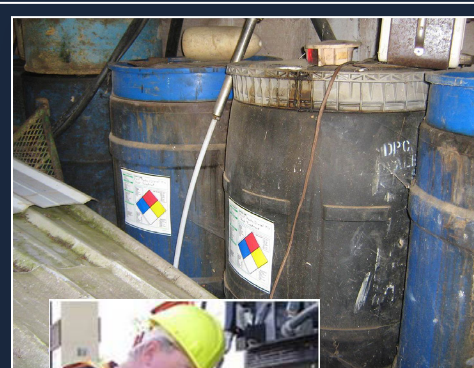
Sediment Contaminants in the Coos Estuary

Summary:

- *Elevated arsenic, chromium, mercury, and nickel levels may diminish sediment quality in parts of Isthmus Slough, the Upper Bay, and North Slough.*
- *Documented releases of metals, tributyltin, petroleum, and other industrial chemicals have occurred primarily in Isthmus Slough and the Upper Bay; toxicity risk is compounded by elevated levels of organic carbon and fine-grained sediment.*
- *Historically, sediment in the Coos Estuary has been relatively uncontaminated by pesticides.*



Evaluation

Areas of elevated metals and industrial pollutants in North Slough, Upper Bay, and Isthmus Slough.

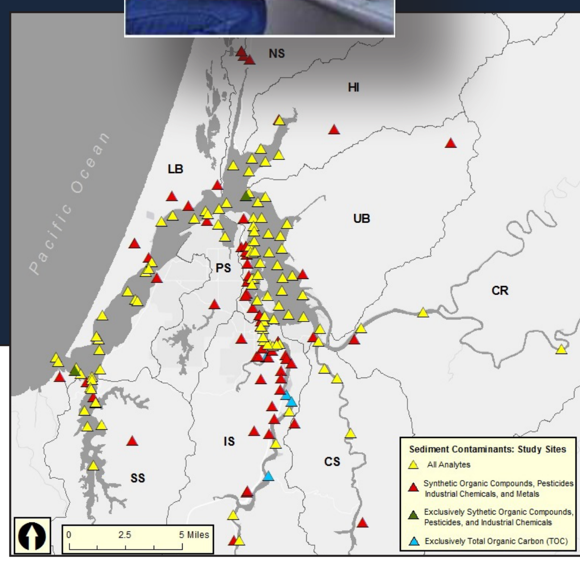


Figure 1. Study sites for sediment contaminants including metals, total organic carbon, synthetic organic compounds, pesticides, and industrial chemicals. CR= Coos River, CS= Catching Slough, HI= Haynes Inlet, IS= Isthmus Slough, LB=Lower Bay, NS= North Slough, PS= Pony Slough , SS= South Slough, UB= Upper Bay. Data: ODEQ 1999, 2001, 2002, 2004, 2005, 2006, 2007, n.d; USACE 1980, 1989, 1994, 1998, 2004, 2009; NOAA 1986,1996, 2006; USEPA 2014b

What's happening?

A variety of contaminants generated from urban, agricultural, and industrial activities in the Coos estuary and surrounding lands can find their way into coastal waters, where they can accumulate in sediments, posing threats to organisms throughout the estuarine food web, including humans (USEPA 2012).

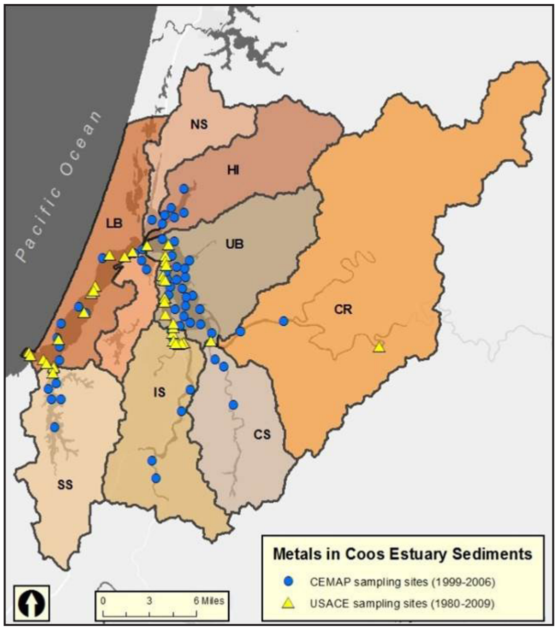


Figure 2. Metals in Coos Sediment Sampling Sites (1980 – 2009)
Data: ODEQ 1999, 2001, 2002, 2004, 2005, 2006; USACE 1980, 1989, 1994, 1998, 2004, 2009

Guideline Values for Assessing Sediment Quality

Long et al. (1995) developed a set of guidelines to help "relate ambient sediment chemistry data to the potential for adverse biological effects." Their method establishes reference points based on the observed biological effects of common sediment contaminants:

Effects Range Low (ERL) - lowest 10th percentile of concentrations associated with harmful biological effects.

Effects Range Median (ERM) - 50th percentile of concentrations associated with harmful biological effects.

ERL and ERM are commonly used by public agencies to evaluate the health of estuarine sediment.

Source: Long et al. 1995

This data summary describes the status and trends of those contaminants and is organized by three main pollutant categories:

1. **Metals**
2. **Synthetic Organic Contaminants** (e.g., chlorinated pesticides, polynuclear aromatic hydrocarbons (PAHs), total petroleum hydrocarbons (TPH), and polychlorinated biphenyls(PCBs))
3. **Total Organic Carbon** (TOC)

The status of these sediment contaminants is evaluated using two metrics: Effects Range Low (ERL) and Effects Range Median (ERM) (Table 1)(see sidebar).

ERL and ERM Values		
Analyte	ERL	ERM
Metals (µg/g dry sediment = ppm)		
Arsenic	8.2	70
Cadmium	1.2	9.6
Chromium	81	370
Copper	34	270
Lead	46.7	218
Mercury	0.15	0.71
Nickel	20.9	51.6
Silver	1	3.7
Zinc	150	410
Synthetic Organic Pollutants (ng/g dry sediment, equivalent to ppb)		
Acenaphthene	16	500
Acenaphthylene	44	640
Anthracene	85.3	1100
Flourene	19	540
2-Methylnaphthalene	70	670
Naphthalene	160	2100
Penhahthrene	240	1500
Benz(a)anthracene	261	1600
Benzo(a)pyrene	430	1600
Chrysene	384	2800
Dibenzo(a,h)anthracene	63.4	260
Fluoranthene	600	5100
Pyrene	665	2600
Low molecular-weight PAH	552	3160
High molecular-weight PAH	1700	9600
Total PAHs	4020	44800
4,4-DDE	2.2	27
Total DDT	1.6	46.1
Total PCB	22.7	180

Table 1. Wentworth Scale for Sediment Classification
Source: Bartram and Balance 1996

Metals

The Oregon Department of Environmental Quality (ODEQ) has monitored the metal content of sediments in the Coos Estuary since 1999 as part of their Coastal Environmental Monitoring and Assessment Program (CEMAP)(ODEQ 1999, 2001, 2002, 2004, 2005, 2006). Additionally, the United States Army Corps of Engineers (USACE) has recorded the status of metals in local sediments since 1980 in a series of sediment quality evaluation reports (USACE 1980, 1989, 1994, 1998, 2004, 2009). Figure 2 shows the spatial distribution of the sampling sites associated with those two programs.

Collectively, the CEMAP data and the USACE reports represent over 1,000 “true detects” (i.e., observations above the minimum detection limit) for arsenic, cadmium, chromium, copper, mercury, nickel, silver, and zinc. Generally, these observations indicate good to fair sediment quality, with 74% of all CEMAP true detects and 87% of all USACE true detects meeting the ERL criteria. However, slightly elevated levels of arsenic, chromium, mercury, and nickel may be of concern (Figure 3).

Below are detailed descriptions of metal concentrations in Coos estuary sediments:

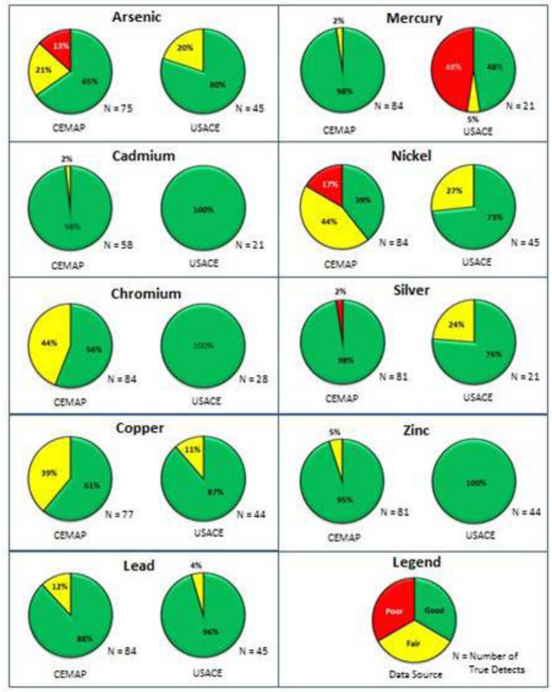


Figure 3. . Percentage of all CEMAP and USACE observations true detects that meet the ERL criteria (good quality), fail to meet the ERL criteria (fair quality), and fail to meet the ERM criteria (poor quality). Data: ODEQ 1999, 2001, 2002, 2004, 2005, 2006; USACE 1980, 1989, 1994, 1998, 2004, 2009

<u>Arsenic (ERL=8.2 ppm, ERM=70 ppm)</u>

Arsenic concentrations in Coos Estuary sediment suggest good to fair sediment quality (Table 2). USACE data show that the mean arsenic level (7.5 ppm) meets the ERL criteria (USACE 1980, 1989, 1994, 1998, 2004, 2009). However, the CEMAP data indicate a mean arsenic level (18.4 ppm) that fails to meet the ERL criteria (ODEQ 1999, 2001, 2002, 2004, 2005, 2006). Maximum mean arsenic concentrations occurred in the North Slough subsystem (CEMAP, 66.4 ppm) and Isthmus Slough (USACE, 16.7 ppm). Although these maxima failed to meet the ERL standard, both met the ERM criteria.

