Sediment Trap Monitoring in Four Inlets of South Puget Sound

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Cover photo: Sedimen trap and mooring ready for deployment on the deck of the Research Vessel Skookum.

Sediment Trap Monitoring in Four Inlets of South Puget Sound

by
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Waterbody Number(s):
WA-PS-0090 (Case Inlet)
WA-15-0060 (Carr Inlet)
WA-14-0020 (Eld Inlet)
WA-13-0020 (Budd Inlet Outer)

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Table of Contents

List of Figures and Tables

Page

Figures

Tables

.

Abstract

The Washington State Department of Ecology used sediment traps to determine gross sediment deposition rates in four inlets of South Puget Sound between September 2007 and June 2008. One station was located in each of the following inlets: Case, Carr, Eld, and Budd.

The data collected will be used to verify sedimentation rates simulated in a water quality model for dissolved oxygen in South Puget Sound.

Mass accumulation rates ranged from 0.2 to 2.1 g/cm2/yr. Based on means, accumulation rates measured in Budd and Eld Inlets were approximately three to five times higher than those measured in Case and Carr Inlets. Mass accumulation rates for Eld and Budd Inlets were similar to those measured in other urban embayments of Puget Sound.

Total organic carbon (TOC) flux rates ranged from 0.005 to 0.063 gOC/cm2/yr. The highest TOC flux rates for TOC were measured in Eld and Budd Inlets. TOC flux rates were much lower in Case and Carr Inlets.

Acknowledgements

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- Casey Deligeannis, Paul Anderson, and Callie Meredith assisted with field collections.
- Mindy Roberts assisted with the study design and review of the project report. Her leadership on the overall South Sound project was outstanding.
- Carolyn Lee entered the project data into the Environmental Information Management (EIM) system.
- Randy Coots provided Geographic Information System (GIS) technical services for the project.
- Joan LeTourneau, Carol Norsen, and Cindy Cook formatted and edited the final report.

Introduction

The Washington State Department of Ecology began a study of low dissolved oxygen levels in South Puget Sound in August 2006 (Albertson et al., 2007). The purpose of the study is to determine how nitrogen from a variety of sources affects dissolved oxygen levels. The project includes data collection, model development and application, and a final report documenting findings.

This current study summarizes the results of one supplemental component of the *South Puget Sound Dissolved Oxygen Study*: sediment trap monitoring conducted from September 2007 to June 2008 to determine sediment deposition rates in four South Puget Sound inlets: Case, Carr, Eld and Budd. Sedimentation rates are simulated in the water quality model for South Puget Sound. Information from this work will be used to verify the model output.

Sampling Methods

Sediment traps were deployed at one location in each of four inlets of South Puget Sound. Deployment locations are shown in Figure 1.

These locations are also described in Addendum #3 to the *South Puget Sound Dissolved Oxygen Study* (Roberts and Pelletier, 2007). Deployment information for each monitoring period is listed in Table 1.

Stations were selected to correspond to the deepest locations occupied for determination of sediment fluxes as described in Addendum #2 to the *South Puget Sound Dissolved Oxygen Study* (Roberts, 2007).

