LITTLE VENICE WATER QUALITY MONITORING PROJECT: PHASE 1 RESULTS

Final Report for EPA Agreement #X994621-94-0
And Monroe County

Prepared by:

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Technical Contribution #T-218 of the Southeast Environmental Research Center at Florida International University

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Executive Summary

This report includes cumulative water quality and bacteriological data from 9 stations within the Little Venice subdivision collected during the period of record May 2001 – Dec. 2003. Water was collected weekly for bacteriological analysis by SYNAGRO for enumeration of fecal coliform and enterococci (counts per 100 ml). Field parameters collected weekly at both the surface and bottom of the water column at each station include salinity, temperature (°C), and dissolved oxygen (DO; mg l^{-1}). Water quality parameters monitored weekly at each station include total nitrogen (TN), total phosphorus (TP), and chlorophyll *a* (CHLA; µg l^{-1}). Monthly monitoring at each station included the dissolved nutrients nitrate+nitrite (NO_x^-), nitrite (NO_2^-), nitrate (NO_3^-), ammonium (NH_4^+), inorganic nitrogen (DIN), soluble reactive phosphate (SRP), and silicate ($Si(OH)_4$). In addition, monthly deployment of ISCO autosamplers at rotating sites were programmed to collect 12 samples per day over a 2 day period. These samples were analyzed for TN and TP. Datasondes accompanied the autosamplers to measure and log temperature, salinity, and DO every two hours.

Fecal coliform counts exceeded the Florida state standard 5 times over the period of record, while enterococci counts exceeded EPA recommended standards 60 times. There were 631 surface DO and 708 bottom DO measurements below the Florida State standard of 4 mg l^{-1}. There is no accepted state standard for nutrients in Florida marine waters. However, State of Florida Rule 62-02.300(13), F.A.C. states that "particular consideration shall be given to the protection from nutrient enrichment of those presently containing very low nutrient concentrations: less than 0.3 milligrams per liter total nitrogen or less than 0.04 milligrams per liter total phosphorus." For the period of record there were 657 TN measurements and 18 TP values above these benchmarks.

The canals of Little Venice subdivision are clearly impacted by landuse and the associated septic treatment systems as well as by their physical design. The presence of enterococci above the EPA recommended level is a relatively robust indicator of sewage input to the canals. In addition, elevated TN levels in the head of the canals and during low tide indicates that the canals are a source of TN to the offshore waters. Whether this is due to sewage input alone is debatable because dead-end canals typically accumulate sediments and seagrass wrack which is decomposed in situ. This degradation of organic matter is important in driving down DO levels as is the physical nature of canals as having increased water residence time. Low DO levels are alleviated during the day by phytoplankton primary production, driven by high inorganic nutrient inputs, but are exacerbated by phytoplankton respiration at night. Thus, the vicious cycle of production, decomposition, and DO depletion is maintained.

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BACKGROUND

The ocean side area of Vaca key from Vaca Cut (east) to 94th Street (west), Marathon, Florida has a large percentage of houses and trailers that are currently serviced by inadequate septic tank systems or cesspit disposal. This are has been collectively called the "Little Venice" Service Area, whereas in fact, Little Venice Subdivision is located on the westernmost portion of the service area. The Little Venice Service Area includes ~540 residences (Figure 1).