<u>Cadmium (ERL=1.2 ppm, ERM=9.6 ppm)</u>

Cadmium data suggest good sediment quality throughout the study area (Table 3). Mean cadmium concentrations for all subsystems easily meet the ERL criteria for both CEMAP (0.26 ppm) and USACE (0.4 ppm) data (ODEQ 1999, 2001, 2002, 2004, 2005, 2006; USACE 1980, 1989, 1994, 1998, 2004, 2009).

Arsenic (CEMAP)					
Subsystem	Number of Observations	Average (ppm)	Min (ppm)	Max (ppm)	Std. error
Catching Slough	4	7.1	5.5	8.4	0.7
Coos River	2	51.5	1.0	102.0	50.5
Haynes Inlet	10	8.4	3.9	12.8	1.0
Isthmus Slough	5	9.7	6.5	12.6	1.0
Lower Bay	12	20.9	3.5	98.2	10.3
North Slough	3	66.4	4.6	97.3	30.9
Pony Slough	2	6.1	5.6	6.5	0.5
South Slough	7	4.5	3.1	5.6	0.4
Upper Bay	30	20.7	2.2	101.6	6.4
All Subsystems	**75**	**18.4**	**1.0**	**102.0**	**3.6**
Arsenic (USACE)					
Catching Slough		No Data			
Coos River	1	1.0	1.0	1.0	----
Haynes Inlet		No Data			
Isthmus Slough	9	16.7	7.5	57.0	5.4
Lower Bay	16	4.6	2.2	12.1	0.5
North Slough		No Data			
Pony Slough		No Data			
South Slough	3	4.5	3.8	5.0	0.4
Upper Bay	15	5.6	3.0	11.3	0.7
All Subsystems	**44**	**7.5**	**1.0**	**57.0**	**1.3**

Good sediment quality (avg. observation meets ERL) Fair sediment quality (avg. observation fails to meet ERL)

Poor sediment quality (avg. observation fails to meet ERM)

Table 2. Summary of all CEMAP and USACE arsenic observations Data: ODEQ 1999, 2001, 2002, 2004, 2005, 2006; USACE 1980, 1989, 1994, 1998, 2004, 2009. Sediment quality guidelines: Long et al. 1995

Cadmium (CEMAP)					
Subsystem	Number of Observations	Average (ppm)	Min (ppm)	Max (ppm)	Std. error
Catching Slough	3	0.16	0.10	0.20	0.03
Coos River	1	0.32	0.32	0.32	N/A
Haynes Inlet	10	0.16	0.09	0.20	0.01
Isthmus Slough	6	0.20	0.16	0.25	0.02
Lower Bay	5	0.38	0.10	0.65	0.12
North Slough	3	0.52	0.21	0.68	0.16
Pony Slough	2	0.23	0.17	0.28	0.05
South Slough	5	0.14	0.07	0.28	0.04
Upper Bay	23	0.31	0.07	2.31	0.10
All Subsystems	**58**	**0.26**	**0.07**	**2.31**	**0.04**
Cadmium (USACE)					
Catching Slough		No Data			
Coos River		No Data			
Haynes Inlet		No Data			
Isthmus Slough	6	0.7	0.2	1.3	0.2
Lower Bay	5	0.1	0.1	0.2	0.01
North Slough		No Data			
Pony Slough		No Data			
South Slough	3	0.1	0.1	0.2	0.03
Upper Bay	9	0.4	0.1	1.5	0.2
All Subsystems	**23**	**0.4**	**0.1**	**1.5**	**0.1**

Good sediment quality (avg. observation meets ERL) Fair sediment quality (avg. observation fails to meet ERL)

Poor sediment quality (avg. observation fails to meet ERM)

Table 3. Summary of all CEMAP and USACE cadmium observations Data: ODEQ 1999, 2001, 2002, 2004, 2005, 2006; USACE 1980, 1989, 1994, 1998, 2004, 2009. Sediment quality guidelines: Long et al. 1995

Chromium (CEMAP)					
Subsystem	Number of Observations	Average (ppm)	Min (ppm)	Max (ppm)	Std. error
Catching Slough	4	78.5	74.7	82.4	2.1
Coos River	3	68.7	27.2	148.8	40.1
Haynes Inlet	10	90.9	77.4	119.0	4.5
Isthmus Slough	6	86.0	59.4	102.0	6.1
Lower Bay	13	66.0	6.8	234.0	22.9
North Slough	3	200.7	107.0	250.0	46.9
Pony Slough	2	92.1	77.2	107.0	14.9
South Slough	7	50.5	14.9	131.0	17.0
Upper Bay	36	93.4	24.6	346.0	14.2
All Subsystems	**84**	**87.0**	**6.8**	**346.0**	**7.9**
Chromium (USACE)					
Catching Slough		No Data			
Coos River		No Data			
Haynes Inlet		No Data			
Isthmus Slough	6	22.2	0.3	46.2	9.7
Lower Bay	9	7.4	0.1	12.0	1.2
North Slough		No Data			
Pony Slough		No Data			
South Slough	1	10.1	10.1	10.1	----
Upper Bay	11	17.6	0.03	38.7	5.4
All Subsystems	**27**	**14.9**	**0.03**	**46.2**	**3.2**

Good sediment quality (avg. observation meets ERL) Fair sediment quality (avg. observation fails to meet ERL)

Poor sediment quality (avg. observation fails to meet ERM)

Table 4. Summary of all CEMAP and USACE chromium observations Data: ODEQ 1999, 2001, 2002, 2004, 2005, 2006; USACE 1980, 1989, 1994, 1998, 2004, 2009. Sediment quality guidelines: Long et al. 1995

Chromium (ERL=81 ppm, ERM=370 ppm)

Average chromium levels indicate good to fair sediment quality (Table 4). USACE (1980, 1989, 1994, 1998, 2004, 2009) data indicate that average chromium concentrations for all subsystems (14.9 ppm) easily meet the ERL criteria. However, the CEMAP data show that average chromium levels (87 ppm) fail to meet the same criteria (ODEQ 1999, 2001, 2002, 2004, 2005, 2006). Elevated mean chromium levels are primarily due to high chromium concentrations in the North Slough subsystem, which were recorded during the 2002 CEMAP monitoring effort (ODEQ 2002). The 2002 CEMAP data are the most current data for North Slough. No CEMAP sampling has occurred in North Slough since 2002; the USACE has not collected data in North Slough.

Four sites in the Isthmus Slough, Lower Bay, and South Slough subsystems are listed on ODEQ's Confirmed Release List (CRL) for the documented release of chromium (see Why is it happening?)(ODEQ n.d.).

Copper (ERL=34 ppm, ERM=270 ppm)

Copper concentrations indicate good to fair sediment quality throughout the study area (Table 5). Mean copper concentrations for all subsystems meet the ERL criteria for both CEMAP (26.8 ppm) and USACE (20.1 ppm) data (ODEQ 1999, 2001, 2002, 2004, 2005, 2006; USACE 1980, 1989, 1994, 1998, 2004, 2009). Average concentrations for individual subsystems were highest in the North Slough (81 ppm) and Isthmus Slough (58.6 ppm), where mean concentrations failed to meet the ERL criteria (CEMAP 2002; USACE 1994,

Copper (CEMAP)					
Subsystem	Number of Observations	Average (ppm)	Min (ppm)	Max (ppm)	Std. error
Catching Slough	4	18.7	16.4	22.9	1.5
Coos River	3	36.1	3.5	100.5	32.2
Haynes Inlet	10	13.7	11.4	17.8	0.8
Isthmus Slough	6	20.5	9.0	26.3	2.6
Lower Bay	8	38.1	2.1	119.0	17.9
North Slough	3	81.0	13.1	115.0	34.0
Pony Slough	2	17.8	14.5	21.1	3.3
South Slough	6	9.8	2.2	23.6	3.3
Upper Bay	35	28.0	4.5	117.0	6.2
All Subsystems	**77**	**26.8**	**2.1**	**119.0**	**4.0**
Copper (USACE)					
Catching Slough		No Data			
Coos River	1	22	22	22	----
Haynes Inlet		No Data			
Isthmus Slough	9	58.6	20.3	180.0	18.9
Lower Bay	15	2.7	0.9	9.1	0.5
North Slough		No Data			
Pony Slough		No Data			
South Slough	3	2.9	2.6	3.1	0.2
Upper Bay	16	17.9	1.80	55.8	4.0
All Subsystems	**44**	**20.1**	**0.86**	**180.0**	**5.1**