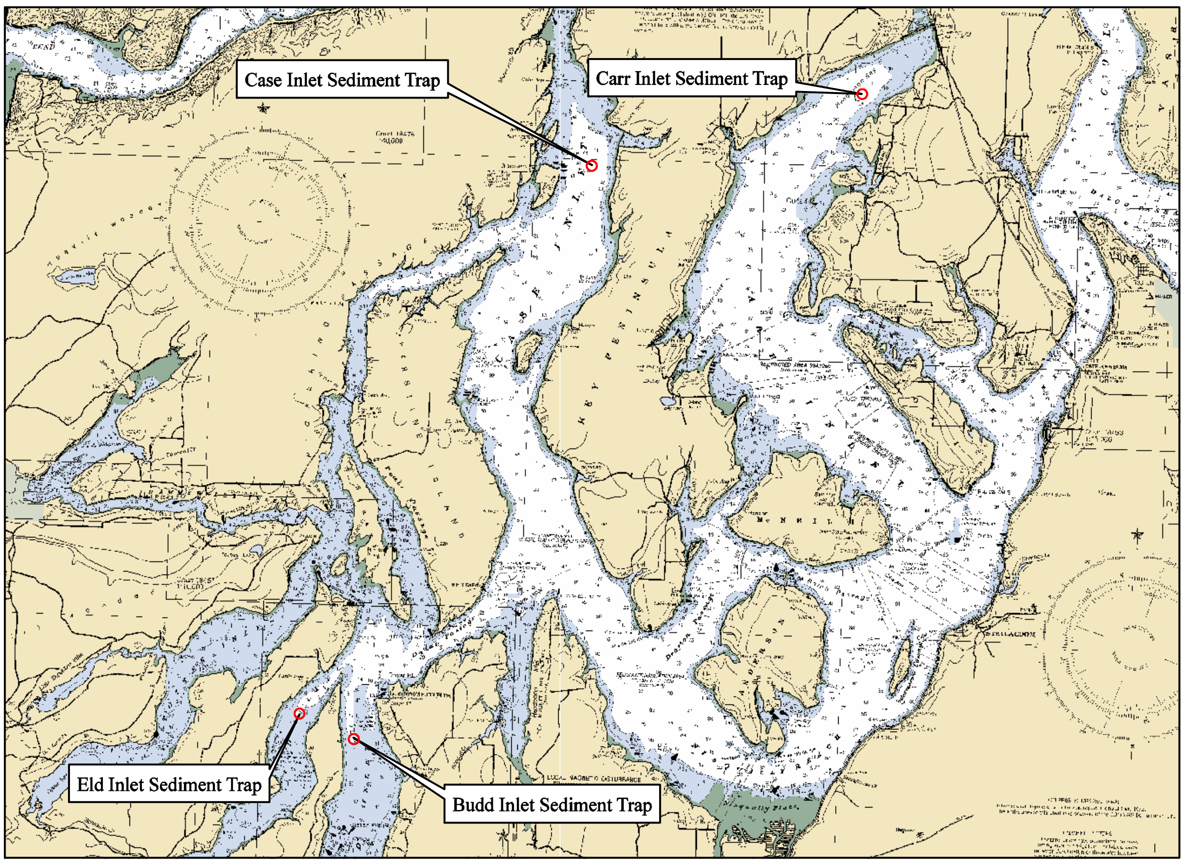

Figure 1: Sediment Trap Station Locations in South Puget Sound.

Table 1: Sediment Trap Deployment and Retrieval Information.