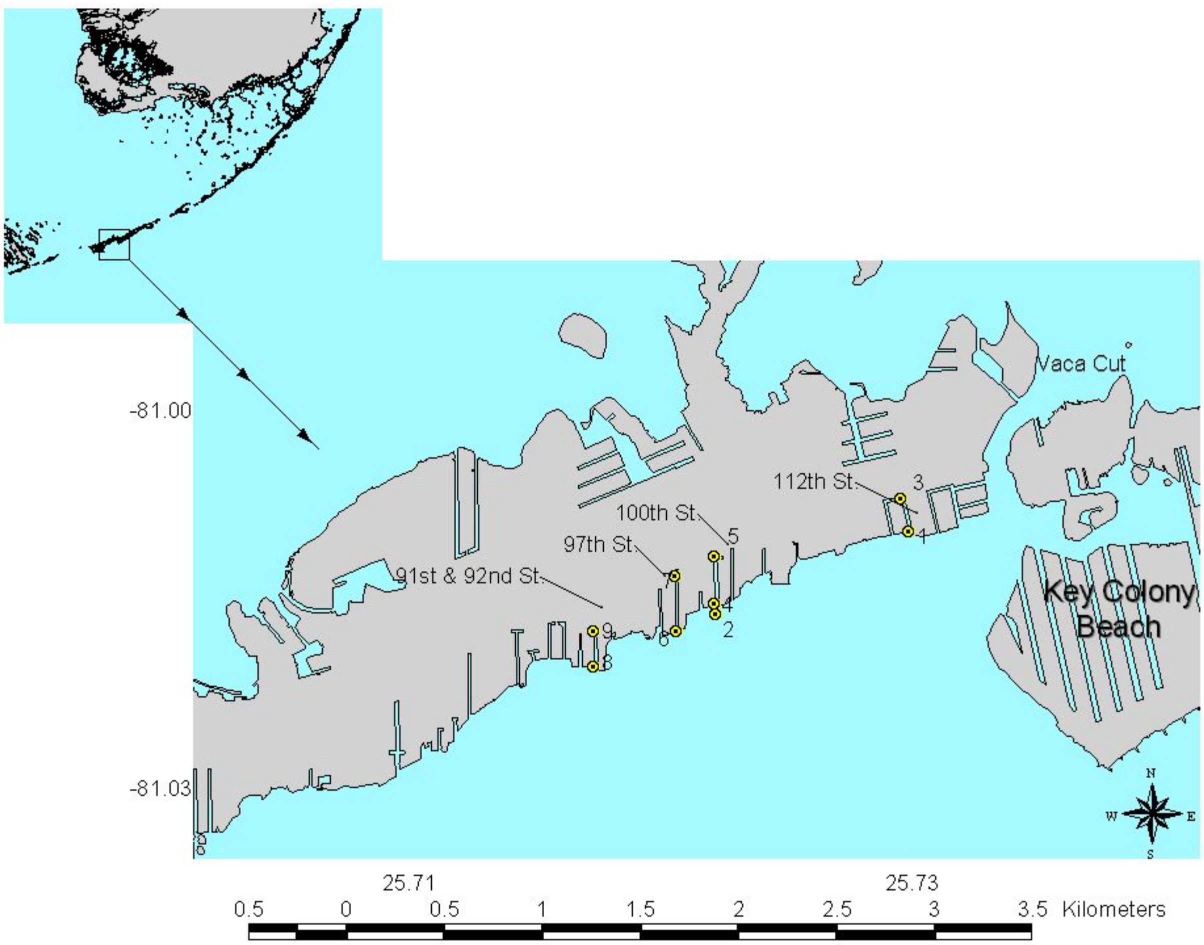


Figure 1

The Little Venice Service Area was selected as the first phase of wastewater improvements for the Marathon Service Area because of the large number of homes on cesspits, the small average size of lots, the density of homes, and known water quality problems in the canals that occur in the area. Water quality of the 89th – 91st Street canals was thoroughly studied in 1984-1985 as part of the Florida Department of Environmental Regulation's Monitoring Study (FDER, 1987). That study demonstrated significant nutrient enrichment of the canals, high chlorophyll a content, and high coprostanol concentrations in sediments. Coprostanol is a break-down product of cholesterol and has been used as an indicator of fecal contamination.

The Little Venice Service Area will receive a low-pressure, vacuum wastewater collection system that will transmit wastewater to a central treatment plant. The treatment plant will produce effluent that meets or exceeds the current advanced wastewater treatment (AWT) standards of 5:5:3:1 (BOD5, TSS, TN, TP) and will use a Class V injection well for disposal of treated wastewater. Central collection and treatment of wastewater will remove a substantial portion of nutrient loading into the canals by removing the sources of wastewater (poorly functioning septic tanks and cesspits).

SAMPLING PROGRAM

The purpose of this water quality sampling program is to document water quality improvements in the canals of the Little Venice Service Area. The sampling program consists of two phases. Phase 1 will be conducted for two years prior to the initiation of operation of the central sewage treatment system. Phase 1 will establish existing conditions in the canals within the service area. Phase 2 will be conducted for two years after initiation of the central sewage treatment system and will document changes in water quality and sediment chemistry of the canals. This report documents the water quality of Little Venice

Four canals within the Little Venice Service Area were selected for sampling (Fig. 1). Canal 1 and 2 are a connected "U-shaped" canal system located at 112th Street. These canals receive better tidal flushing than other canals within the Service Area because of their flow-through design and their relatively short length. Canals 1 and 2 are lined with single-family residences that were constructed prior to 1970 and a high percentage of those residences are thought to have no sewage treatment systems (cesspits). Canal 3 is located adjacent to 100th Street and Canal 4 is located adjacent to 97th Street. Both Canal 3 and 4 are dead-end canals that are lined with single-family houses and mobile homes. Many of these residences are thought to have poorly functional septic systems or cesspits. The 91st Street canal has been selected as a reference canal and is located outside the Little Venice Service Area. Historic water quality and sediment data exist for this canal (FDER 1987).

Weekly Canal Sampling

Nine sampling stations were chosen for this project: two per canal (Fig. 1). Stations were located at the mouth of the canal and at the head with the exception of station 2 which was located ~100 m off the 100th Street Canal. Surface and bottom measurements of salinity, temperature (ºC), and dissolved oxygen (DO, mg l-1) were performed at each station on a weekly basis. Duplicate water samples were collected in mid-channel at 20cm below the surface. Water samples were also collected just below the surface for bacteriological analysis. To ensure that we captured the greatest potential terrestrial inputs, sampling was performed on the low, low tide whenever possible. Sampling commenced May 23, 2001 and ended Dec. 15, 2003.

Monthly Diurnal Sampling

In addition to the weekly sampling program, each month we deployed two ISCO autosamplers at rotating sites which were programmed to collect 12 samples per day over a two day period. Hydrolab datasondes accompanied the ISCO autosamplers and were programmed to measure and log temperature, salinity, DO, and pH on an hourly basis. This resulted in diurnal profiles of physical and chemical variables associated with tidal cycles and precipitation events.

