APPENDIX 8B-2

SEWAGE EFFLUENT MODELLING AT STEENSBY INLET

Sewage Water Discharge at Steensby Inlet: Estimation of the Trapped Depth

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Report Submitted

To

Coastal and Ocean Resources Inc.

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1. Method.

We will determine the trapped depth D_T as the depth where sewage water will accumulate after being discharged at 20 m depth and mixing in the diffuser with ambient seawater. We assume that the seawater density increases with depth; i.e. the water column is stable. Thus the trapped depth is the depth where the mixed sewage water density is equal to the ambient water density:

$$\rho_M = \rho(D_T) \tag{1}$$

Instead of density below we will use the sigma-t value, which is equal to the density exceeding 1000 kg m^{-3} value; i.e., sigma-t=ρ-1000. The mixed sewage water density is determined by its temperature T_M and salinity S_M,

$$\sigma_M = \sigma(T_M, S_M) \tag{2}$$

which, in turn, are determined by original sewage water temperature T_S and salinity S_S, ambient water temperature T_{20} and salinity S_{20} at the discharge depth (20 m) and the diffuser ratio:

$$\begin{aligned} T_M &= cT_S + (1-c)T_{20} \\ S_M &= cS_S + (1-c)S_{20} \end{aligned} \tag{3}$$

where c is a concentration of sewage in the mix.

2. Data processing

We use the location of the sewage discharge sites, shown in Table 1.

Table 1. Proposed sewage discharge site positions

Site	Longitude, degrees west	Latitude, degrees north
A1	78.525328W	70.306106N
A2	78.518964W	70.304202N

For the calculations we use the following parameters of the sewage water:

S_S=0 (fresh water)
T_S=10 C

We use 3 different series of the CTD observation: September 2007, June 2008 and August 2010. There were many measurements in each series from which we choose 3-4

locations which were closest to the proposed sewage discharge sites. The locations of the chosen measurements are indicated in the Tables 2 to 4.

Temperature and salinity profiles are shown in Figures 1 to 10. These series show different hydrological regimes. In September 2007 for all profiles, salinity increases with depth and temperature decreases, which corresponds to strong stable stratification of the water column. In June 2008, all profiles, though positive, show generally weak stratification except for the thin near-surface layer which contains relatively warm and fresh water. In August 2010 the salty water is near the surface, while fresh and cold water fill intermediate depths. As a result, a condition existed with a neutral or even unstable layer at depth and with a strong salinity inversion in the upper layer. This situation probably would quickly change by convective vertical mixing.

Table 2. September 2007 Steensby Inlet CDT station location

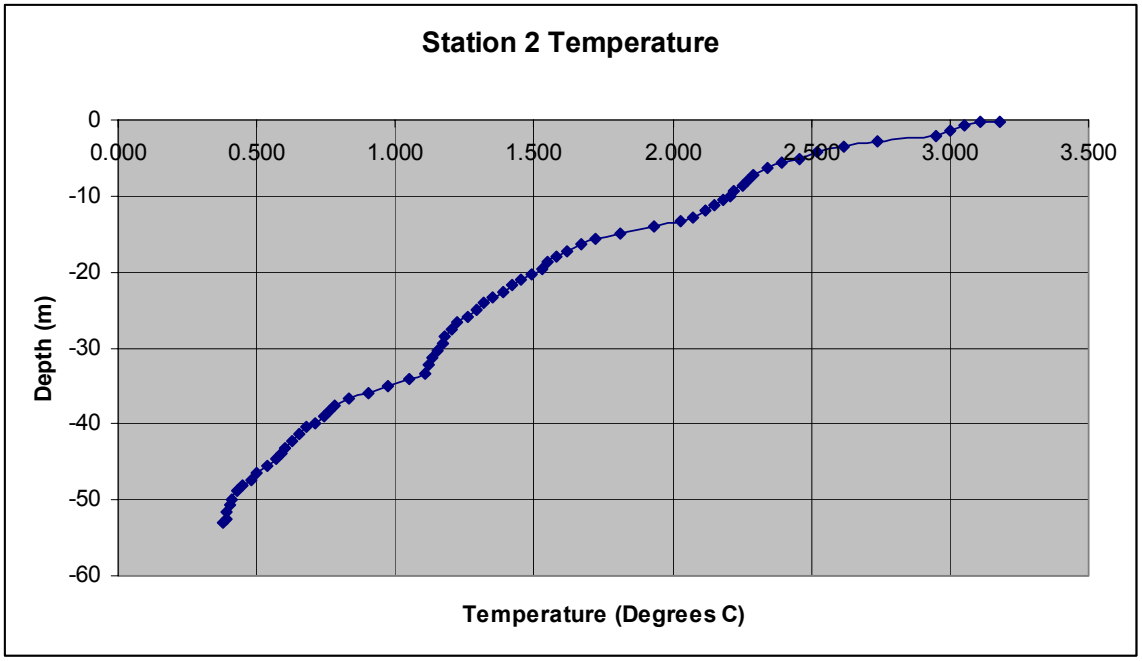
Stations	Date	UTM_E	UTM_N
STN-2	4-Sep	592690	7800090
STN-9	5-Sep	591960	7803397
STN-15	5-Sep	590244	7802348
STN-16	5-Sep	591201	7802738

Table 3. June 2008 Steensby Inlet CDT station location

Stations	Date	UTM_E	UTM_N	Longitude, (degrees west)	Latitude, (degrees north)
CTD-29	11-Jun-08	589025	7802907	78.63127116	70.3165445
CTD-32	09-Jun-08	591960	7803397	78.55274234	70.31989325
CTD-39	12-Jun-08	590838	7799793	78.58636958	70.28800729

Table 4 August 2010 CTD station location

Stations	Date	UTM_E	UTM_N	Longitude, (degrees west)	Latitude, (degrees north)
A18	16-Aug-2010	592665	7802110	78.5353845	70.3081054
A19	16-Aug-2010	592665	7802042	78.5354709	70.3075036
A20	16-Aug-2010	592560	7801922	78.5383902	70.3064659