Station	Deployment Period	Days Deployed	Start Time	End Time	Salinity Start (o/oo)	Salinity End (o/oo)	Sample Number 48-	Depth @MLLW (m)	Latitude	Degree/Minutes NAD83 Longitude
Quarter 1: September to November 2007 (NaCl preservative)										
Case A	Sept 13-Nov 15 07	63	1234	1445	40	36	4020	25	47 19.9258	-122 48.1513
Case B	Sept 13-Nov 15 07	63	1234	1445	40	35	4021	25	47 19.9258	-122 48.1513
Carr A	Sept 13-Nov 15 07	63	1039	1130	40	37	4022	24	47 21.5722	-122 39.6986
Carr B	Sept 13-Nov 15 07	63	1039	1130	40	37	4023	24	47 21.5722	-122 39.6986
Eld A	Sept 13 -Nov 21 07	69	1344	940	40	34	4024	26	47 08.1117	-122 56.7952
Eld B	Sept 13 -Nov 21 07	69	1344	940	40	35	4025	26	47 08.1117	-122 56.7952
Budd A	Sept 13-Nov 15 07	Cylinder Broken Sample Lost						23	47 07.6260	-122 55.1580
Budd B	Sept 13-Nov 15 07	63	1424	1646	40	35	4027	23	47 07.6260	-122 55.1580
Quarter 2: November 2007 to January 2008 (NaCl preservative)										
Case A	Nov 15- 07-Jan 22 08	Sample Lost in Retrieval						25	47 19.9252	-122 48.1471
Case B	Nov 15- 07-Jan 22 08	Sample Lost in Retrieval						25	47 19.9252	-122 48.1471
Carr A	Nov 15- 07-Jan 22 08	68	1250	1043	38	37	4010	24	47 21.5709	-122 39.7000
Carr B	Nov 15- 07-Jan 22 08	68	1250	1043	38	38	4011	24	47 21.5709	-122 39.7000
Eld A	Nov 21- 07-Jan 22 08	57	1030	1410	38	33	4012	26	47 08.0880	-122 56.8169
Eld B	Nov 21- 07-Jan 22 08	57	1030	1410	38	34	4013	26	47 08.0880	-122 56.8169
Budd A	Nov 15- 07-Jan 22 08	68	1708	1450	38	33	4014	23	47 07.6349	-122 55.1770
Budd B	Nov 15- 07-Jan 22 08	68	1708	1450	38	33	4015	23	47 07.6349	-122 55.1770
Quarter 3: January to March 2008 (Cylinder A- HgCl preservative, Cylinder B- NaCl preservative)										
Case A	Jan 22-Mar 24 07	64	1259	1255	44	ND	4042	25	47 19.9227	-122 48.1458
Case B	Jan 22-Mar 24 07	64	1259	1255	46	ND	4043	25	47 19.9227	-122 48.1458
Carr A	Jan 22-Mar 24 07	64	1110	1030	44	ND	4040	24	47 21.5864	-122 39.7002
Carr B	Jan 22-Mar 24 07	64	1110	1030	46	ND	4041	24	47 21.5864	-122 39.7002
Eld A	Jan 22-Mar 24 07	64	1430	1430	44	ND	4044	26	47 08.0900	-122 56.8199
Eld B	Jan 22-Mar 24 07	64	1430	1430	46	ND	4045	26	47 08.0900	-122 56.8199
Budd A	Jan 22-Mar 24 07	64	1530	1520	44	ND	4046	23	47 07.6336	-122 55.1583
Budd B	Jan 22-Mar 24 07	64	1530	1520	46	ND	4047	23	47 07.6336	-122 55.1583
ND= No Data										
Quarter 4: March to June 2008 (Cylinder A- HgCl preservative, Cylinder B- NaCl preservative)										
Case A	Mar 24-Jun 2 08	70	1315	1230	ND	32	4042	25	47 19.9330	-122 48.1275
Case B	Mar 24-Jun 2 08	70	1315	1230	ND	32	4043	25	47 19.9330	-122 48.1275
Carr A	Mar 24-Jun 2 08	70	1108	1015	ND	35	4040	24	47 21.5728	-122 39.7041
Carr B	Mar 24-Jun 2 08	70	1108	1015	ND	34	4041	24	47 21.5728	-122 39.7041
Eld A	Mar 24-Jun 2 08	70	1448	1441	ND	32	4044	26	47 08.0895	-122 56.8177
Eld B	Mar 24-Jun 2 08	70	1448	1441	ND	32	4045	26	47 08.0895	-122 56.8177
Budd A	Mar 24-Jun 2 08	70	1540	1530	ND	32	4046	23	47 07.6336	-122 55.1583
Budd B	Mar 24-Jun 2 08	70	1540	1530	ND	32	4047	23	47 07.6260	-122 55.1580

MLLW = mean lower low water.
ND = no data.

Each station was located at a depth of approximately 25 meters mean lower low water (MLLW). Positions of each mooring were recorded with a Leica MX420 differentially corrected Global Positioning System (GPS). The sediment traps were positioned at mid-depth, 10 meters from the bottom, to minimize collection of re-suspended bottom sediments.

Each sediment trap holds two collection cylinders. The cylinders are straight-sided glass with a collection area of 78.5 cm^2 and a height-to-width ratio of 5. A collection cylinder with trapped particulates is shown in Figure 2.

During Quarters 1 and 2, two liters of high salinity water (4% NaCl) was added to each cylinder prior to deployment to create a density gradient. The density gradient aids in trapping the collected particulates.