Good sediment quality (avg. observation meets ERL) Fair sediment quality (avg. observation fails to meet ERL)
Poor sediment quality (avg. observation fails to meet ERM)

Table 5. Summary of all CEMAP and USACE copper observations Data: ODEQ 1999, 2001, 2002, 2004, 2005, 2006; USACE 1980, 1989, 1994, 1998, 2004, 2009. Sediment quality guidelines: Long et al. 1995

Lead (CEMAP)					
Subsystem	Number of Observations	Average (ppm)	Min (ppm)	Max (ppm)	Std. error
Catching Slough	4	14.2	13.9	14.6	0.2
Coos River	3	54.3	10.1	141.9	43.8
Haynes Inlet	10	12.4	10.2	14.9	0.5
Isthmus Slough	6	15.7	12.5	20.3	1.2
Lower Bay	13	24.1	9.3	98.8	9.1
North Slough	3	66.2	11.8	93.5	27.2
Pony Slough	2	14.0	13.2	14.8	0.8
South Slough	7	11.0	8.8	13.7	0.6
Upper Bay	36	25.6	7.7	147.4	5.6
All Subsystems	**84**	**23.5**	**7.7**	**147.4**	**3.4**
Lead (USACE)					
Catching Slough		No Data			
Coos River	1	7	7	7	----
Haynes Inlet		No Data			
Isthmus Slough	9	26.9	10.1	81.0	8.7
Lower Bay	16	2.0	1.3	3.1	0.1
North Slough		No Data			
Pony Slough		No Data			
South Slough	3	2.0	1.8	2.5	0.2
Upper Bay	16	7.9	1.9	23.8	1.7
All Subsystems	**45**	**9.2**	**1.3**	**81.0**	**2.2**

Good sediment quality (avg. observation meets ERL) Fair sediment quality (avg. observation fails to meet ERL)
Poor sediment quality (avg. observation fails to meet ERM)

Table 6. Summary of all CEMAP and USACE lead observations Data: ODEQ 1999, 2001, 2002, 2004, 2005, 2006; USACE 1980, 1989, 1994, 1998, 2004, 2009. Sediment quality guidelines: Long et al. 1995

Mercury (CEMAP)					
Subsystem	Number of Observations	Average (ppm)	Min (ppm)	Max (ppm)	Std. error
Catching Slough	4	0.07	0.05	0.12	0.02
Coos River	3	0.14	0.06	0.29	0.08
Haynes Inlet	10	0.04	0.03	0.06	< 0.01
Isthmus Slough	6	0.06	0.03	0.09	0.01
Lower Bay	14	0.05	0.01	0.29	0.02
North Slough	3	0.06	0.04	0.07	0.01
Pony Slough	2	0.06	0.06	0.06	< 0.01
South Slough	7	0.03	0.01	0.05	0.01
Upper Bay	35	0.04	0.01	0.10	< 0.01
All Subsystems	**84**	**0.05**	**0.01**	**0.29**	**0.01**
Mercury (USACE)					
Catching Slough		No Data			
Coos River	1	10	10	10	----
Haynes Inlet		No Data			
Isthmus Slough	8	12.6	0.1	66.0	8.1
Lower Bay	1	1.3	1.3	1.3	----
North Slough		No Data			
Pony Slough		No Data			
South Slough	1	0.01	0.01	0.01	----
Upper Bay	10	3.7	0.02	10.6	1.5
All Subsystems	**21**	**7.1**	**0.01**	**66.0**	**3.2**

Good sediment quality (avg. observation meets ERL) Fair sediment quality (avg. observation fails to meet ERL)
Poor sediment quality (avg. observation fails to meet ERM)

Table 7. Summary of all CEMAP and USACE mercury observations Data: ODEQ 1999, 2001, 2002, 2004, 2005, 2006; USACE 1980, 1989, 1994, 1998, 2004, 2009. Sediment quality guidelines: Long et al. 1995

2004, 2009). Four sites in the Isthmus Slough, Lower Bay, and South Slough subsystems are listed on ODEQ's CRL for the document release of copper (see Why is it happening?) (ODEQ n.d.).

Lead (ERL= 46.7 ppm, ERM= 218 ppm)

Lead concentrations averaged across all subsystems met the ERL criteria (Table 6)(ODEQ 1999, 2001, 2002, 2004, 2005, 2006; USACE 1980, 1989, 1994, 1998, 2004, 2009). The CEMAP data show that average lead concentrations exceed the ERL criteria in the North Slough (66.2 ppm) and Coos River (54.3 ppm) subsystems (ODEQ 1999, 2001, 2002, 2004, 2005, 2006).

There is one site in the Upper Bay Subsystem that is listed on ODEQ's CRL for the document release of lead (see Why is it happening?) (ODEQ n.d.).

Mercury (ERL=0.15 ppm, ERM=0.71 ppm)

Mercury levels generally indicate good sediment quality; however, elevated levels in Isthmus Slough suggest localized areas of poor quality sediment (Table 7)(ODEQ 1999, 2001, 2002, 2004, 2005, 2006; USACE 1980, 1989, 1994, 1998, 2004, 2009). There is one site in the South Slough Subsystem that is listed on ODEQ's CRL for the document release of mercury (see Why is it happening?)(ODEQ n.d.).

Nickel (ERL=20.9 ppm, ERM=51.6 ppm)

Although data sources are somewhat conflicting, elevated nickel concentrations in Coos sediments may represent fair to poor sediment quality (Table 8).

Nickel (CEMAP)					
Subsystem	Number of Observations	Average (ppm)	Min (ppm)	Max (ppm)	Std. error
Catching Slough	4	36.23	31.80	40.90	2.45
Coos River	3	42.43	12.90	100.10	28.84
Haynes Inlet	10	35.02	30.30	43.30	1.65
Isthmus Slough	6	33.82	20.90	44.10	3.17
Lower Bay	13	35.68	3.70	136.00	13.26
North Slough	3	94.93	35.80	125.00	29.57
Pony Slough	2	38.15	33.90	42.40	4.25
South Slough	7	18.16	5.20	44.20	5.76
Upper Bay	36	55.44	7.50	326.00	13.38
All Subsystems	**84**	**44.92**	**3.70**	**326.00**	**6.39**
Nickel (USACE)					
Catching Slough		No Data			
Coos River	1	0.01	0.01	0.01	----
Haynes Inlet		No Data			
Isthmus Slough	9	23.3	0.06	37.9	5.8
Lower Bay	15	4.7	3.1	7.4	0.3
North Slough		No Data			
Pony Slough		No Data			
South Slough	3	5.7	4.7	7.7	1.0
Upper Bay	16	13.7	0.02	31.4	3.3
All Subsystems	**44**	**11.8**	**0.01**	**37.9**	**2.0**

Good sediment quality (avg. observation meets ERL) Fair sediment quality (avg. observation fails to meet ERL)

Poor sediment quality (avg. observation fails to meet ERM)

Table 8. Summary of all CEMAP and USACE nickel observations Data: ODEQ 1999, 2001, 2002, 2004, 2005, 2006; USACE 1980, 1989, 1994, 1998, 2004, 2009. Sediment quality guidelines: Long et al. 1995

Silver (CEMAP)					
Subsystem	Number of Observations	Average (ppm)	Min (ppm)	Max (ppm)	Std. error
Catching Slough	4	0.08	0.07	0.09	< 0.01
Coos River	3	3.68	0.03	10.96	3.64
Haynes Inlet	10	0.06	0.05	0.07	< 0.01
Isthmus Slough	6	0.08	0.07	0.09	< 0.01
Lower Bay	12	0.13	0.03	0.54	0.06
North Slough	3	0.39	0.07	0.56	0.16
Pony Slough	2	0.09	0.07	0.10	0.02
South Slough	7	0.04	0.03	0.06	< 0.01
Upper Bay	34	0.40	0.03	9.65	0.28
All Subsystems	**81**	**0.36**	**0.03**	**10.96**	**0.18**
Silver (USACE)					
Catching Slough		No Data			
Coos River					
Haynes Inlet		No Data			
Isthmus Slough	7	0.8	0.11	1.7	0.3
Lower Bay	2	0.3	0.2	0.4	0.1
North Slough		No Data			
Pony Slough		No Data			
South Slough	1	0.03	0.03	0.03	----
Upper Bay	11	0.4	0.01	2.1	0.2
All Subsystems	**21**	**0.5**	**0.01**	**2.1**	**0.1**

Good sediment quality (avg. observation meets ERL) Fair sediment quality (avg. observation fails to meet ERL)

Poor sediment quality (avg. observation fails to meet ERM)

Table 9. Summary of all CEMAP and USACE silver observations Data: ODEQ 1999, 2001, 2002, 2004, 2005, 2006; USACE 1980, 1989, 1994, 1998, 2004, 2009. Sediment quality guidelines: Long et al. 1995