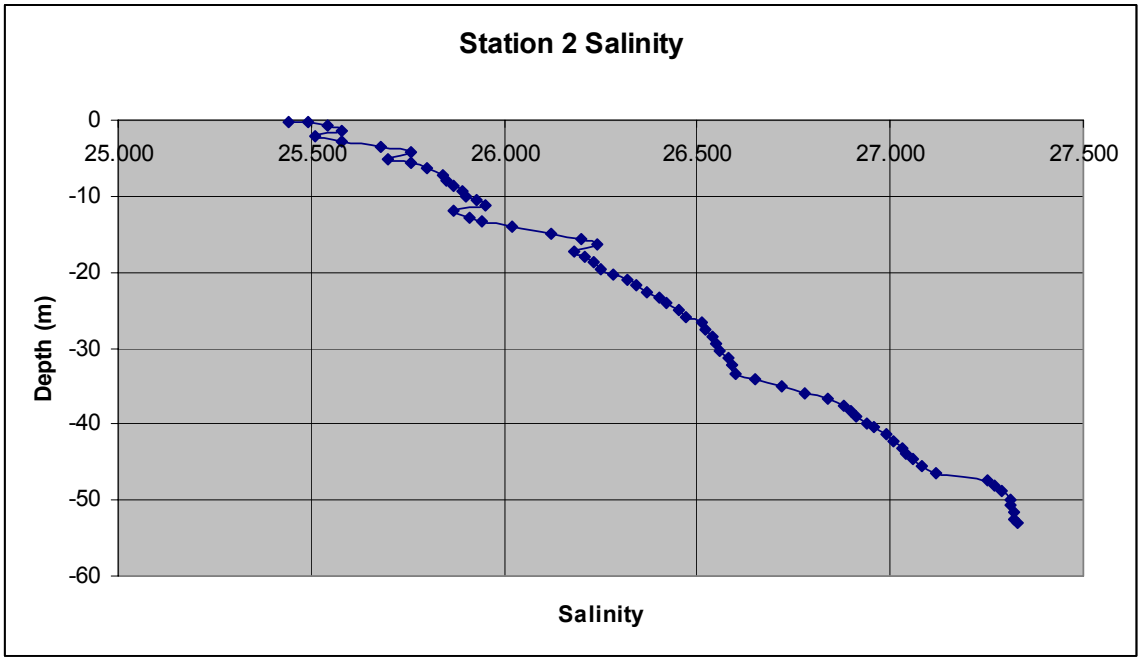
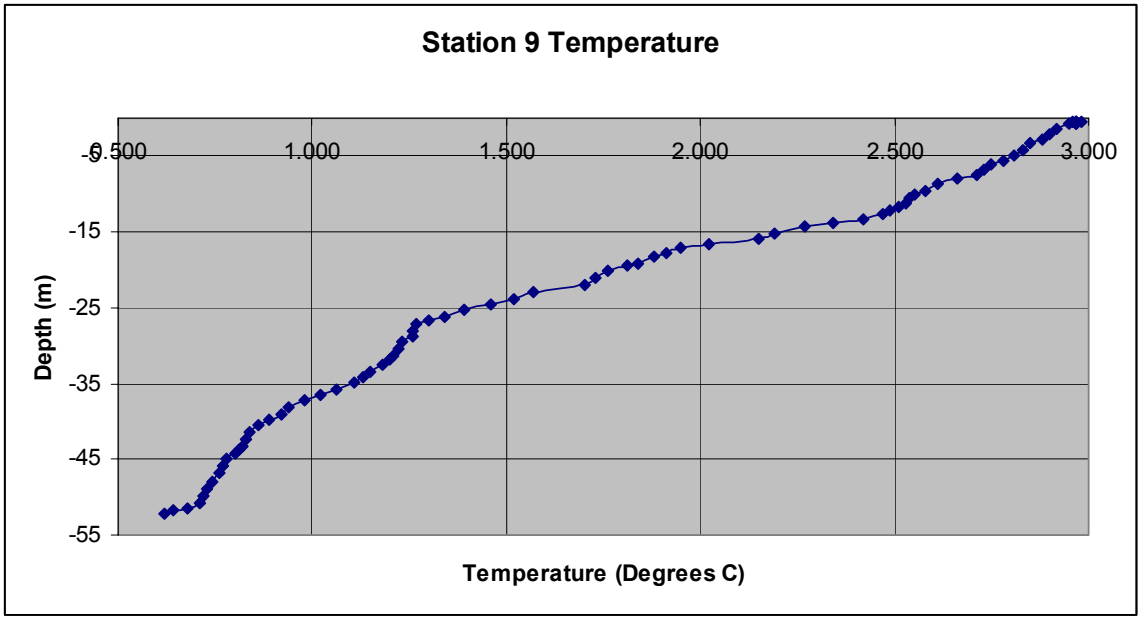


Figure 1. Temperature and salinity profiles at the Station 2 on September 5, 2007.