During Quarters 3 and 4 one cylinder in each pair had high salinity water only, while the other cylinder had high salinity water plus HgCl (1 g/liter) as a toxicant to kill microbial growth. Separate preservatives were used in Quarters 3 and 4 in the event that supplemental analysis for carbon, nitrogen, and phosphorus was needed on archived particulate samples in the future. Excess material for archival purposes was only available for the Quarter 4 deployment.

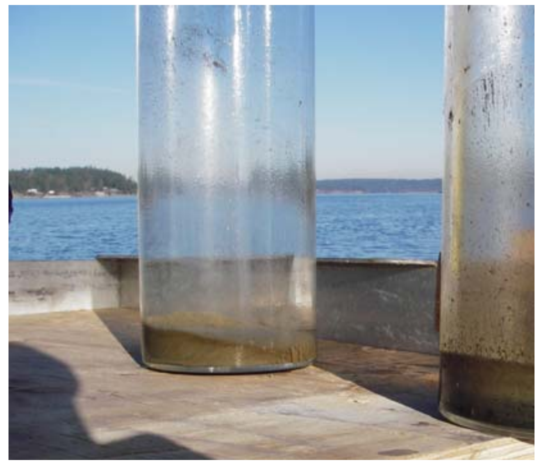

Figure 2: Sediment Trap Collection Cylinder.

The sediment trap design and mooring descriptions are described in detail in Norton (1996). After retrieving the traps, overlaying water in the upper 2/3 of the each cylinder was pumped off with a peristaltic pump. The remaining contents of each cylinder were transferred to a pre-cleaned 0.5-gallon glass jar and stored in coolers at 4°C pending processing in the laboratory.

Processing of samples consisted of first decanting off a portion of the overlying water and then centrifuging the remaining slurry in a pre-weighed, 16-oz glass jar at 1000 rpm for ten minutes to isolate the particulate fraction. Upon completion of centrifuging, the remaining overlaying water was decanted off and the jar was re-weighed to determine the total wet grams of material collected. Aliquots for percent solids and total organic carbon (TOC) were prepared from the centrifuged solids.

The fluxes of settling particulate matter (SPM) and TOC were determined by dividing the total mass of material collected on a dry weight basis, by the surface area of the trap, and by the duration of the deployment.

Analysis and Quality Assurance

Samples for determination of percent solids and TOC were analyzed by Manchester Environmental Laboratory. Percent solids were determined by SM2540G (APHA, 1999). TOC was determined at 70°C using the Puget Sound Estuary Protocol (PSEP, 1997).

Case narratives for percent solids and TOC analysis were prepared by staff at Manchester Laboratory. No major problems were encountered with the analysis of the samples for this project. Percent solids results for Quarter 4 were qualified as estimates due to the samples being analyzed past holding times. This is not expected to affect the analysis for percent solids.

Table 2 presents the results of laboratory replicates analyzed for percent solids. Laboratory replicates were analyzed for Quarters 1 and 4 only. Relative percent differences of replicates were well within the acceptance range of 0-20%.

Table 2: Laboratory Replicates Results for Percent Solids.

Quarter	Replicate 1	Replicate 2	RPD (%)
1	32.8	32.7	0.3
2	-	-	-
3	-	-	-
4	11.6	11.4	2.0

RPD = Relative percent difference.
- = Laboratory did not prepare and analyze replicate samples.

Table 3 presents the results of laboratory replicate analyzed for TOC. Relative percent differences of replicates were within the acceptance range of 0-20%, with the exception of those analyzed for Quarter 3. The relative percent difference between replicates for Quarter 3 was 26%.

Table 3: Laboratory Replicate Results for Total Organic Carbon.

Quarter	Replicate 1	Replicate 2	Replicate 3	RPD (%)
1	2.89	2.95	2.95	2.0
2	2.88	2.85	2.86	1.0
3	3.01	2.90	2.31	26
4	-	-	-	-

RPD = Relative percent difference.
- = Laboratory did not prepare and analyze replicate samples.