Zinc (CEMAP)					
Subsystem	Number of Observations	Average (ppm)	Min (ppm)	Max (ppm)	Std. error
Catching Slough	4	75.8	70.4	85.8	3.4
Coos River	3	54.3	29.9	101.6	23.7
Haynes Inlet	10	63.6	52.3	79.9	3.2
Isthmus Slough	6	81.1	54.3	95.9	6.3
Lower Bay	11	32.2	9.7	93.6	9.7
North Slough	3	125.7	62.0	158.0	31.8
Pony Slough	2	66.1	58.1	74.1	8.0
South Slough	7	28.5	11.8	55.5	6.6
Upper Bay	35	64.1	24.6	155.0	6.1
All Subsystems	81	60.4	9.7	158.0	3.9
Zinc (USACE)					
Catching Slough		No Data			
Coos River	1	10.0	10.0	10.0	----
Haynes Inlet		No Data			
Isthmus Slough	9	83.2	43.7	140.0	8.6
Lower Bay	15	10.4	7.8	13.0	0.4
North Slough		No Data			
Pony Slough		No Data			
South Slough	3	14.2	11.8	17.6	1.7
Upper Bay	16	36.8	7.6	74.3	6.1
All Subsystems	**44**	**35.1**	**7.6**	**140.0**	**4.9**

Good sediment quality (avg. observation meets ERL) Fair sediment quality (avg. observation fails to meet ERL)

Poor sediment quality (avg. observation fails to meet ERM)

Table 10. . Summary of all CEMAP and USACE zinc observations Data: ODEQ 1999, 2001, 2002, 2004, 2005, 2006; USACE 1980, 1989, 1994, 1998, 2004, 2009. Sediment quality guidelines: Long et al. 1995

CEMAP data show that the mean nickel concentration, averaged across all subsystems, fails to meet the ERL criteria (ODEQ 1999, 2001, 2002, 2004, 2005, 2006). This is primarily due to elevated nickel concentrations in North Slough (94.9 ppm) and Upper Bay (55.44 ppm), both of which failed to meet the ERM criteria (ODEQ 1999, 2002, 2004, 2005, 2006). CEMAP data also indicate that six of the remaining seven subsystems fail to meet the ERL criteria, with the exception of South Slough (18.2 ppm).

Contrary to CEMAP, USACE (1980, 1989, 1994, 1998, 2004, 2009) data suggest that mean nickel concentrations easily meet the ERL critieria in most subsystems. However, elevated nickel levels in the Isthmus Slough subsystem (23.3 ppm) failed to meet the ERL criteria.

Five sites in the Isthmus Slough, Lower Bay, and South Slough Subsystems are listed on ODEQ's CRL for the document release of nickel (see Why is it happening?)(ODEQ n.d.).

<u>Silver (ERL=1 ppm, ERM= 3.7 ppm)</u>

Silver concentrations indicate generally good sediment quality throughout the study area (Table 9). However, CEMAP data suggest that silver concentrations in Coos River sediments (3.68 ppm) failed to meet the ERL criteria (ODEQ 1999). It should be noted that these are 1999-era data, and the Coos River subsystem has not been monitored by CEMAP since.

<u>Zinc (ERL= 150 ppm, ERM=410 ppm)</u>

Zinc concentrations suggest good sediment quality throughout the study area (Table 10)

(ODEQ 1999, 2001, 2002, 2004, 2005, 2006; USACE 1980, 1989, 1994, 1998, 2004, 2009). Three sites in the Isthmus Slough and Lower Bay Subsystems are listed on ODEQ's CRL for the documented release of zinc (see Why is it happening?)(ODEQ n.d.).

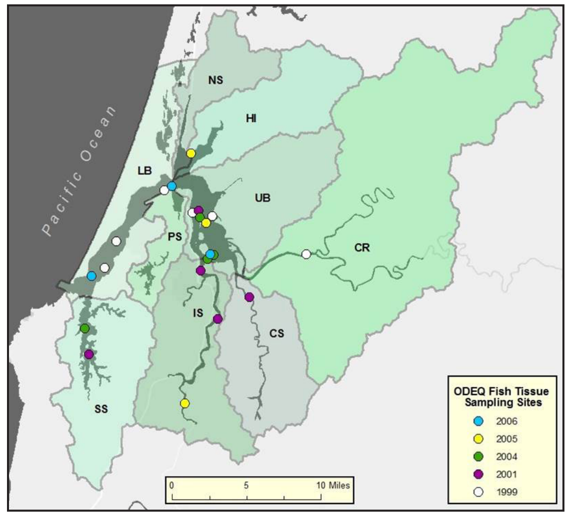


Figure 4. Fish Tissue Sampling Locations. Data ODEQ 1999, 2001, 2004, 2005, 2006

Metals in Fish Tissues

Contaminants may accumulate in the fatty or muscle tissue of fish and shellfish. Even low levels of contaminants in the water column or sediment may result the contamination of recreationally or commercially harvested fish and shellfish that can result in serious human health risks (USEPA 2000).

ODEQ (1999, 2001, 2004, 2005, 2006) collected data detailing tissue contamination in bottom dwelling fish from sites in the Lower Bay, Upper Bay, South Slough, and Coos River subsystems as part of their CEMAP monitoring program (Figure 4). These data are summarized in Table 11.

Metal	Number of Observations	Average (ppm wet weight)	Maximum (ppm wet weight)
Aluminum	12	144.2	376.5
Arsenic	11	0.51	1.14
Cadmium	74	0.04	0.05
Chromium	12	0.31	0.83
Copper	11	1.06	2.06
Iron	12	38.78	190.76
Lead	4	0.13	0.26
Mercury	9	0.03	0.05
Nickel	8	0.27	0.61
Selenium	12	0.29	0.42
Silver	4	0.01	0.01
Tin	1	2.8	2.8
Zinc	12	16.08	24.08

Table 11. Metal concentrations in fishes of Coos Estuary. Data ODEQ 1999, 2002, 2004, 2005, 2006; USEPA 2000

The ODEQ data are difficult to interpret because the development of human health standards for safe fish consumption requires making numerous assumptions about people's dietary preferences, body type (e.g., body weight, age), level of risk aversion, and other variables (USEPA 2000).

However, some indication about the overall suitability of fish for human consumption in the Coos Estuary is provided by the National Listing of Fish Advisories, a compendium created by the United States Environmental Protection Agency (USEPA) to alert the public of any potential health hazards. Similarly, the Oregon Division of Public Health maintains a listing of active fish advisories and consumption guidelines in Oregon (OR Health Division n.d.).

For additional information regarding nationally recommended safe consumption limits, refer to Volume 2 of USEPA's "Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories" (USEPA 2000).

Synthetic Organic Contaminants, Chlorinated Pesticides, and Other Contaminants

Long et al. (1995) established sediment quality guidelines (SQG) for a series of commonly occurring synthetic organic contaminants, including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and dichlorodiphenyltrichloroethane (DDT)(Table 1). These SQGs use the ERL and ERM evaluation criteria (see Guidelines for Assessing Sediment Quality sidebar).

With respect to synthetic organic contaminants and pesticides, sediment quality in Pacific Northwest estuarine sediments has historically been relatively good. In 1999 and 2000, the USEPA sampled 8,670 square kilometers (3,348 square miles) of estuarine sediment in Oregon and Washington as part of their Environmental Monitoring and Assessment Program (EMAP)(Hayslip et al. 2006). Their data suggest limited exposure to pesticides and other synthetic organic contaminants (Figure 5).

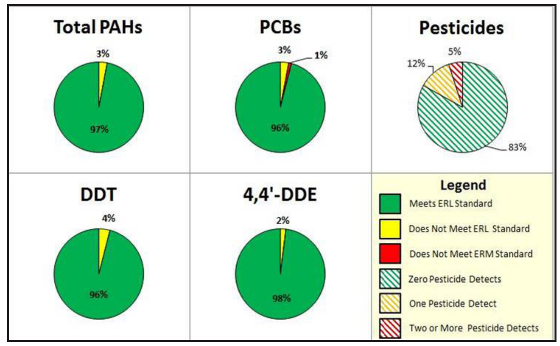


Figure 5. EMAP data (1999-2000) showing sediment contamination by percent of total study area (3,348 square miles) in Washington and Oregon estuaries. Data: Hayslip et al. 2006

The Coos Estuary is typical of a regional pattern of relatively low sediment contamination. In 2002, the USEPA conducted a survey of soft sediment habitat in the estuaries of Washington, Oregon, and California (Nelson et al. 2007). They examined sediment toxicity by calculating the Effects Range Median Quotient (ERM-Q), which is intended to be an indicator of overall sediment contamination.