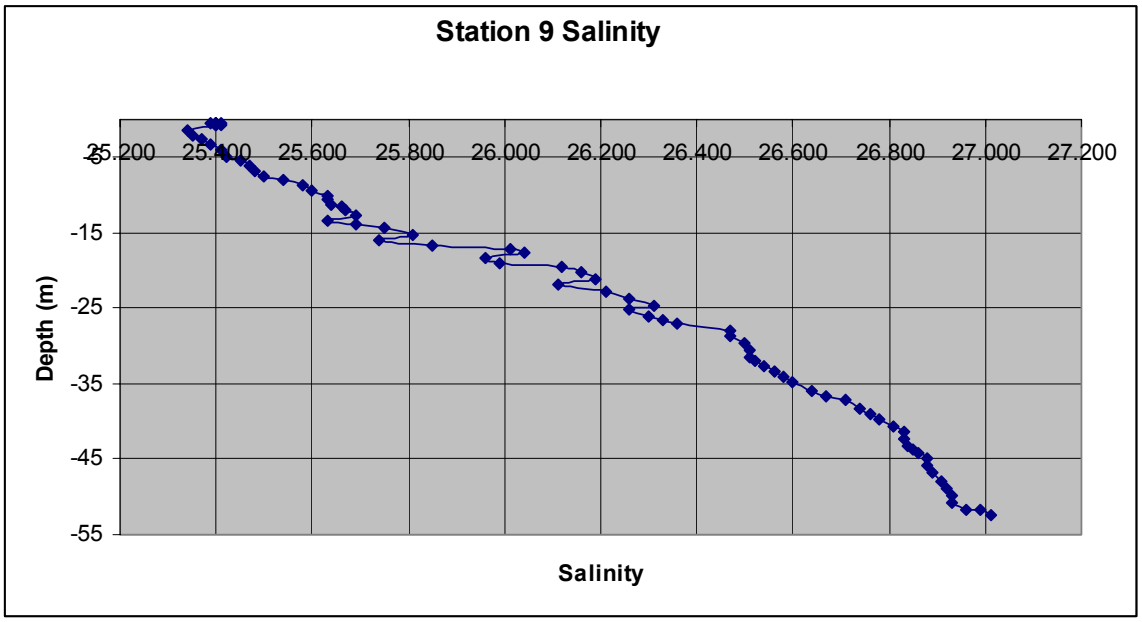
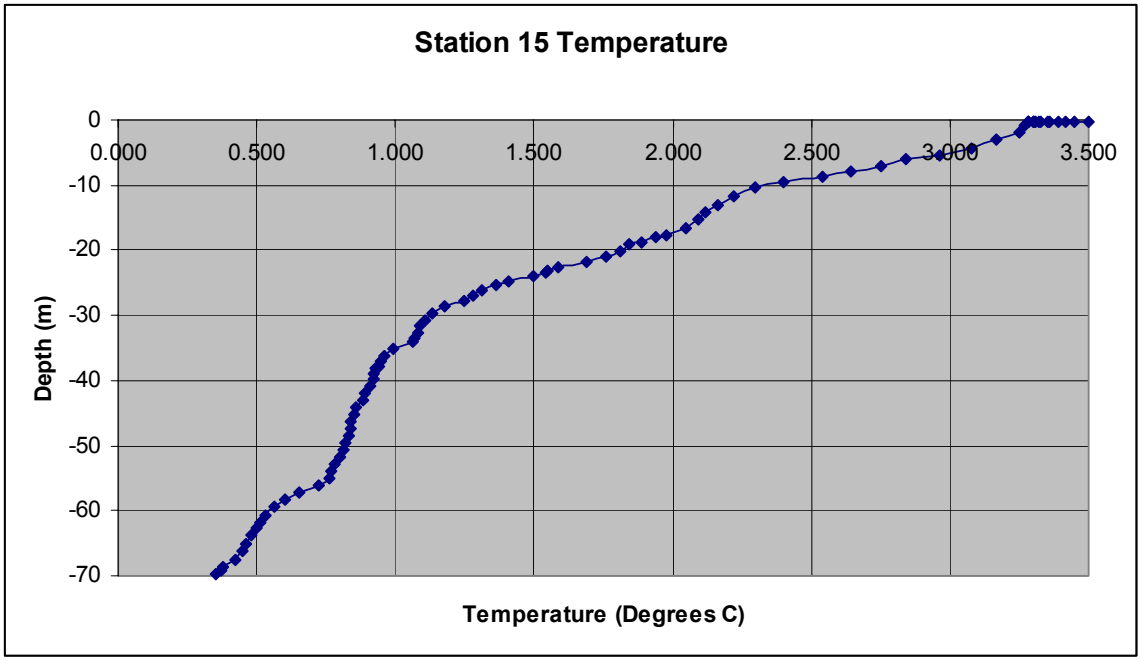


Figure 2. Same as Fig.1 at