LABORATORY ANALYSIS

Nutrient Analysis

Water samples were analyzed for total nitrogen (TN), total phosphorus (TP), and chlorophyll *a* (CHLA) by the SERC laboratory using standard methodology outlined in our Quality Assurance Plan. ISCO water samples were analyzed only for TN and TP. Once a month, grab samples from each site were analyzed for the full suite of nutrients including ammonium (NH_4^+), nitrate + nitrite (NO_x^-), nitrite (NO_2^-), silicate ($Si(OH)_4$), soluble reactive phosphate (SRP), and total organic carbon (TOC). Some parameters were not measured directly, but calculated by difference. Nitrate (NO_3^-) was calculated as NO_x^- - NO_2^-, dissolved inorganic nitrogen (DIN) was calculated as NO_x^- + NH_4^+, and total organic nitrogen (TON) was defined as TN - DIN.

Bacteriological Analysis

Water samples were collected as above and transported to SYNAGRO for enumeration of fecal coliform (SM 9222D) and enterococci (EPA 1600). All samples were kept at 4 ºC and tested within 6 hours of sampling. The SYANGRO lab is NELAC certified by the Florida Department of Health.

DATA ANALYSIS

Data distributions of water quality variables are reported as box-and-whiskers plots. The box-and-whisker plot is a powerful statistic as it shows the median, range, the data distribution as well as serving as a graphical, nonparametric ANOVA. The center horizontal line of the box is the median of the data, the top and bottom of the box are the 25th and 75th percentiles (quartiles), and the ends of the whiskers are the 5th and 95th percentiles. The notch in the box is the 95% confidence interval of the median. When notches between boxes do not overlap, the medians are considered significantly different. Outliers (<5th and >95th percentiles) were sometimes excluded from the graphs in order to reduce visual compression. Differences in variables were also tested between groups using the Wilcoxon Ranked Sign test (comparable to the *t*-test) and among groups by the Kruskall-Wallace test (ANOVA) with significance set at $P<0.05$.

RESULTS AND DISCUSSION

Figures 2-10 show weekly bacterial numbers for the canal stations from May 23, 2001 to Dec. 15, 2003. The Florida state standard for single counts of fecal coliforms in bathing waters is 800 counts/100ml while the EPA recommended standard for enterococci is 104 counts/100ml. Fecal coliform counts exceeded the Florida state standard 5 times over the period of record, while enterococci counts exceeded EPA recommended standards 60 times. Enterococci are a subgroup of fecal streptococci, which are bacteria primarily found in the gut of warm-blooded animals. They have the ability to survive in salt water and closely mimic survival of pathogens in recreational environments while also being closely related to recreational water contaminants. As such, they are better indicators of sewage than fecal coliforms. Grouping fecal coliform and enterococci counts by month showed a small seasonal signal (Fig. 11), however it was not statistically significant ($P>0.05$). The head of the canals had significantly greater bacterial numbers than the mouth (Fig.12) as would be expected because of tidal mixing with cleaner offshore waters.

Figures 13-21 show time series of TN, TP, CHLA, salinity, and DO at all stations. The State of Florida Rule 62-302.530, for Class II marine waters specifies that DO "shall never be less than 4.0" mg l^{-1}. For the period of record there were 631 surface DO and 708 bottom DO measurements below the State standard. As to nutrient criteria, there is no accepted state standard for Florida marine waters. However, State of Florida Rule 62-02.300(13), F.A.C. states that "particular consideration shall be given to the protection from nutrient enrichment of those presently containing very low nutrient concentrations: less than 0.3 milligrams per liter total nitrogen or less than 0.04 milligrams per liter total phosphorus." Therefore, these benchmarks included in the TN and TP graphs are for illustrative purposes only. For the period of record there were 657 TN measurements and 18 TP values above these benchmarks.

Figures 22-30 show time series of dissolved nutrients (NO_2, NO_3, NH_4, DIN, SRP, and $Si(OH)_4$) and TOC collected monthly. The heads of the canals generally have the highest TN, TP, CHLA (Fig. 31) and DIN (Fig. 32) and lowest DO (Fig. 33). This implies that the canals are a source of nutrient to offshore waters.

Results of monthly diurnal sampling events are shown in Figures 34-61. The ISCO samplers were programmed to collect a sample every 4 hours for two days. The shaded bar at the bottom of the graph denoted night time sampling. The arrows at the top of the graph denote tidal stage. A couple points are abundantly obvious from these data. First, TN is highest during low tides when the groundwater is draining back into the canals. Second, TP, salinity, and temperature do not fluctuate with tidal regime. Third, DO is light driven rather than tidally influenced. Very low DO levels occur in the canals (<2 mg l^{-1}) and may persist for 6-7 hours.

SUMMARY

The canals of Little Venice subdivision are impacted by landuse and the associated septic treatment systems as well as by their physical design. The presence of enterococci above the EPA recommended level is a relatively robust indicator of sewage input to the canals. In addition, elevated TN levels in the head of the canals and during low tide indicates that the canals are a source of TN to the offshore waters. Whether this is due to sewage input alone is debatable because dead-end canals typically accumulate sediments and seagrass wrack which is decomposed in situ. This degradation of organic matter is important in driving down DO levels as is the physical nature of canals having increased water residence time. Low DO levels are alleviated during the day by phytoplankton primary production, driven by high inorganic nutrient inputs, but are exacerbated by phytoplankton respiration at night. Thus, the vicious cycle of production, decomposition, and DO depletion is maintained.

ACKNOWLEDGEMENTS

We thank all the field and laboratory technicians involved with this project. This project was possible due to continued funding by the US-EPA (Agreement #X994621-94-0) and Monroe County. This is Technical Report #T-218 of the Southeast Environmental Research Center at Florida International University.