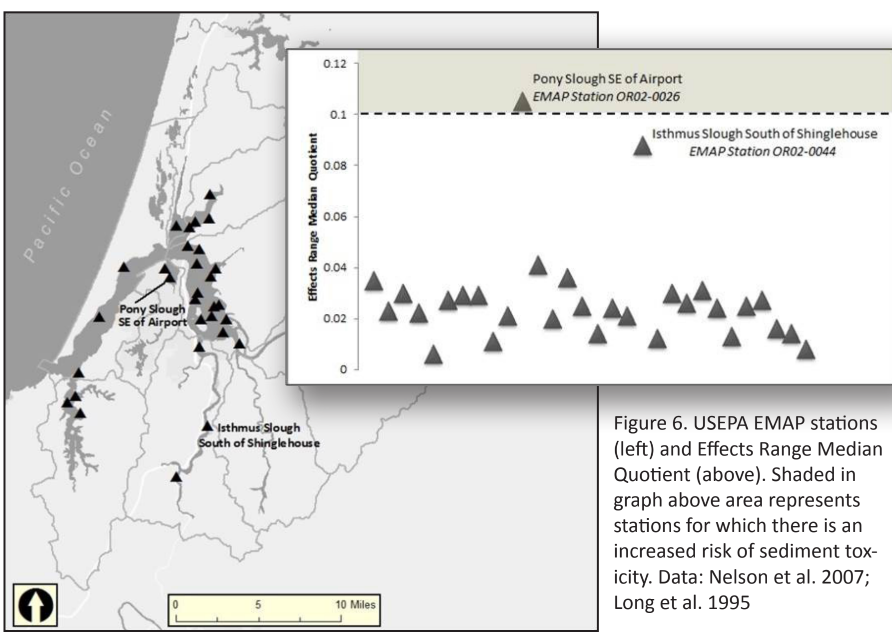


Figure 6. USEPA EMAP stations (left) and Effects Range Median Quotient (above). Shaded in graph above area represents stations for which there is an increased risk of sediment toxicity. Data: Nelson et al. 2007; Long et al. 1995

An ERM-Q < 0.1 corresponds to low probability (11.6%) of sediment toxicity (Long et al. 1995). Most Coos estuary stations easily met the low toxicity risk benchmark. Only one station (Pony Slough subsystem) failed to meet the benchmark (Figure 6).

ODEQ monitors pesticides, tributyltin (TBT), and PCBs in the Coos estuary as part of their Coastal Environmental Monitoring and Assessment Program (CEMAP). CEMAP monitoring was conducted in 1999, 2001, 2002, 2004, 2005, and 2006 at 60 Coos estuary sites (Figure 7).

The CEMAP data indicate little exposure to pesticides, PCBs, or TBT in the Coos estuary. Between 1999 and 2006, CEMAP recorded nearly 2,500 observations in the study area. Just over 1 percent of all CEMAP observations were "true detects" (40 observations)(i.e., above reporting limits)(Table 12).

USACE also evaluates sediment quality by comparing sediment contaminant levels to a "screening level," which is used to determine the acceptability of management alternatives for dredged materials (Sediment Evaluation Framework for the Pacific Northwest 2009).

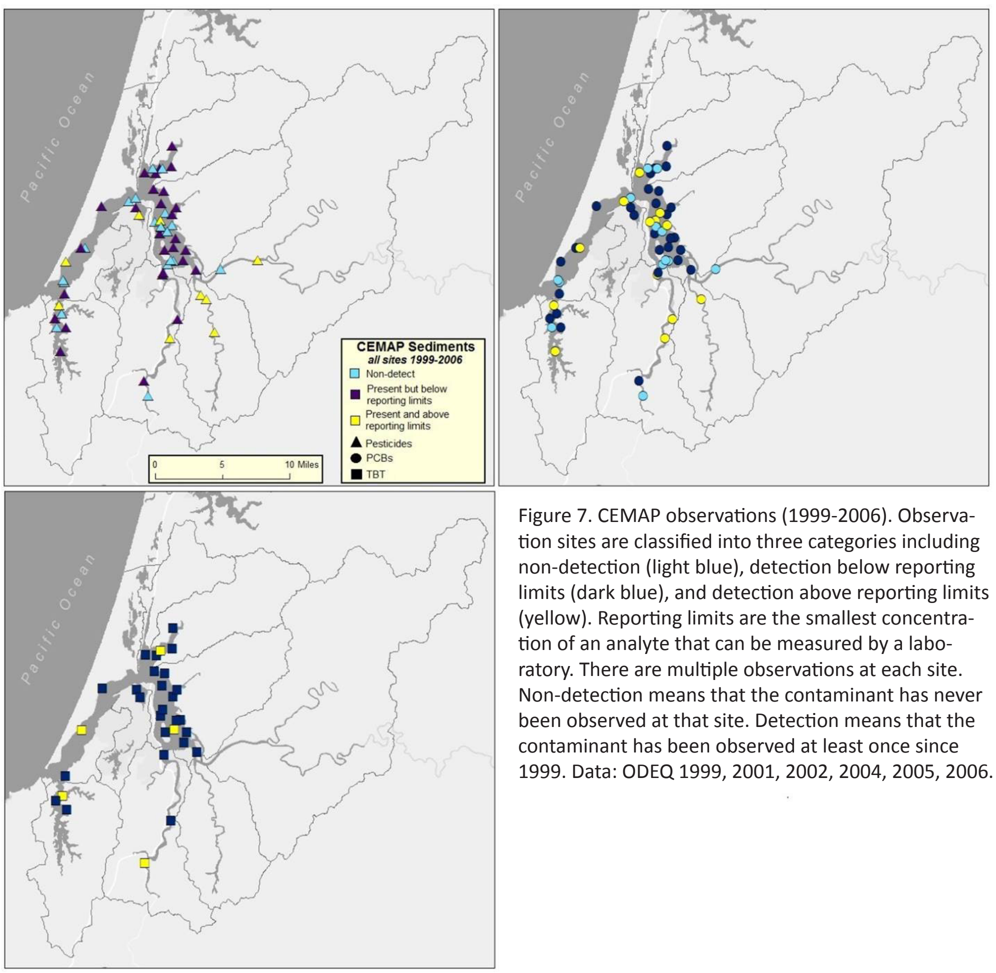


Figure 7. CEMAP observations (1999-2006). Observation sites are classified into three categories including non-detection (light blue), detection below reporting limits (dark blue), and detection above reporting limits (yellow). Reporting limits are the smallest concentration of an analyte that can be measured by a laboratory. There are multiple observations at each site. Non-detection means that the contaminant has never been observed at that site. Detection means that the contaminant has been observed at least once since 1999. Data: ODEQ 1999, 2001, 2002, 2004, 2005, 2006.

Contaminant	Observations	True Detects
Aldrin	65	5
Alpha-Chlordane	65	0
Dieldrin	66	0
Endosulfan I	66	0
Endosulfan II	66	0
Endosulfan Sulfate	66	0
Endrin	66	0
Endrin Aldehyde	77	0
Endrin Ketone	77	0
Heptachlor	66	6
Heptachlor epoxide	66	1
Lindane (gamma-BHC)	66	1
Mirex	66	0
Toxaphene	66	0
Trans-Nonachlor	65	0
Total DDT	1,272	2
Total PCBs	1,440	22
Total TBTs	132	3
All Contaminants	**3,853**	**40**

Table 12. CEMAP Sediment Contaminants Observations (1999-2006)

From 1989 to 2009, the USACE evaluated Coos sediments for several contaminants including pesticides and PCBs, TBT and other butyltin compounds, PAHs, total petrolium hydrocarbons (TPH), chlorinated hydrocarbons, phenols, phthalates, and “miscellaneous extractables” (see Figure 2)(USACE 1980, 1989, 1994, 1998, 1999, 2004, 2009).

Generally, chemical analyses indicated very little sediment contamination. Many of the USACE observations were below reporting limits (Table 13). However, in 1994, testing at Mid-coast Marine and Hilsrom Marine (two formerly operational shipbuilding sites in Isthmus Slough) revealed elevated TBT levels (USACE 1994).

Since 1986, the National Oceanic and Atmospheric Administration (NOAA) has monitored sediment contamination at two Coos estuary sites for their Mussel Watch Contaminant Monitoring Program (Figure 8)(NOAA 1986, 1996, 2006). The NOAA data set includes 216 observations for contaminants with established SQGs (See Table 1 for SQGs). All of these observations met the SQGs (Table 14).

Total Organic Carbon

Total Organic Carbon (TOC) occurs naturally in estuarine sediments, but elevated TOC can change the “benthic” (i.e., sea floor) environments, deplete oxygen levels (ODEQ 2014, Pearson and Rosenberg 1978), and can be associated with the presence of other pollutants (Hyland et al. 2005). In the 2012 National Coastal Condition Report, USEPA outlines sediment quality standards for TOC (Table 15).

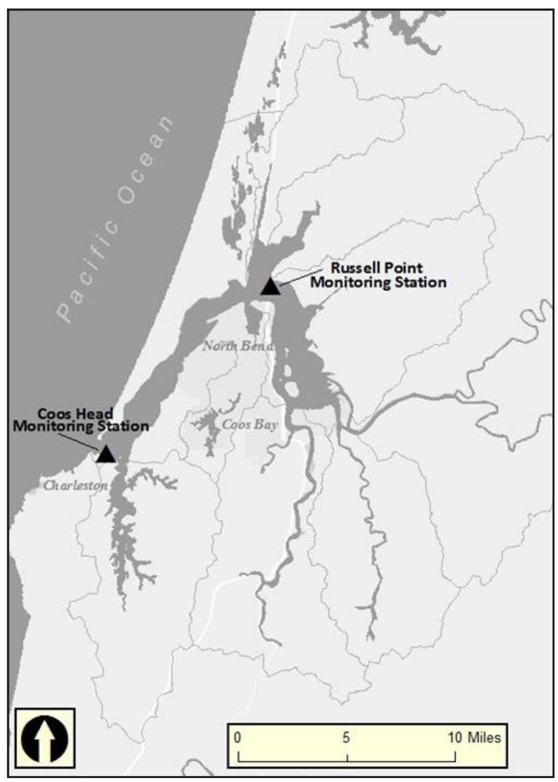


Figure 8. NOAA Mussel Watch Contaminant Monitoring Program site locations Data: NOAA 1986, 1996, 2006.