Station 9 on September 5, 2007



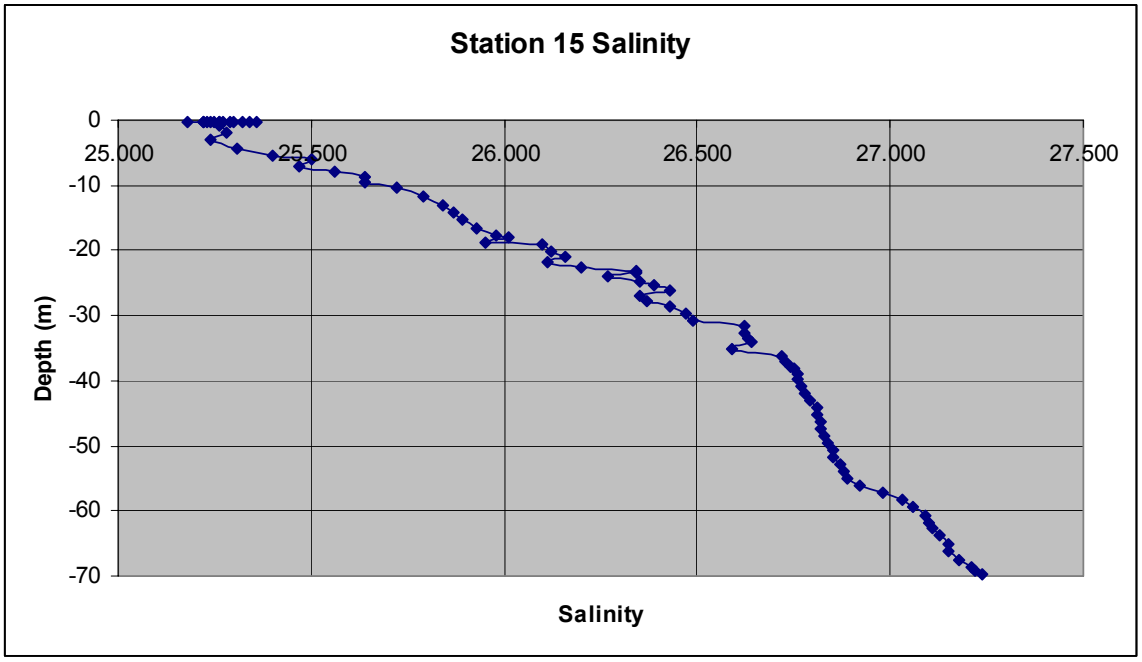
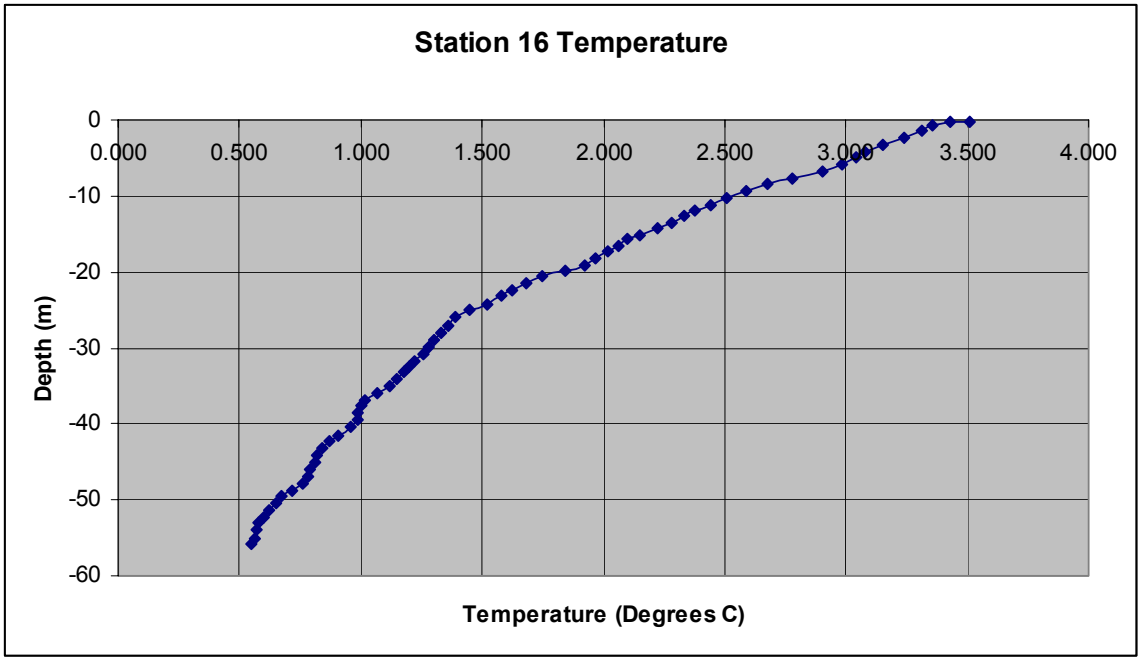