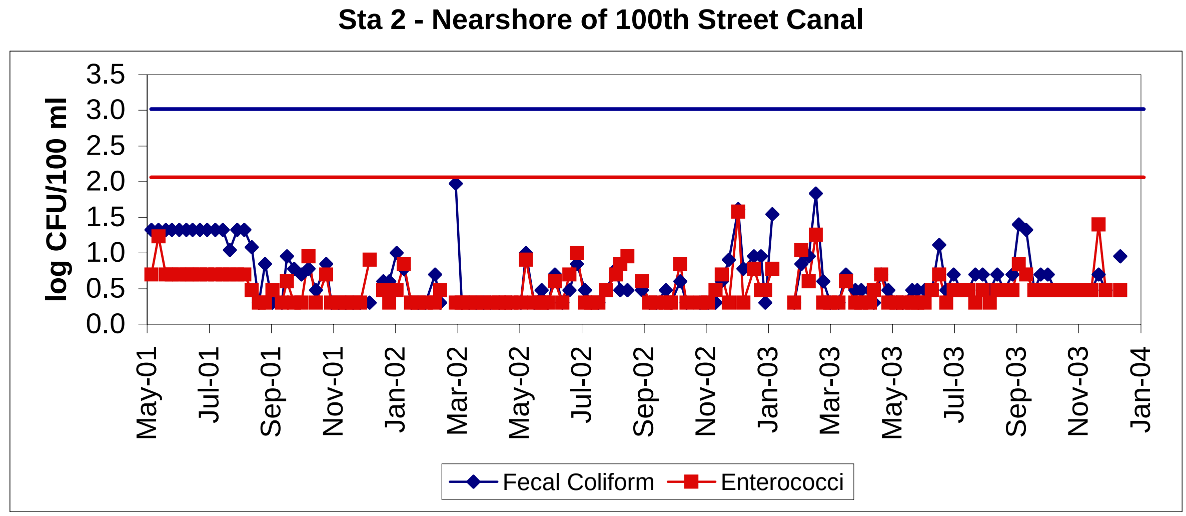
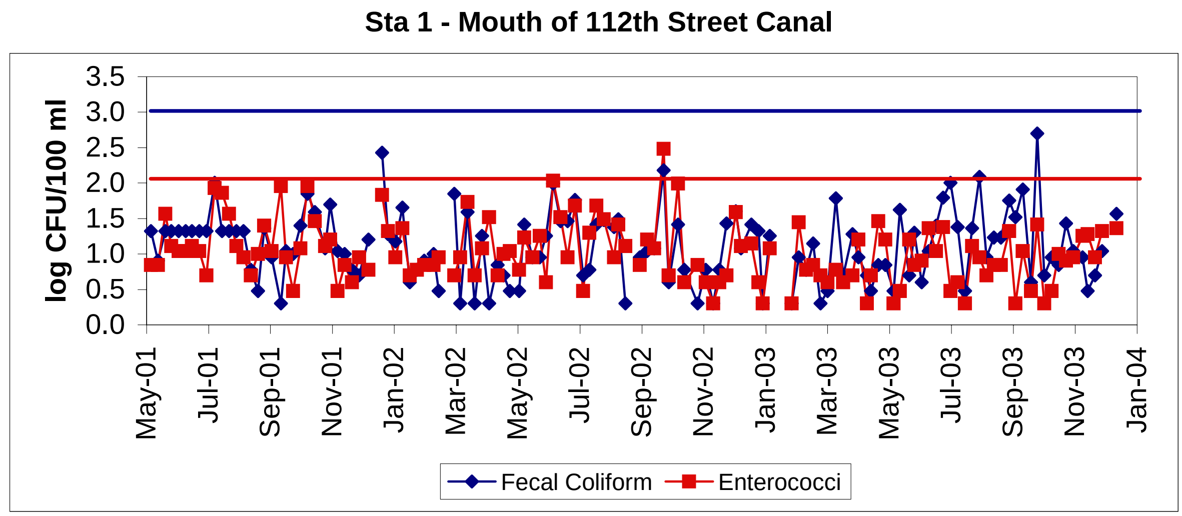


Figure 2



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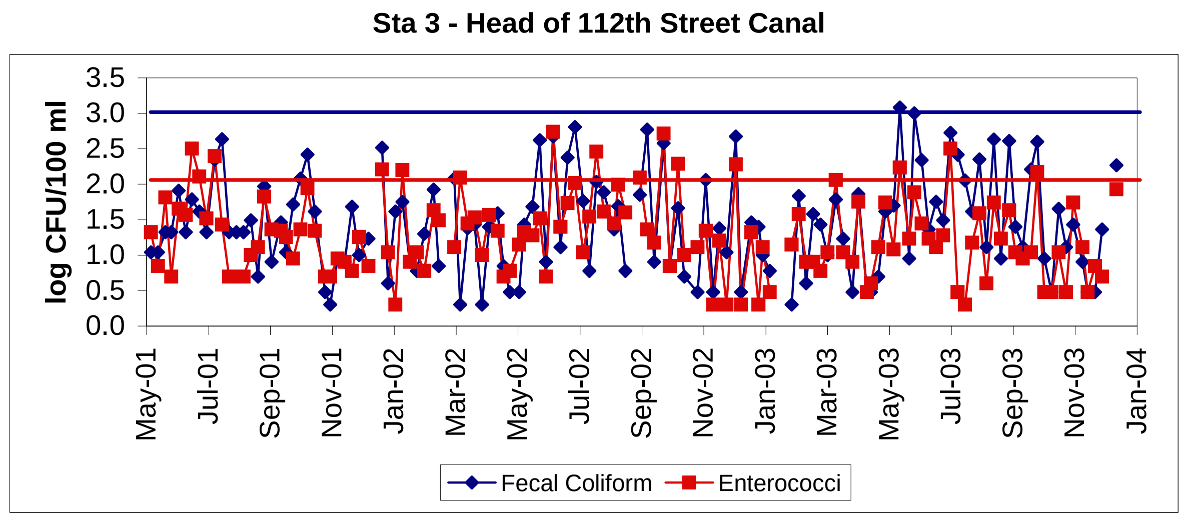