Table 13. Summary of USACE Sediment Quality Evaluation Report Conclusions (1989-2009)

Year	Pesticides and PCBs	Chlorinated hydrocarbons, phenols, phthalates, and misc extractables	TBT and butyltin compounds	Polynuclear Aromatic Hydrocarbons (PAHs)	Total Petrolium Hydrocarbons (TPH)
2009	No pests or PCBs detected above reporting limits	No chlorinated hydrocarbons were above reporting limits. Phenols, phthalates, benzoic acid, and dibenzofuran were detected in several samples, but did not approach screening levels.		PAHs were detected in some samples, but levels were well below screeing levels.	Diesel detected at an estimated 6 ppm in one sample and 40 ppm in another. Residual range organics (i.e. lubricating oils from motor oil, hyrdolic fluid, etc) detected in two samples at 59 ppm and 330 ppm.
2004	No PCB or DDT detected. Some elevated Chlordane levels. Historically Chrlodance has not been detected in Coos sediments.	Two phenol and three phtalate compounds detected in fine-grained sediments from Isthmus samples, but these observations did not approach screening levels.	No butylin compounds present at detection limits	Several PAHs were detected within Isthmus Slough. However, these observations did not approach screening levels.	
1999					Testing conducted to evaluate the acceptability of dredge spoils disposal after the New Carrissa spill event. Did not detect petrolium hydrocarbons at levels exceeding recommended screening level.
1998	No pesticides, PCBs, or chlorinated organic compounds were above method detection limits	Several phenol, phtalates, and dibenzofuran detections, but all of them were below the screening level	Evaluated Isthmus Slough sediment at sites of concern, including Mid-Coast Marine and Hilstrom Marine. Only 2 stations (both at Hilstrom) indicated the presence of a butyltin compous (monobutyltin). The highest concentration exceeded screening levels by 43%.		
1994			Sediment contained elevated levels of TBT near Hilstrom and Mid-coast Marine. Evidence of toxic effects to oysters in some areas. Refuse appears to settle quickly near the edges of the channel in sediment that is not frequently dredged.		
1989		The concentration of dioxin/furans in sediment samples were very low, with only 3 of the 17 dioxin/furan congeners tested detected.			

Year	Analyte	Observed Value (ng/ g dry sediment)	ERL (ng/ g dry sediment)	ERM (ng/ g dry sediment)
Coos Head Monitoring Station				
1996	Total DDT	0.09	1.58	46.1
1996	Total PAH	2.23	4,022	44,792
1996	Total PCB	0.26	22.7	180
2006	Total DDT	0.02	1.58	46.1
2006	Total PAH	6	4,022	44,792
2006	Total PCB	0.13	22.7	180
Russell Point Monitoring Station				
1986	Total DDT	0.45	1.58	46.1
1987	Total DDT	0.57	1.58	46.1
1996	Total DDT	0.19	1.58	46.1
1996	Total PAHs	50.43	4,022	44,792
1996	Total PCB	0.95	22.7	180
2006	Total DDT	0.67	1.58	46.1
2006	Total PAHs	130.27	4,022	44,792
2006	Total PCB	2.09	22.7	180

Table 14. Summary of NOAA Mussel Watch Contaminant Monitoring Program (1986-2006) Data: NOAA 1986, 1996, 2006.

Rating	Cutpoints
Good	The TOC concentration is less than 2% of sediment composition
Fair	The TOC concentration is between 2% and 5% of sediment composition
Poor	The TOC concentration is greater than 5% of sediment composition

Table 15. Sediment quality standards. Data: USEPA 2012

According the USEPA, TOC levels in Oregon coast sediments generally meet the criteria for good sediment quality (Figure 9)(Nelson et al. 2007). In 2002, less than 2% of estuarine sediment on the Oregon coast had TOC levels associated with poor quality sediment (> 5% TOC)(Nelson et al. 2007).

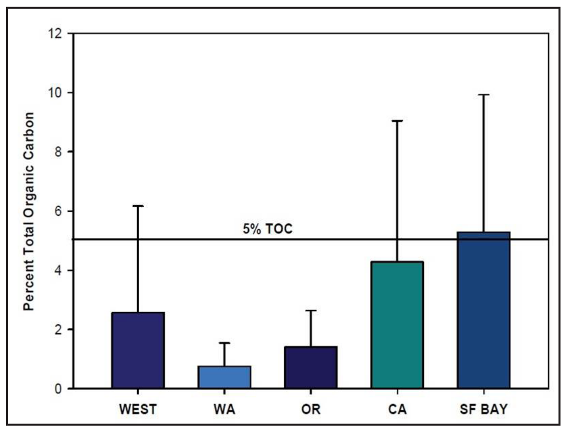


Figure 9. TOC levels in west coast estuarine sediment (mean ± 1 sd). Data: Nelson et al. 2007

The regional trend for low TOC is reflected in Coos Estuary sediments. Lee II and Brown (2009)(Western Ecology Division of the USEPA) reported that median Coos estuary TOC levels were the second highest in the state, but overall sediment quality was still high (TOC < 1% of sed. composition)(Table 16).

The USACE has maintained records of TOC in Coos Bay sediments since 1980 for the the Lower and Upper Bay subsystems (USACE 1980, 1989, 1994, 1998, 2004, 2009). A few samples were also collected in the South Slough (1998 and 2004), Pony Slough (1998), Isthmus Slough (1898, 1994, 2004, and 2009), and Coos River (1980)(see Figure 2).

USACE records indicate that the organic content of Coos River sediments has historically been low, and, in the Upper Bay Subsystem, "TOC [concentrations]… were typical of uncontaminated coastal and estuarine sediment" (USACE 1980, 1989).

Estuary	Median TOC (% Sediment Composition)	Percent of Area with fair quality sediment (2-5% TOC)	Percent of Area with poor quality sediment (> 5% TOC)
Coos	**0.90**	**17**	**< 1**
Alsea	0.69	2.5	0
Nestucca	0.16	7.1	0
Salmon	0.34	7.3	< 1
Tilamook	0.41	2.6	0
Umpqua	0.51	9.6	0
Yaquina	1.30	21.4	0

Table 16. TOC sediment composition of Oregon estuaries. Data: Lee II and Brown 2009

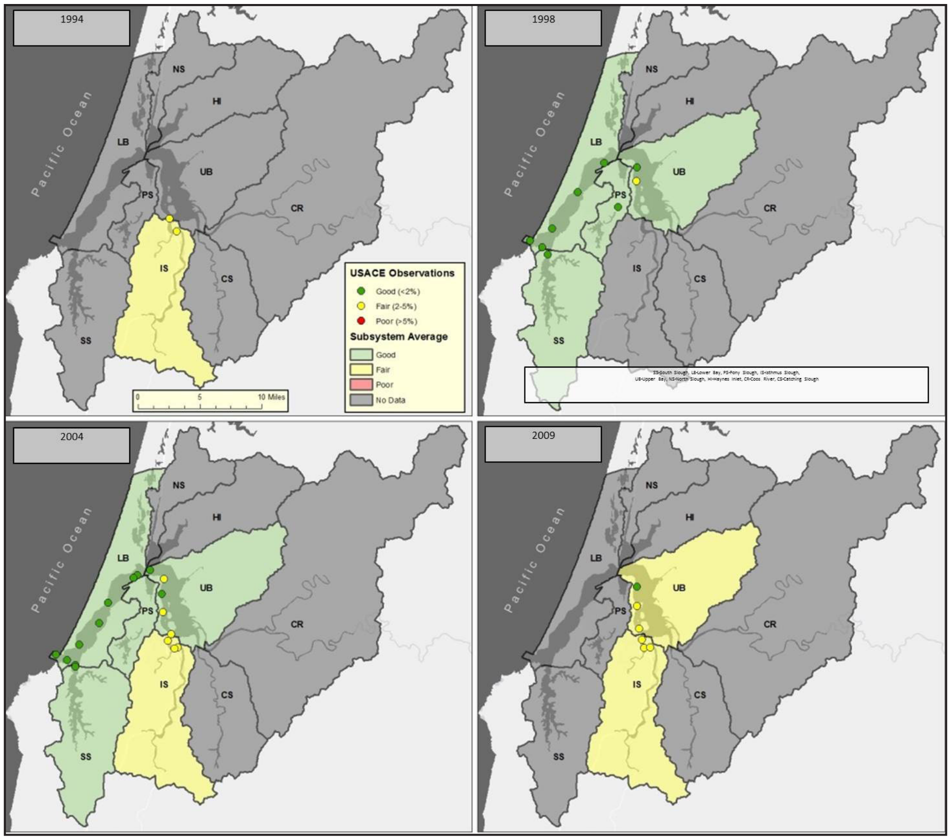


Figure 10. USACE TOC observations (1994-2009) and subsystem averages. Data: USACE 1994, 1998, 2004, 2009 Sediment quality standards: USEPA 2012

In 1994, the USACE evaluated sediment quality near Hilstrom Marine and Mid Coast Marine, two formerly operational boat repair sites in Isthmus Slough (USACE 1994). By current standards, the average sediment quality at both Hilstrom (2.85% TOC) and Mid Coast Marine (4.87 % TOC) was fair, but Mid Coast Marine sediment tended towards poor quality, with four of the five samples exceeding 5% TOC.