Figure 3. Same as Fig.1 at Station 15 on September 5, 2007



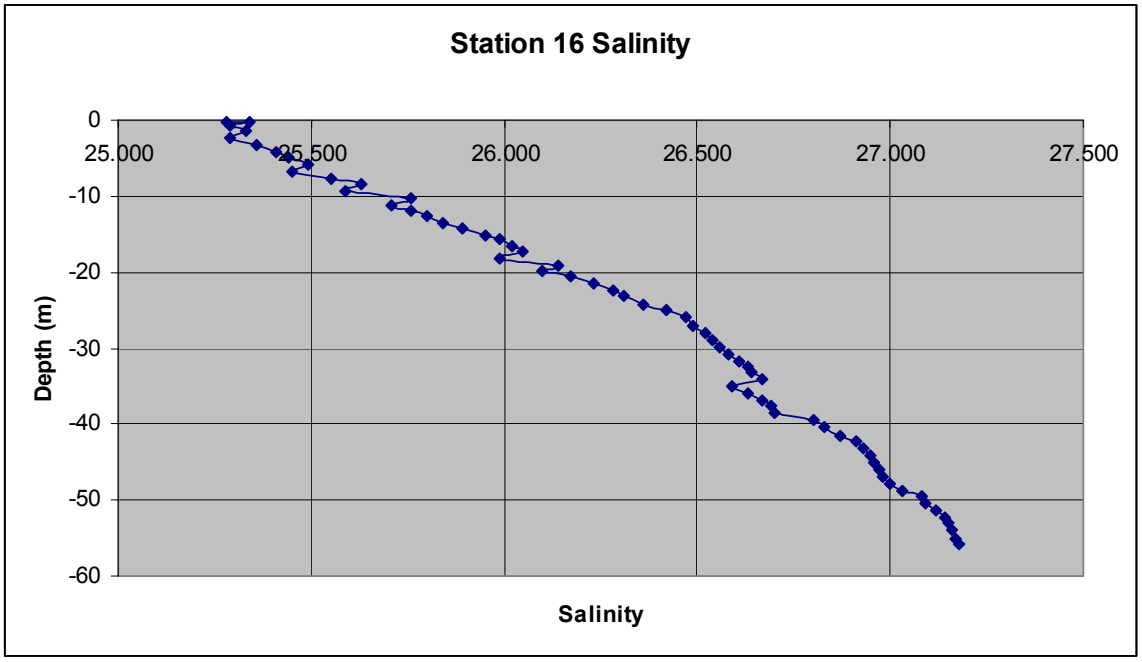


Figure 4. Same as Fig.1 at Station 16 on September 5, 2007

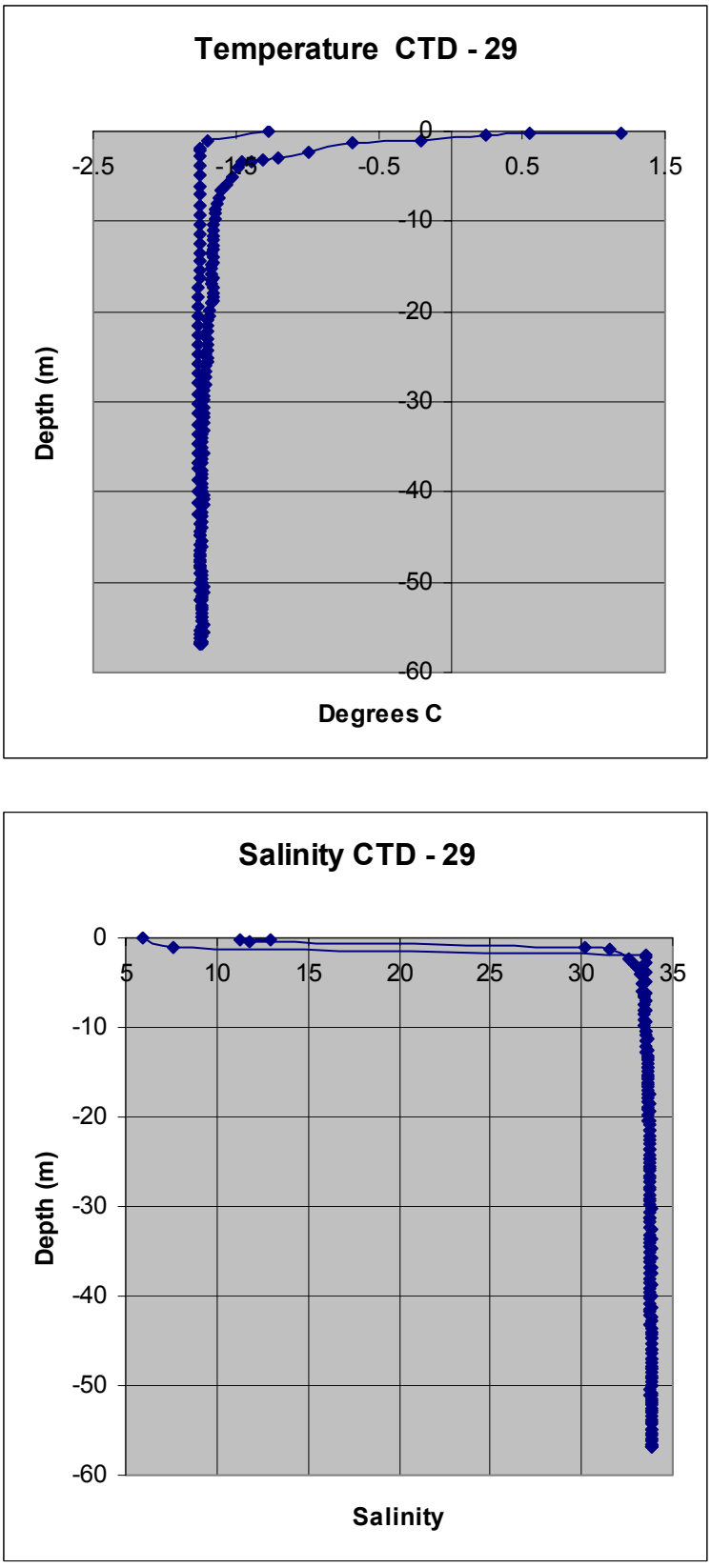
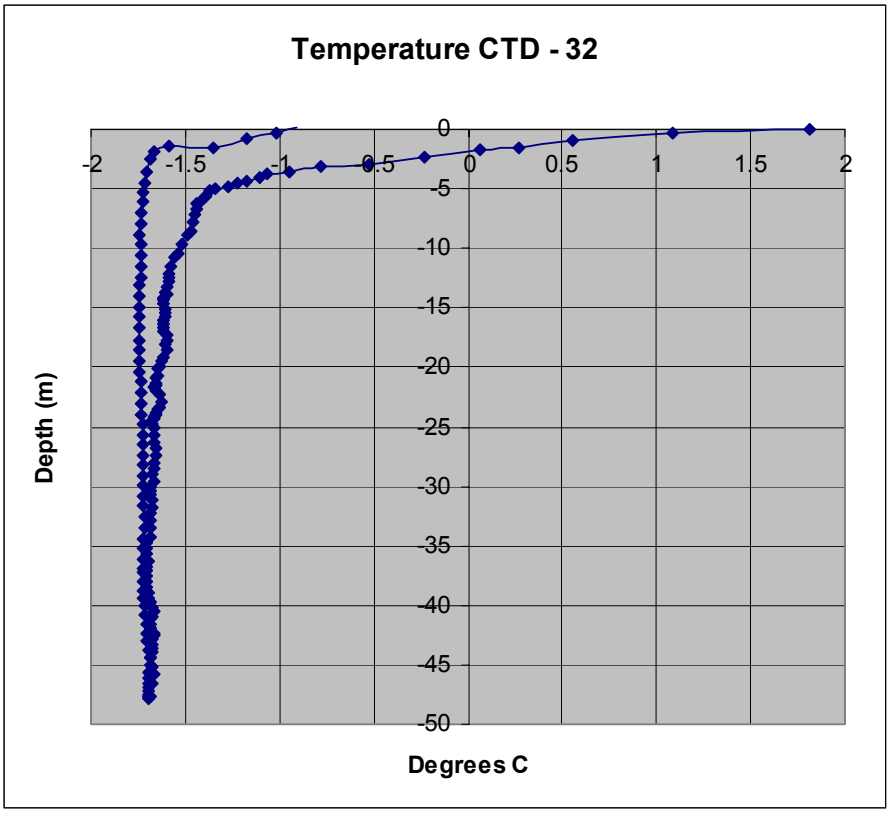


