--	0.16	0.65	--	0.17	nd	--	--	--	--	-6	200	--	--	--

[a] Volume in parentheses represents the volume from produced water discharges alone; RPD calculation based on total volume from all liquid oil platform sources.

[b] Volume only includes produced water and sanitary/domestic waste; volumes for 1996 and 2000 include all non-drilling associated volumes, including cooling water.

[c] Results from 1989 and 1995 used for 1990 and 1996, respectively since assessment for latter years not available.

[d] Positive values indicates the large POTW discharge was higher than discharges from oil platforms.

[e] Positive value indicates the small POTW discharge was higher than discharges from oil platforms.

[f] Total phenols is the sum of individually resolved phenols; 1990 data for large POTWs taken from Cross and Raco (1992); 1996 data for large POTWs taken from Raco-Rands (1999); 1996 data for small POTWs taken from Raco-Rands (1997)

nc = Data not comparable.