In more recent years, USACE data have indicated good sediment quality on average in some subsystems (e.g., South Slough and Lower Bay) and fair sediment quality in others (e.g., Upper Bay and Isthmus Slough)(Figure 10).

TOC was monitored in all nine project area subsystems (see Figure 2) as part of the Coastal Environmental Monitoring and Assessment Program (CEMAP) in 1999, 2002, and 2004 (ODEQ 1999, 2002, 2004).

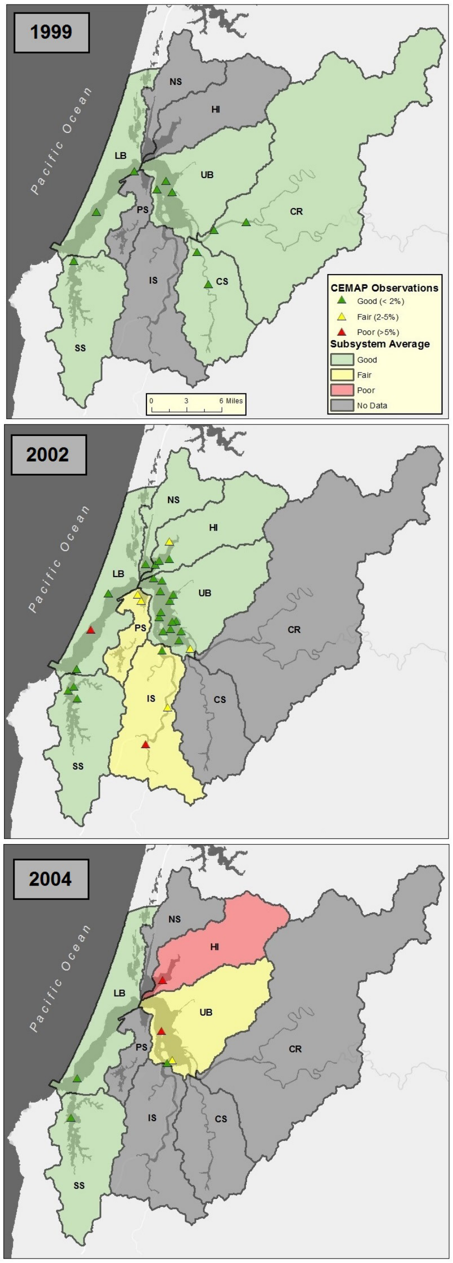


Figure 11. CEMAP TOC observations and subsystem averages. Data: ODEQ 1999, 2002, 2004. Sediment quality standards: USEPA 2012

In 1999, TOC levels easily met the USEPA recommended water quality criteria (ODEQ 1999). Observations in 2002 generally met USEPA guidelines. However, there were instances of fair to poor sediment quality (2-5%

Subsystem	Number of Sites	Number of Observations	Average TOC (% Sediment Composition)	Minimum	Maximum
1999 CEMAP DATA					
Catching Slough	2	4	0.73	0.03	1.48
Coos River	2	4	0.1	0.06	0.15
Lower Bay	2	4	0.41	0.05	0.47
South Slough	1	2	0.11	0.1	0.11
Upper Bay	3	6	0.46	0.2	0.93
ALL SUBSYSTEMS	**10**	**20**	**0.41**	**0.03**	**1.48**
2002 CEMAP DATA					
Haynes Inlet	4	5	1.49	1.15	2.01*
Isthmus Slough	3	3	3.43*	1.17	5.13**
Lower Bay	4	6	1.13	0.07	5.41**
North Slough	1	1	1.47	1.47	1.47
Pony Slough	2	2	2.36*	2.07*	2.65*
South Slough	3	3	1.03	0.4	1.45
Upper Bay	13	13	0.99	0.29	2.41*
ALL SUBSYSTEMS	**30**	**33**	**1.41**	**0.07**	**5.41****
2004 CEMAP DATA					
Haynes Inlet	1	1	12**	12**	12**
Lower Bay	1	1	0.8	0.8	0.8
South Slough	1	1	1.4	1.4	1.4
Upper Bay	3	3	3.87*	1.3	5.4**
ALL SUBSYSTEMS	**6**	**6**	**4.3**	**0.8**	**12**

* Exceeds EPA guidelines for fair water quality (>2%) ** Exceeds EPA guidelines for poor water quality (>5%)

Table 17. CEMAP observations and subsystem averages (1999-2004). Data: ODEQ 1999, 2002, 2004. Sediment quality standards: USEPA 2012

TOC) in Haynes Inlet, Pony Slough, Isthmus Slough, and the Upper and Lower Bay subsystems (ODEQ 2002). In 2004, CEMAP observations suggested good sediment quality in the Lower Bay and South Slough subsystems and fair to poor sediment quality in the Upper Bay and Haynes Inlet. TOC levels in Haynes Inlet were more than double USEPA's recommended values (Figure 11 and Table 17)(ODEQ 2004).

In 2006, ODEQ measured TOC in Isthmus Slough (ODEQ 2007). Sediment quality was fair to poor, with only one measurement indicating good sediment quality (Figure 12).

TOC in suspension has been measured sporadically from 1995-2012 in the South Slough, Isthmus Slough, Coos River, Pony Slough, and Lower Bay subsystems (ODEQ 2001, 2007, 2009a, 2009b, Water Board 2012). Generally, TOC concentrations in these subsystems range between 3-4 mg/L. However, anomalously high TOC levels were measured near the Joe Ney Construction Debris Landfill in South Slough, with several instances of

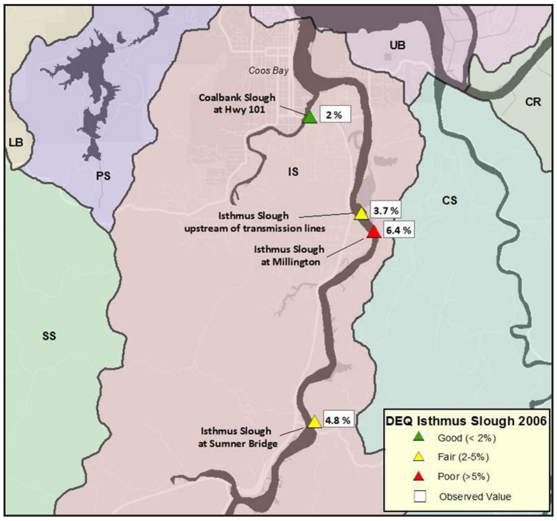


Figure 12. Isthmus Slough TOC observations 2006. Data: ODEQ 2007. Sediment quality standards: USEPA 2012. SS-South Slough, LB-Lower Bay, PS-Pony Slough, IS-Isthmus Slough, UB-Upper Bay, NS-North Slough, HI-Haynes Inlet, CR-Coos River, CS-Catching Slough

concentrations ranging from 20-42 mg/L and once instance of 60 mg/L (ODEQ 2009a). For more detail, refer to the Organic Carbon section of the Water Quality Chapter.

Why is it happening?

There are many potential sources of metals, synthetic organic pollutants, chlorinated pesticides, petroleum hydrocarbons, and other pollutants in estuarine sediment (USEPA 2002). The toxicity of these chemicals in estuarine sediment depends on several factors (Bauer and Bianchi 2011; USEPA 2002, 2007a; Bentivegna et al. 2004; Flemming and Trevors 1989). As a result, it can be difficult to determine sediment contaminant sources.
Despite these difficulties, several tools have been developed to track potential contaminant sources, including USEPA's Toxic Release Inventory (TRI) and "Brownfield" site listings as well as ODEQ's Environmental Cleanup Site Information (ECSI) program.

It's important to note that these programs often list sites as "potential" or "suspected" sources of pollution. Therefore, registry with these programs does not necessarily mean that a facility is responsible for the release of pollutants into the environment. Supplemental details about the sites that are enrolled in these programs can be found in the online databases (ODEQ n.d., USEPA 2014b).

In addition to ECSI, ODEQ also manages a confirmed release list (CRL). Registry with the CRL means that the release of pollutants has been confirmed and documented at that site (ODEQ n.d.).

There are 3 TRI sites, 4 Brownfield sites, and sixty ECSI sites in the study area (ODEQ n.d., USEPA 2014a)(Figure 13). Although there are sites in all 9 subsystems, the majority (61%) of these sites are located in the Isthmus Slough and Upper Bay Subsystems (ODEQ n.d., USEPA 2014a).

These sites represent a potential source of contamination to the soil, groundwater, surface water, and sediment. They're listed for a variety of reasons, including but not limited to mismanagement of hazardous wastes, accidental spills, and historic practices that are presently ill-advised. The suspected pollutants include metals, PCBs, PAHs, TPH, TBT, dioxins, and other industrial chemicals (e.g., wood preservation chemicals).