Figure 4

Sta 4 - Mouth of 100th Street Canal

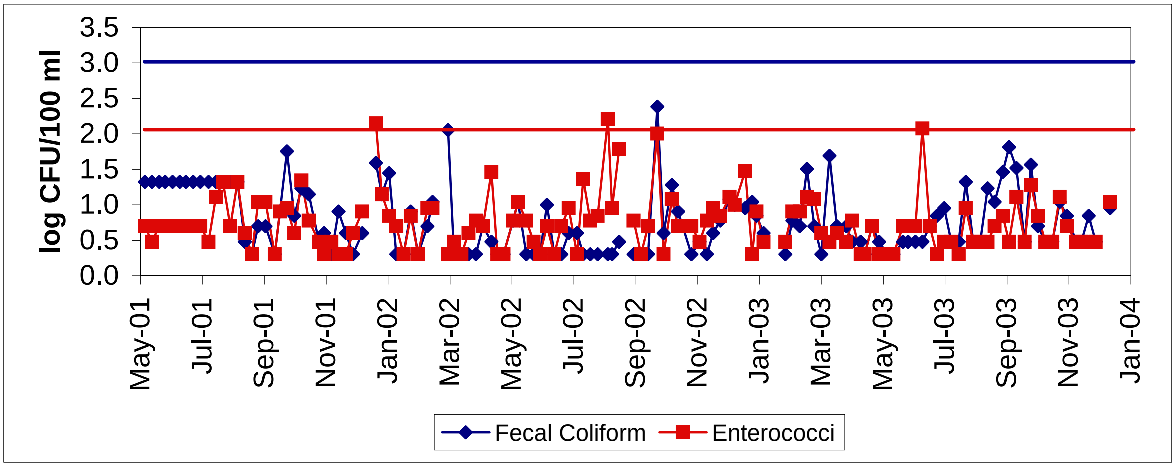


Figure 5

Sta 5 - Head of 100th Street Canal

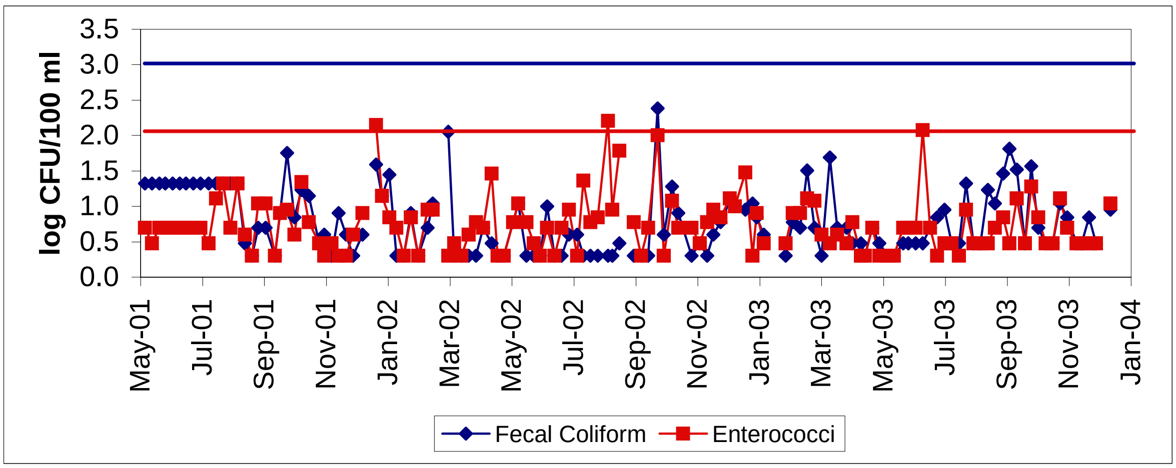
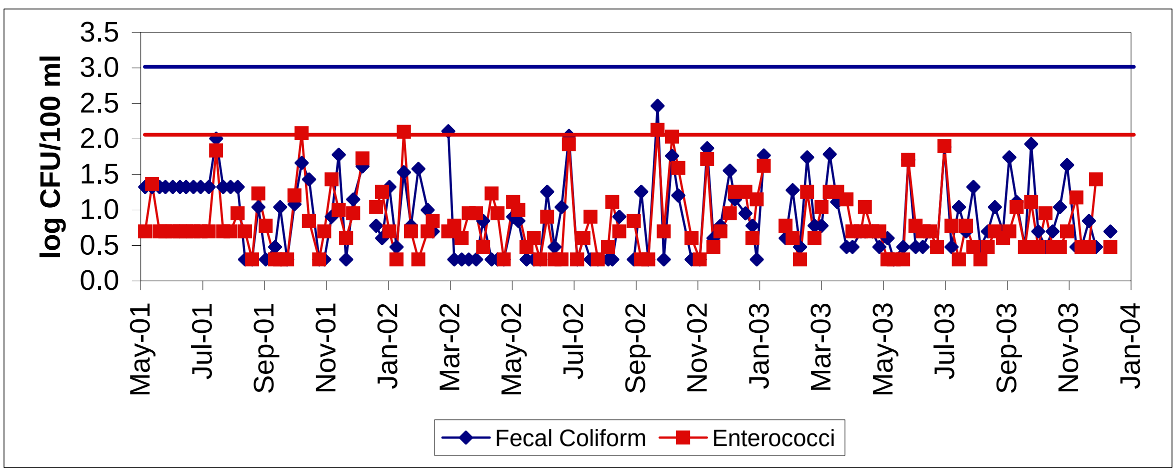