Results

Gross Sedimentation Rates

Sediment accumulation rates calculated for Case, Carr, Eld, and Budd Inlets are listed in Table 4. Two types of accumulation rates are shown:

1. Mass accumulation ($g/cm^2/yr$), which is the measured sediment flux into the traps.
2. Accumulation rate (cm/yr), which is calculated to represent the actual thickness of new sediment once the particulates have consolidated on the bottom.

Both these values should be viewed as estimates of gross sedimentation (i.e., net sedimentation + resuspension) since no evaluation of resuspension was performed. Calculations used to generate the reported sedimentation rates are shown below:

Mass Accumulation ($g/cm^2/yr$) = [(P/A)/D] x Y

Where:

P= Amount of material collected (dry grams).
A= Collection area of cylinder (cm^2).
D= Number of days sediment trap was deployed.
Y= Number of days in a year (365).

Accumulation Rate (cm/yr) = Mass accumulation ($g/cm^2/yr$)/Dry density (g/cm^3).

Where:

Dry density = [Wet density x (Bottom Sediment % solids/100)].

Where:

Wet density = Estimated from Puget Sound Density Model using % solids data from in-situ bottom sediments (Crecelius, 1989).

Table 4: Sediment Accumulation Rates and Total Organic Carbon Results.

Station	Number Days Deployed	Collection Area (cm2)	SPM (wet grams)	SPM Percent Solids	BS Percent Solids	SPM (dry grams)	Dry Density* (g/cm3)	Mass Accumulation (g/cm2/year)	Accumulation Rate (cm/year)	TOC @70°C (%)
Quarter 1: September to November 2007										
Case A	63	78.5	25.0	10.5	41.1	2.6	0.55	0.2	0.4	5.65
Case B	63	78.5	36.0	7.1	41.1	2.6	0.55	0.2	0.3	4.79
Carr A	63	78.5	66.0	6.9	41.0	4.6	0.55	0.3	0.6	3.69
Carr B	63	78.5	57.0	9.6	41.0	5.5	0.55	0.4	0.7	3.57
Eld A	69	78.5	117.0	27.2	29.3	31.8	0.35	2.1	6.1	2.76
Eld B	69	78.5	91.0	32.8	29.3	29.8	0.35	2.0	5.7	2.69
Budd A	-	-	-	-	-	-	-	-	-	-
Budd B	63	78.5	87.0	25.1	30.1	21.8	0.36	1.6	4.4	2.93
Quarter 2: November 2007 to January 2008										
Case A	-	-	-	-	-	-	-	-	-	-
Case B	-	-	-	-	-	-	-	-	-	-
Carr A	68	78.5	26.0	15.2	41.0	4.0	0.55	0.3	0.5	2.88
Carr B	68	78.5	23.0	17.7	41.0	4.1	0.55	0.3	0.5	3.24
Eld A	57	78.5	86.0	26.5	29.3	22.8	0.35	1.9	5.3	2.74
Eld B	57	78.5	85.0	27.0	29.3	23.0	0.35	1.9	5.3	2.66
Budd A	68	78.5	39.0	25.6	30.1	10.0	0.36	0.7	1.9	2.53
Budd B	68	78.5	37.0	26.0	30.1	9.6	0.36	0.7	1.8	2.63
Quarter 3: January to March 2008										
Case A	64	78.5	76.0	5.4	41.1	4.1	0.55	0.3	0.5	2.50
Case B	64	78.5	60.0	5.3	41.1	3.2	0.55	0.2	0.4	4.18
Carr A	64	78.5	29.0	9.0	41.0	2.6	0.55	0.2	0.3	2.66
Carr B	64	78.5	17.0	15.4	41.0	2.6	0.55	0.2	0.3	4.57
Eld A	64	78.5	53.0	24.1	29.3	12.8	0.35	0.9	2.6	3.02
Eld B	64	78.5	52.0	24.2	29.3	12.6	0.35	0.9	2.6	2.90
Budd A	64	78.5	48.0	23.7	30.1	11.4	0.36	0.8	2.3	2.98
Budd B	64	78.5	49.0	23.1	30.1	11.3	0.36	0.8	2.3	3.01
Quarter 4: March to June 2008										
Case A	70	78.5	108.0	5.0	41.1	5.4	0.55	0.4	0.7	5.59
Case B	70	78.5	109.0	4.7	41.1	5.1	0.55	0.3	0.6	3.43
Carr A	70	78.5	102.0	5.1	41.0	5.2	0.55	0.3	0.6	5.05
Carr B	70	78.5	105.0	4.8	41.0	5.0	0.55	0.3	0.6	3.71
Eld A	70	78.5	191.0	12.8	29.3	24.4	0.35	1.6	4.6	3.86
Eld B	70	78.5	91.0	27.2	29.3	24.8	0.35	1.6	4.7	3.50
Budd A	70	78.5	180.0	11.5	30.1	20.7	0.36	1.4	3.8	4.05
Budd B	70	78.5	86.0	20.7	30.1	17.8	0.36	1.2	3.3	3.59