Figure 5. Same as Fig.1 at CTD-29 on June 11, 2008



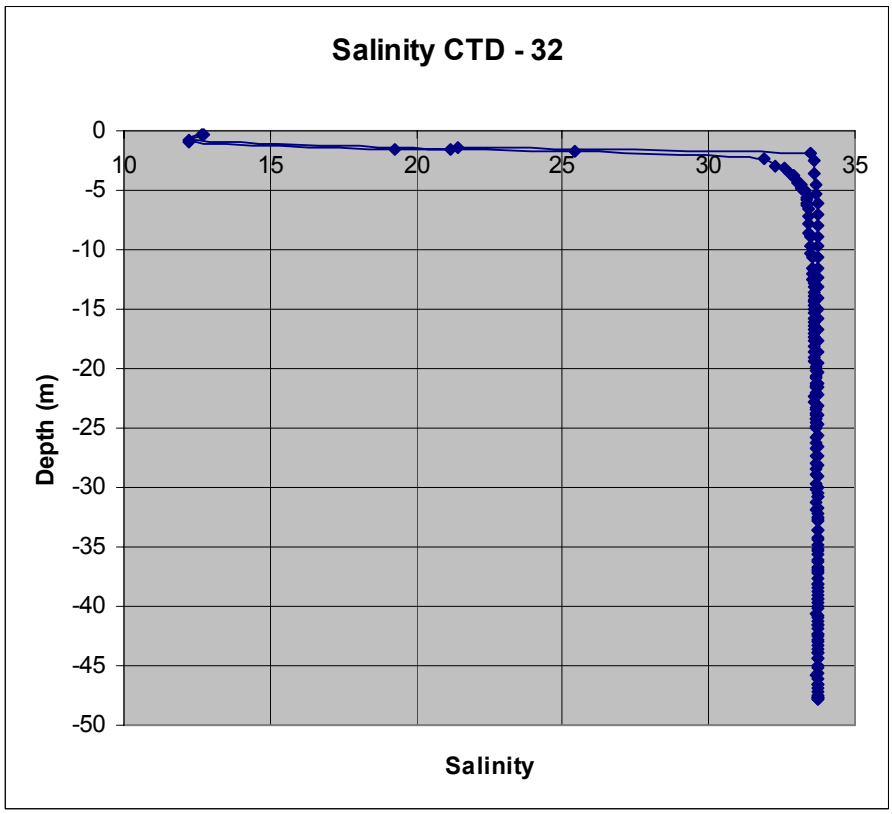


Figure 6. Same as Fig.1 at CTD-32 on June 09, 2008

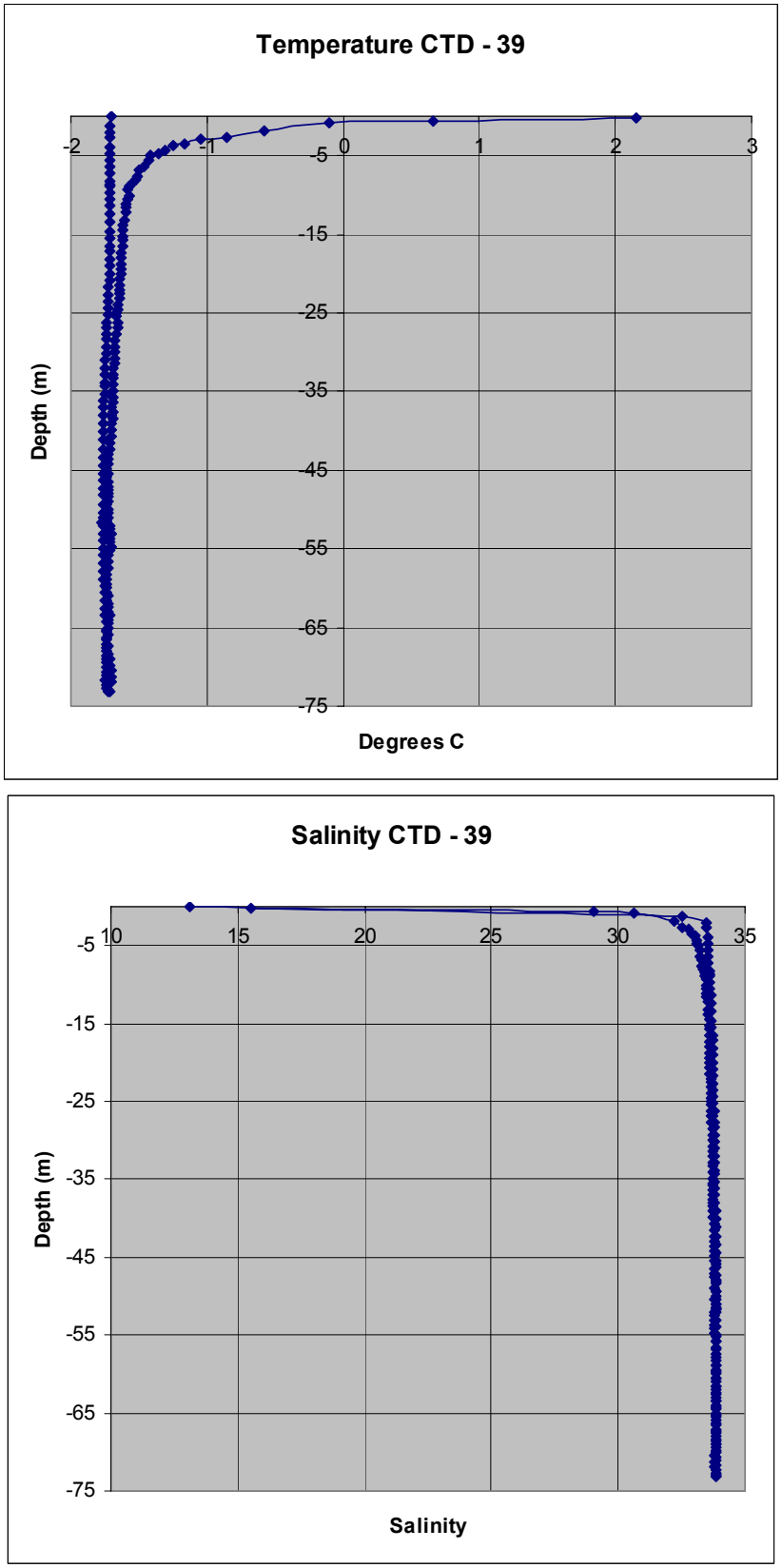
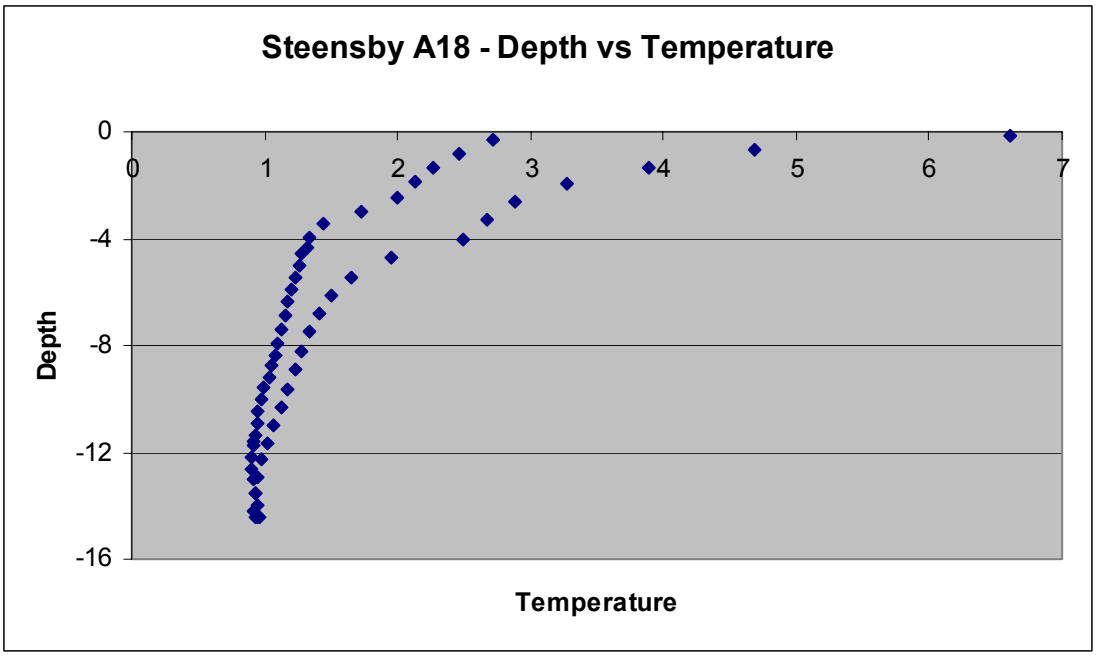