Figure 6

Sta 6 - Mouth of 97th Street Canal



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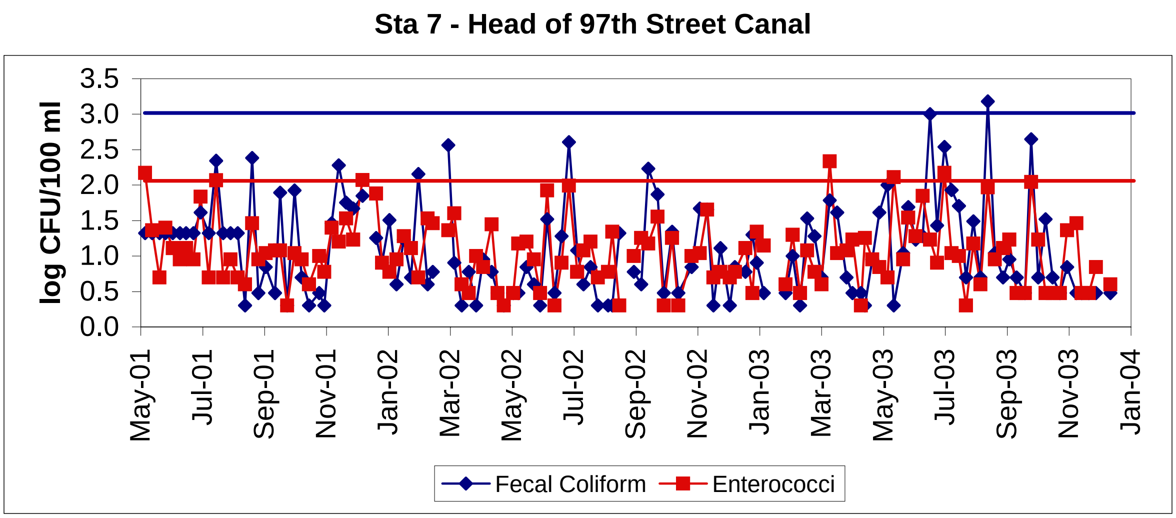

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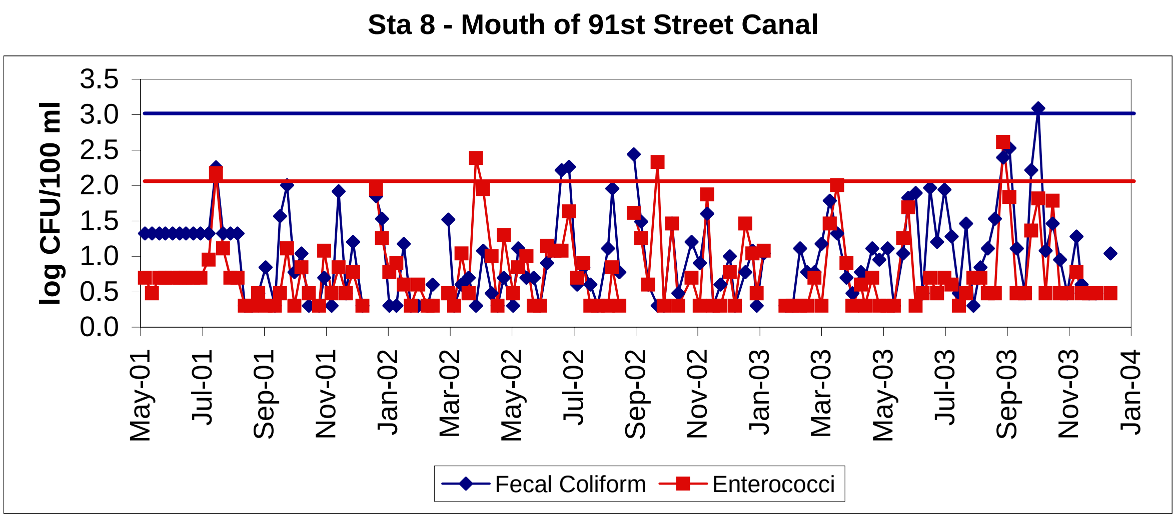