Quarter 4 percent solids are estimated values due to holding times.
* = Estimated from Bottom Sediment Percent Solids using Puget Sound Density Model (Crecelius, 1989).
SPM = Settling particulate matter.
BS = Bottom sediment.

Annual mean mass accumulation rates from the present study are summarized in Table 5. No differences were seen in the calculated accumulation rates for paired samples (i.e. individual cylinders) in Quarters 3 and 4 despite using different preservatives (Table 4). As a result, each cylinder in a pair was treated as a replicate sample for the purposes of data analysis.

Table 5: Summary of Mass Accumulation Rates (g/cm2/yr).

Location	N=	Mean	Standard Deviation	Minimum	Maximum
Case Inlet	6	0.3	0.08	0.2	0.4
Carr Inlet	8	0.3	0.06	0.2	0.4
Eld Inlet	8	1.6	0.5	0.9	2.1
Budd Inlet	7	1.0	0.4	0.7	1.6

Based on means, mass accumulation rates for Budd and Eld Inlets were approximately three to five times higher than those measured in Case and Carr Inlets.

Figure 3 shows mass accumulation rates over time.

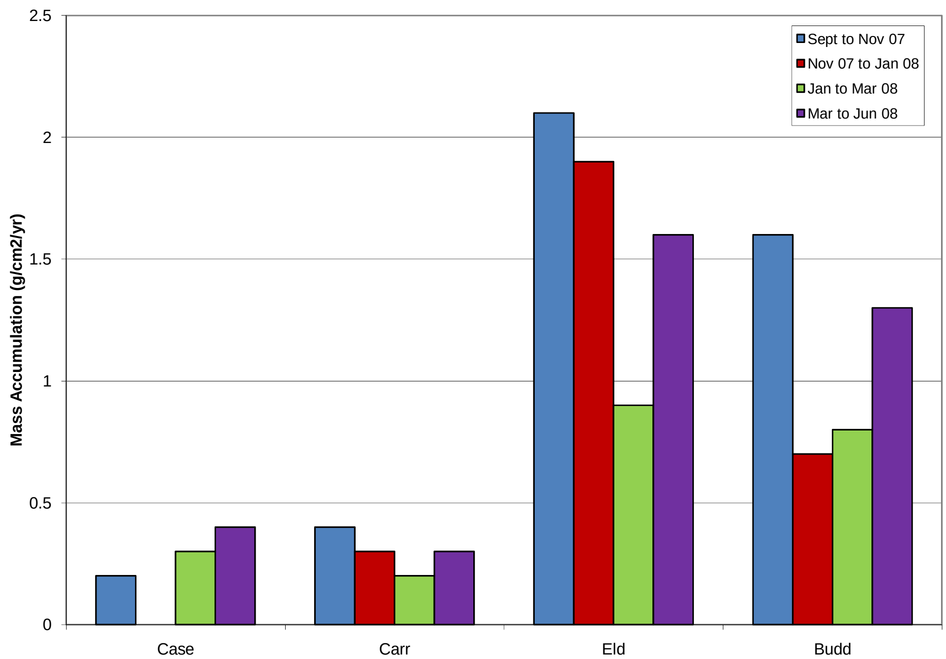

Figure 3: Mass Sediment Accumulation Rates for Case, Carr, Eld, and Budd Inlets.