Figure 7. Same as Fig.1 at CTD-39 on June 12, 2008



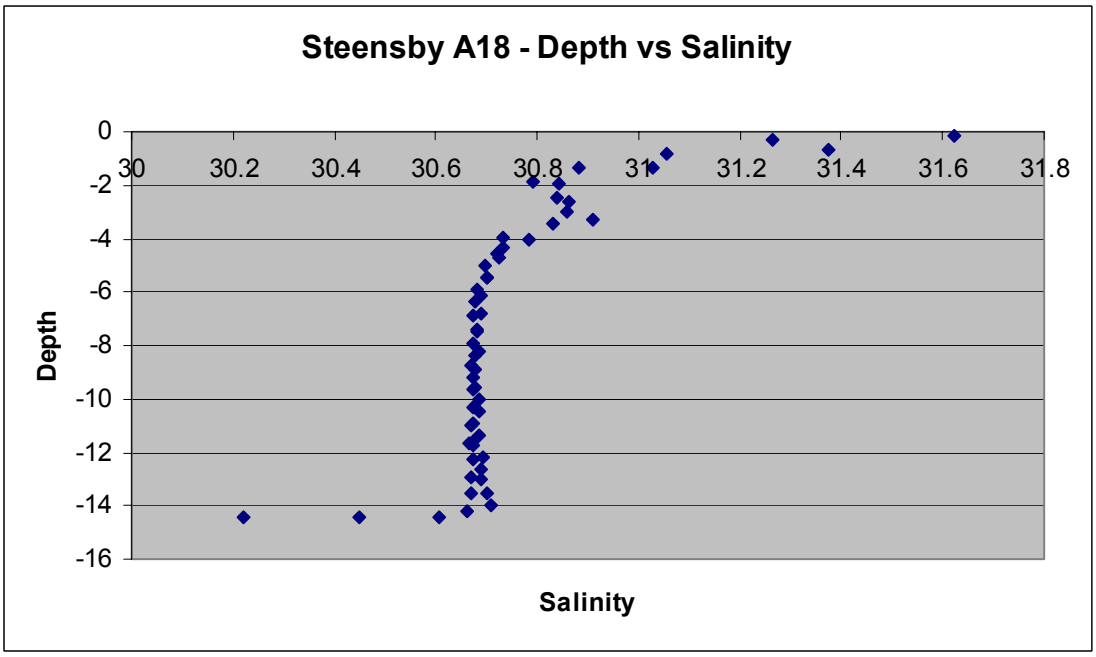
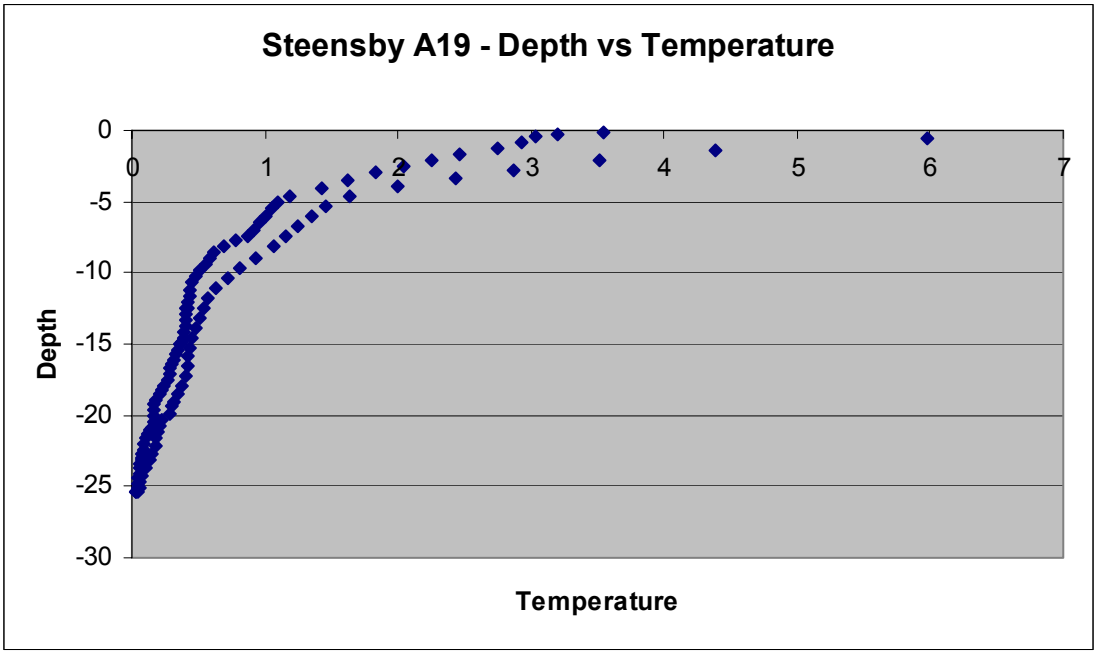


Figure 8. Same as Fig.1 CTD-A18 on August, 16, 2010.



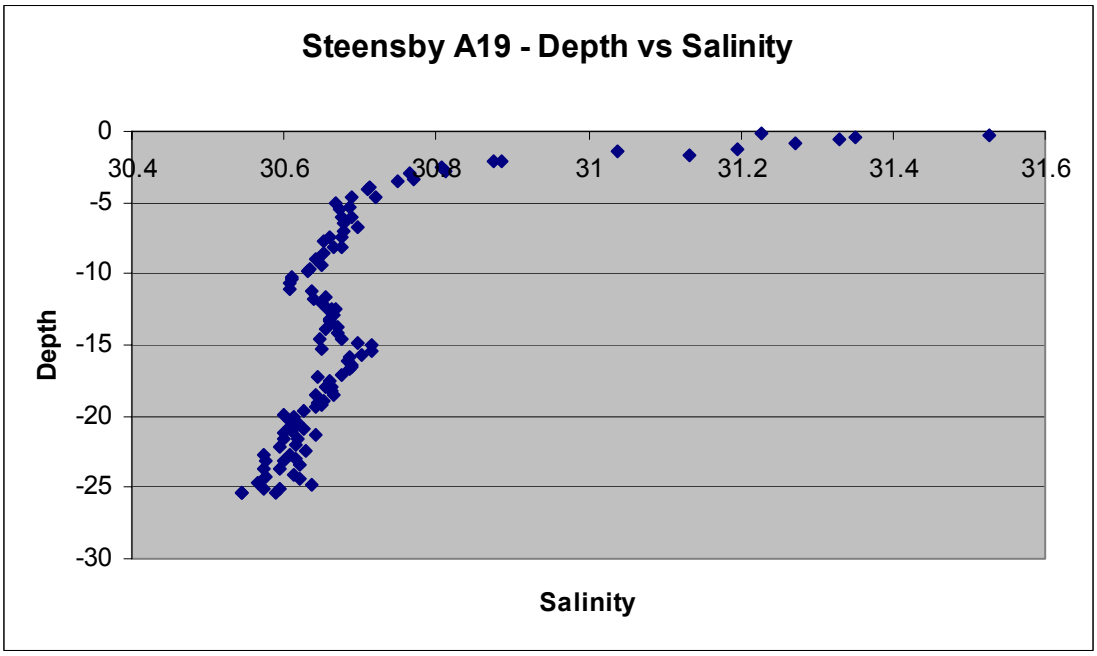
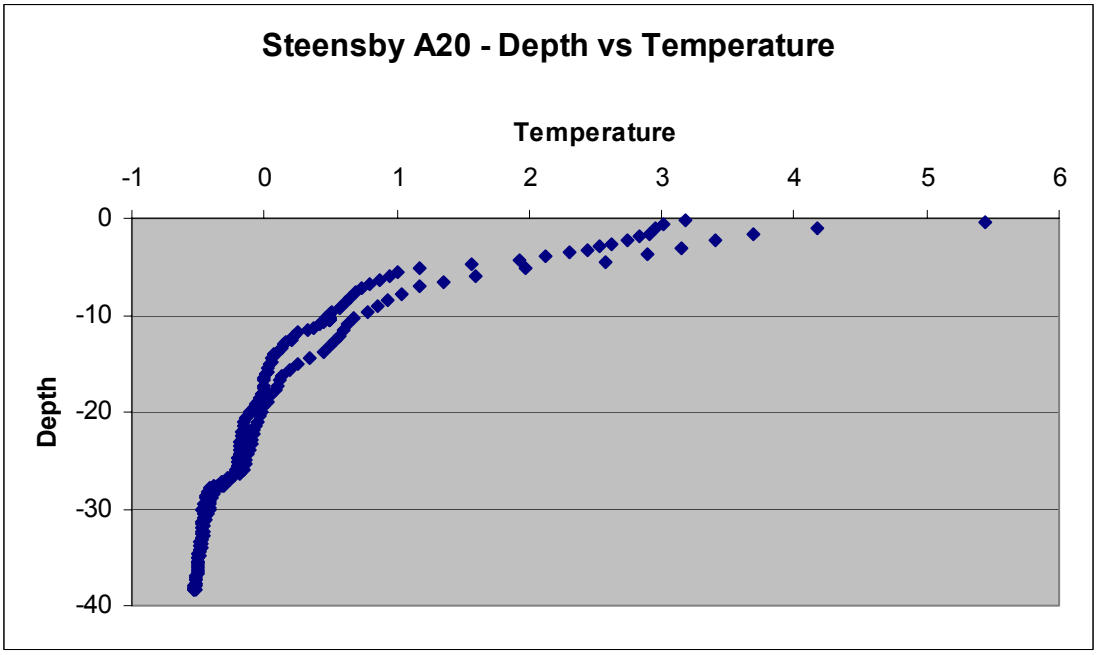