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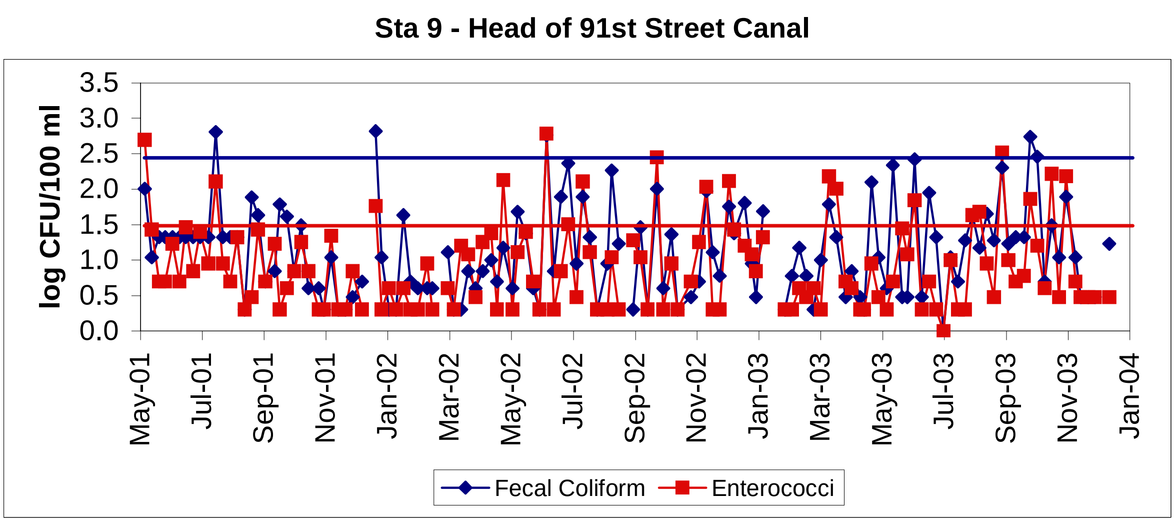

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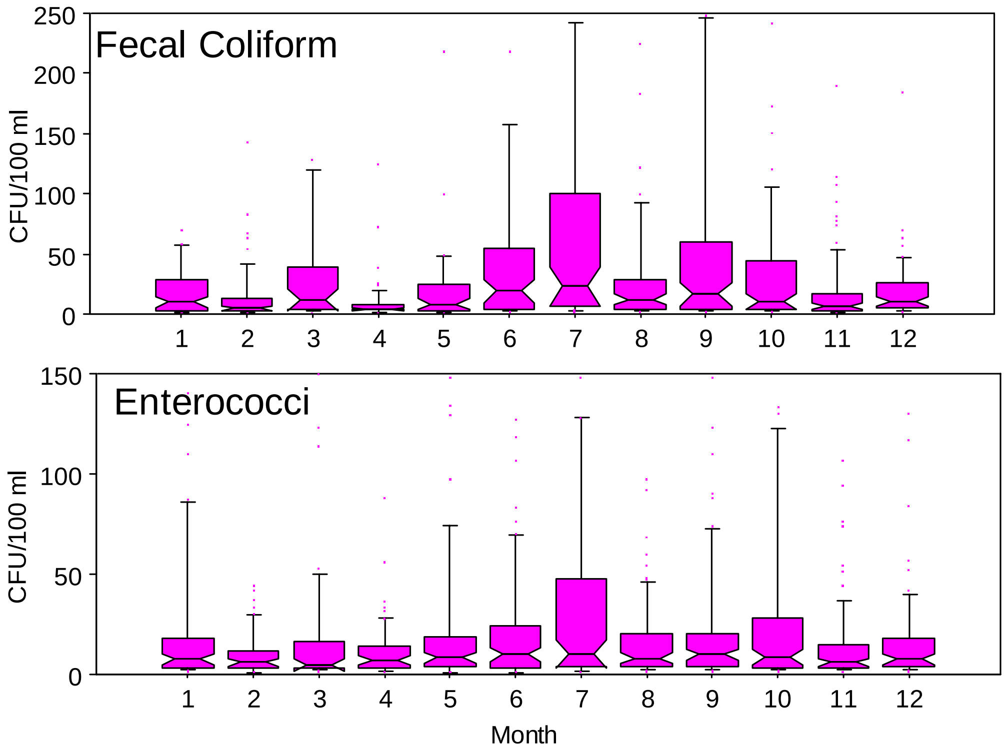


Figure 11. Box-and-whisker plots of bacterial numbers for all sampling sites grouped by month.