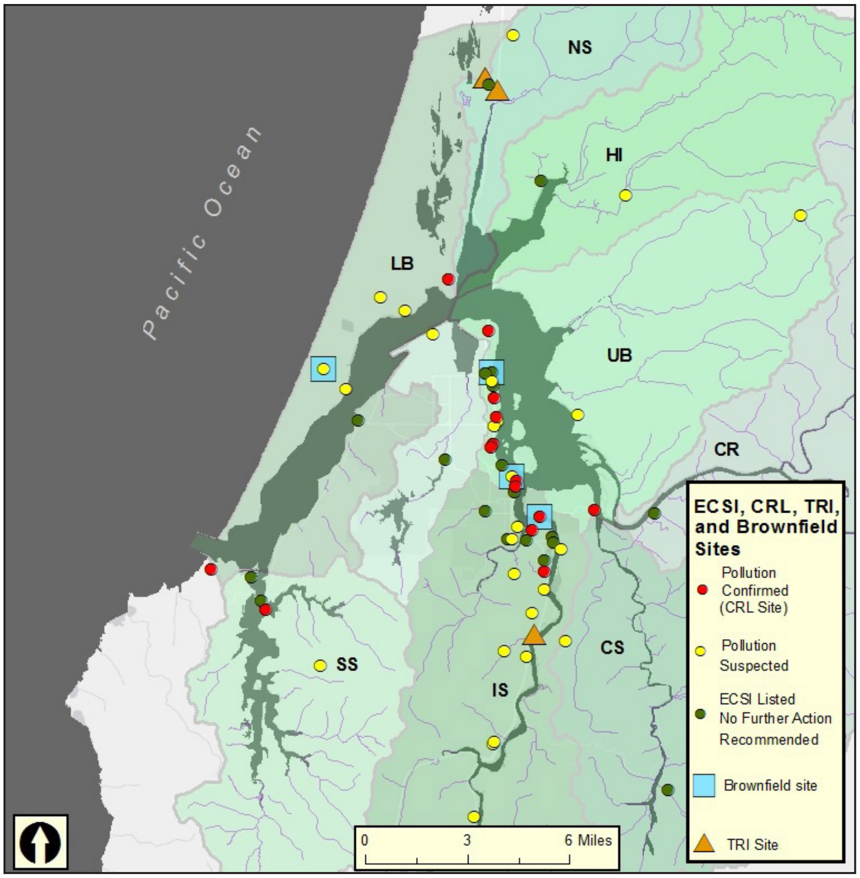


Figure 13. Location of potential sediment pollution sources (green, yellow, blue) and documented pollution sources (red) Source: ODEQ n.d., USEPA 2014a

Fourteen of the 60 ECSI sites in the study area are CRL sites, meaning that the release of pollutants has been documented in nearly a quarter (23%) of all ECSI sites (ODEQ n.d.). Similar to all ECSI, the majority (78%) of these CRL sites are in the Upper Bay and Isthmus Slough Subsystems (Figure 13). These CRL sites are industrial properties, including boat building, metal works, lumber mills, and fueling stations. They are listed for mismanagement and improper disposal of pollutants resulting in the confirmed release of metals, PCBs, PAHs, TPH, TBT, and other industrial chemicals into the soil, groundwater, surface water, or sediment.

Background

Metals, synthetic organic contaminants, chlorinated pesticides, and other pollutants can enter estuaries from a variety of sources, including effluent from nearby industry or agriculture activities (USEPA 2002). Many metals (e.g., iron, copper) are also naturally abundant elements found in coastal watersheds (Shacklette and Boerngen 1984; USEPA 2007b). Contaminants that enter estuaries are often adsorbed onto suspended particles that eventually settle into depositional basins, where they enter the sediment (USEPA 2002). Some metals (e.g., copper and zinc) are a necessary part of a healthy estuarine environment, because they facilitate important metabolic functions (USEPA 2002, USEPA 2006). Other metals (e.g., mercury, lead, chromium, and cadmium) have no known metabolic function (USEPA 2006).

The toxicity of contaminants in sediment is determined by several factors, including the physical characteristics of the sediment (e.g., grain size and organic content) as well as other chemical and environmental factors such as pH, redox potential (i.e., the tendency of a contaminant to acquire electrons), water hardness, organic content, and the availability of other pollutants or binding agents (Bentivegna et al. 2004; USEPA 2002, 2007a; Flemming and Trevors 1989). Since toxic responses in plants and animals require the transfer of chemicals from the environment to biochemical receptors on or in an organism, the toxicity of these pollutants may also depend on species-specific physiology (USEPA 2007b). Estuaries are complex interfaces between terrestrial, marine, and atmospheric organic carbon (OC) sources, both naturally occurring and human-generated (Bauer and Bianchi 2011)(Figure 14). Estuarine OC may be lost through naturally occurring geological mechanisms (e.g., sedimentation and remineralization) as well as chemical processes (e.g., flocculation and precipitation)(Bauer and Bianchi 2011).

Estuarine carbon cycling is influenced by human activities (e.g., wetland drainage, damming and diversion of waterways, and other land use changes, as well as aerosol sources such as fossil fuel combustion and biomass burning). These activities have the potential to rapidly change and further complicate an already intricate process (Bauer and Bianchi 2011).

Organic matter (OM), such as TOC, is an important source of food for benthic fauna. However, an overabundance of OM in the sediment may reduce biodiversity, because the decomposition of excess OM is associated with oxygen depletion and the accumulation of toxic by-products (e.g., ammonia and sulphide)(Hyland et al. 2005, Diaz and Rosenberg 2008). Excess OM may also be accom-

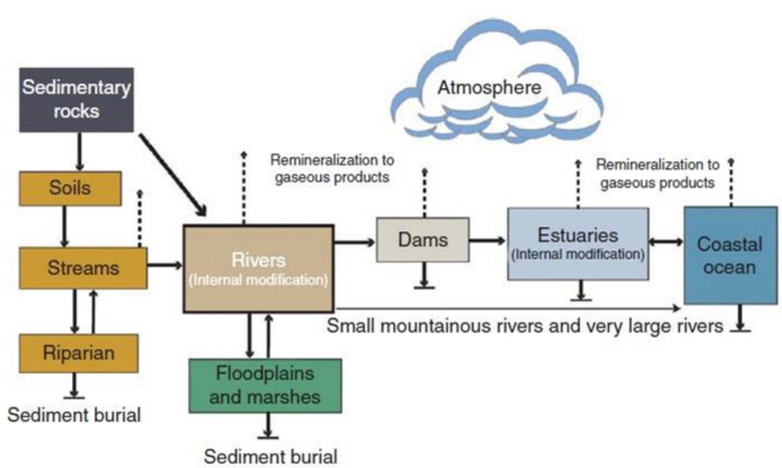


Figure 14. Potential sources and pathways of introduction of terrestrial dissolved organic carbon (DOC) and particulate organic carbon (POC) to the coastal ocean via watersheds, rivers, and estuaries. DOC and POC are the components of TOC. Also shown are the potential losses from natural (e.g. remineralization and sedimentation) and anthropogenic (e.g., damming and watershed modification) factors. Figure and caption: Bauer and Bianchi 2011

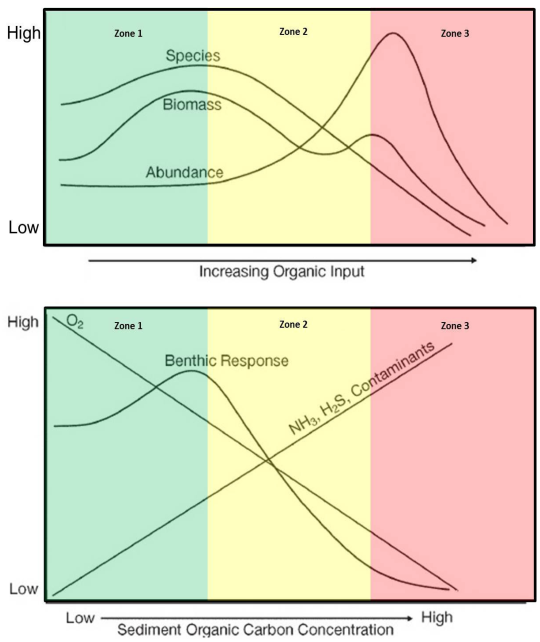


Figure 15. Species richness, biomass, and abundance in response to increasing organic input (top) and the benthic response to organic carbon in the sediment and co-varying stressors (bottom). Responses have been divided into three conceptual "zones," representing low organic carbon (green), intermediate levels (yellow), and high levels (red). Source: Pearson and Rosenberg 1978; Hyland et al. 2005

panied by increases in chemical pollutants, because high OM levels require some of the same environmental factors that facilitate increases in other contaminants (e.g., increase in finer-grained sediments that allow a greater surface area for adsorption)(Hyland et al. 2005). Pearson and Rosenberg (1978) have modeled of benthic response to increasing OM levels (Figure 15).

In their model, low OM levels (Figure 15, Zone 1) result in high species richness due to the combined effects of the sufficient food availability and few environmental stressors. Over the intermediate OM range (Zone 2), species richness declines, because sensitive organisms are unable to withstand increasing exposure to environmental stressors (e.g., depleted oxygen, toxic by-products of OM decomposition, and increased chemical contaminants). However, hardier/opportunistic species may be tolerant of increased OM levels, resulting in a net increase in species abundance and a secondary peak in biomass. At high OM levels (Zone 3), environmental stressors exceed most tolerance levels; consequently, there is a precipitous loss of biodiversity.

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