Figure 9. Same as Fig.1 at CTD-A19 on August, 16, 2010.



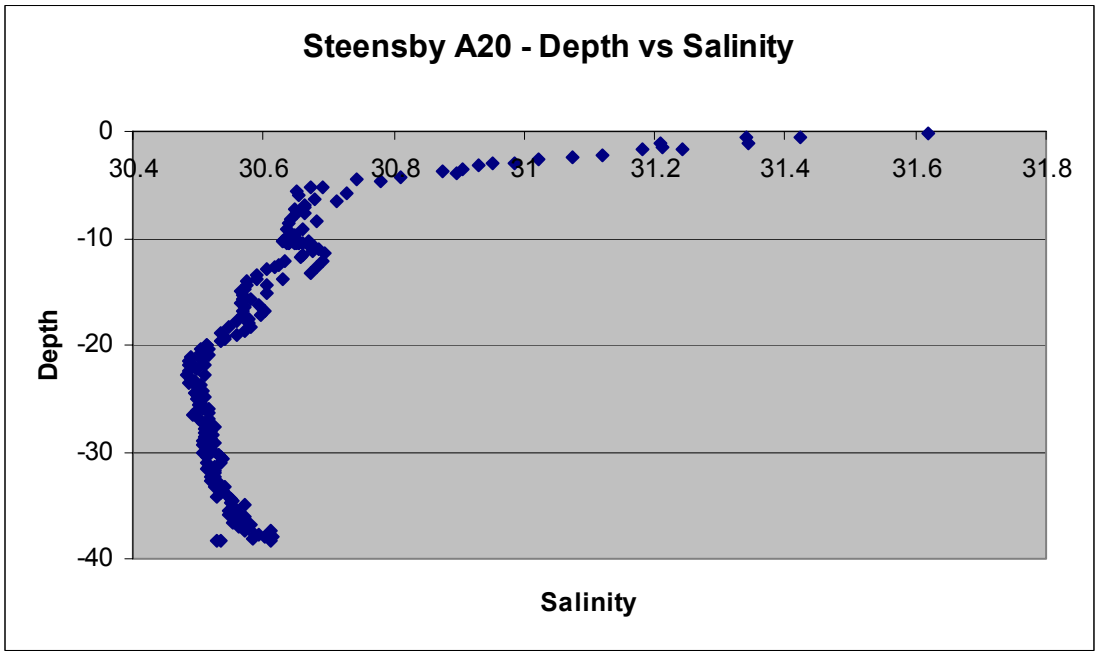


Figure 10. Same as Fig.1 at CTD-A20 on August, 16, 2010.

3. Results

Using the profiles placed (Figures 1 to10), we calculated the density profiles for each series and then computed the trapped depth for each profile for two cases, when the diffuser provides a mixing ratio 1:100 and 1:1000. The results of the calculation are shown in Tables 5 and Table 6.

We did not show any results for the August 2010 measurements because the data show an unstable layer which will likely cause a strong vertical mixing; this cannot be estimated by current analysis.

As is clear seen from the table, stronger stratification in September, 2007 led to deeper trapped depths: sewage water does not go up to the near-surface layer. If the diffuser works properly with a ratio 1:1000 or better, all sewage water will stay in the near-bottom layer.

For the June 2008 conditions, the fate of the sewage water depends on the quality of the diffuser: if the diffuser ratio is 1:100 or less, the sewage water can reach the near-surface.

For the August 2010 conditions, the water column will likely undergo strong vertical mixing, as a result, the sewage concentration will decrease quite rapidly.

Table 4. Results for September 2007 measurements

Stations	T_{20} (°C)	S_{20} (psu)	σ_M		Trapped depth (m)	
			c=1:100	c=1:1000	c=1:100	c=1:1000
STN-2	1.5	26.25	20.7939	20.9728	11.0	19.0
STN-9	1.75	26.1	20.6530	20.8407	13.0	19.5
STN-15	1.8	26.2	20.7298	20.9182	13.0	19.5
STN-16	1.8	26.15	20.6901	20.8782	12.0	19.0

Table 5. Results for June 2008 measurements

Stations	T_{20} (°C)	S_{20} (psu)	σ_M		Trapped depth (m)	
			c=1:100	c=1:1000	c=1:100	c=1:1000
CTD-29	-1.8	33.7	26.853	27.097	7.5	15.0
CTD-32	-1.6	33.6	26.766	27.001	8.0	16.0
CTD-39	-1.7	33.5	26.690	26.933	7.0	15.0