The highest rates were typically measured in the fall (September to November) and lowest in the winter (January to March). An exception was Case Inlet where the highest rates were measured in the spring (March to June).

For comparison, mass accumulation rates determined with sediment traps for other areas of Puget Sound are shown in Table 6.

Table 6: Mass Accumulation Rates Determined with Sediment Traps for Other Areas of Puget Sound.

Location	Mean+/- SD (g/cm2/yr)
Inner Budd Inlet (Norton and Boatman, 1998)	1.4 +/- 1.0
Inner Commencement Bay (Norton, 1996)	1.5 +/- 0.9
Elliott Bay Waterfront (Norton and Michelson, 1995)	0.7 +/- 0.3

SD = standard deviation.

Mass accumulation rates for Eld and Budd Inlets are similar to those measured in other urban embayments of Puget Sound.

Total Organic Carbon Fluxes

TOC flux rates measured during this study are summarized in Table 7.

Table 7: Summary of Total Organic Carbon Flux Rates (gOC/cm2/yr).

Location	N=	Mean	Standard Deviation	Minimum	Maximum
Case Inlet	6	0.012	0.005	0.007	0.02
Carr Inlet	8	0.011	0.004	0.005	0.017
Eld Inlet	8	0.11	0.2	0.027	0.063
Budd Inlet	7	0.033	0.02	0.017	0.056

The highest flux rates for TOC were measured in Eld and Budd Inlets. TOC flux rates were much lower in Case and Carr Inlets.

Figure 4 displays TOC flux rates for the four quarters of this study.

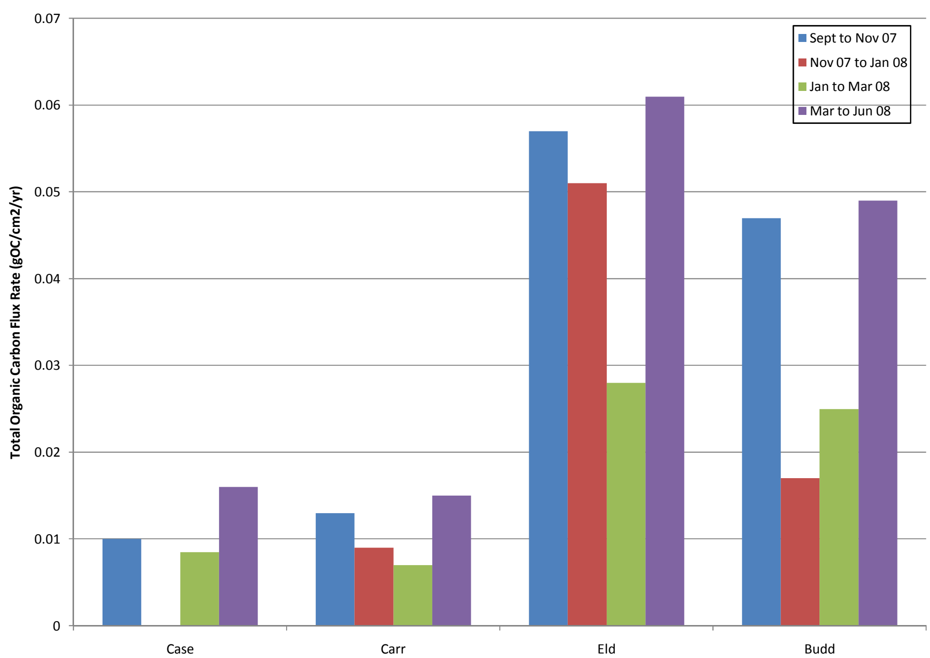

Figure 4: Total Organic Carbon Flux Rates for Case, Carr, Eld, and Budd Inlets.

The highest TOC flux rates were typically measured during Quarters 1 (September to November) and 4 (March to June) in all four Inlets.

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