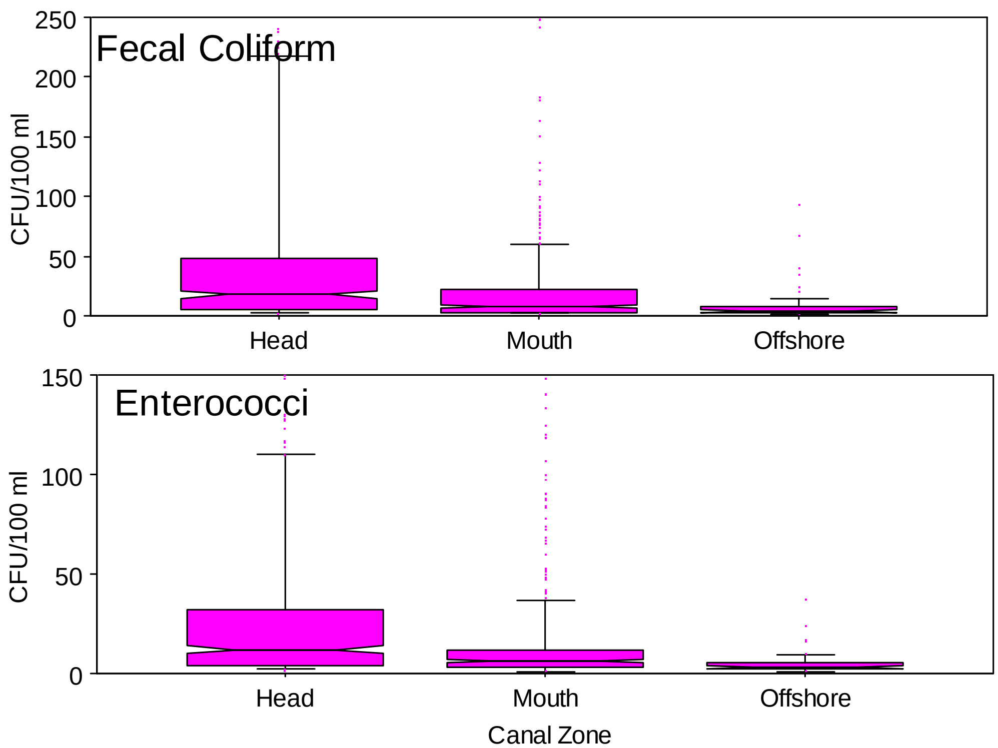


Figure 12. Box-and-whisker plots of bacterial numbers for all sampling sites grouped by canal zone.

Sta. 2 - Nearshore of 100th Street Canal

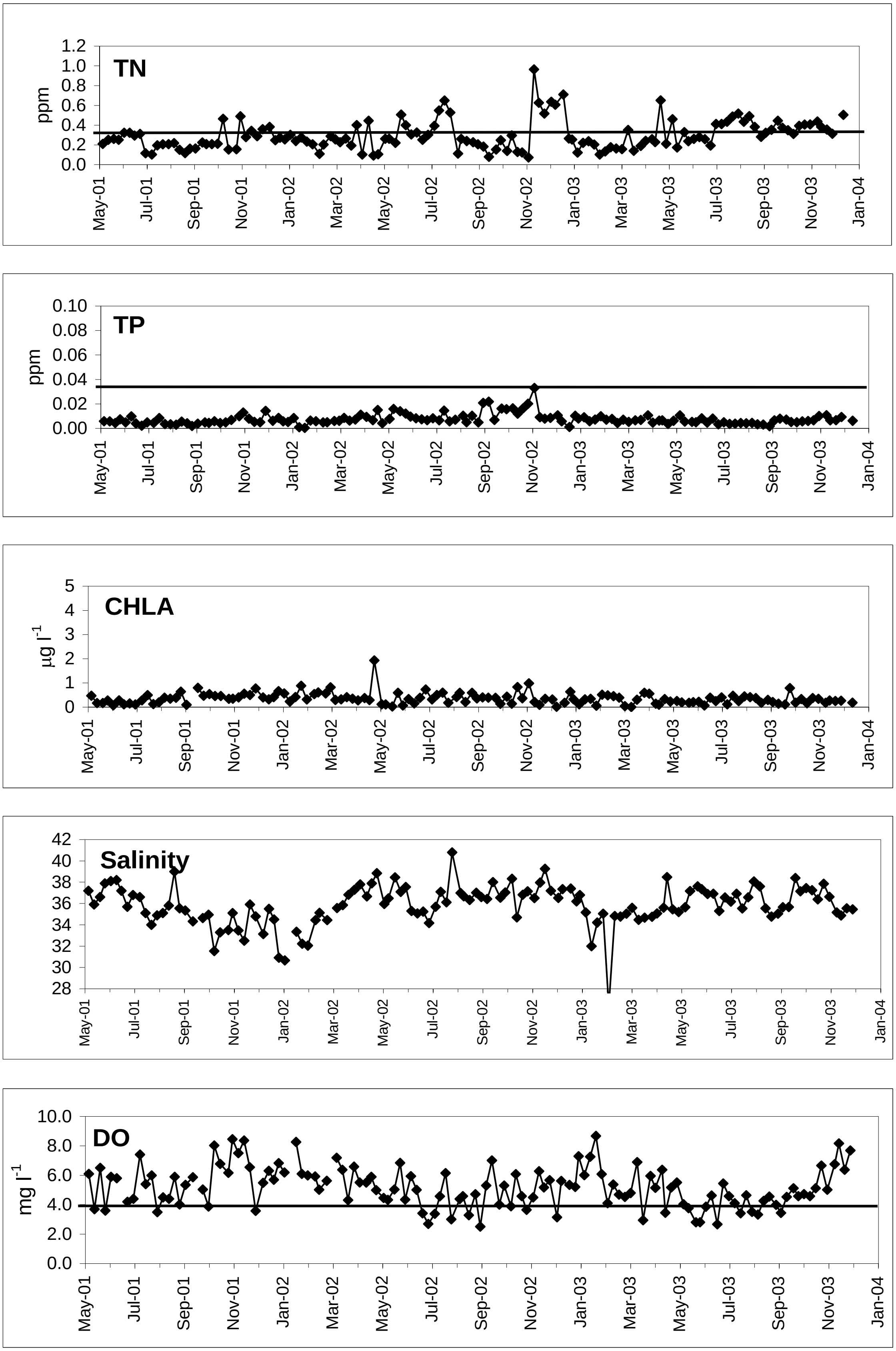


Figure 13

Sta. 1 - Mouth of 112th Street Canal

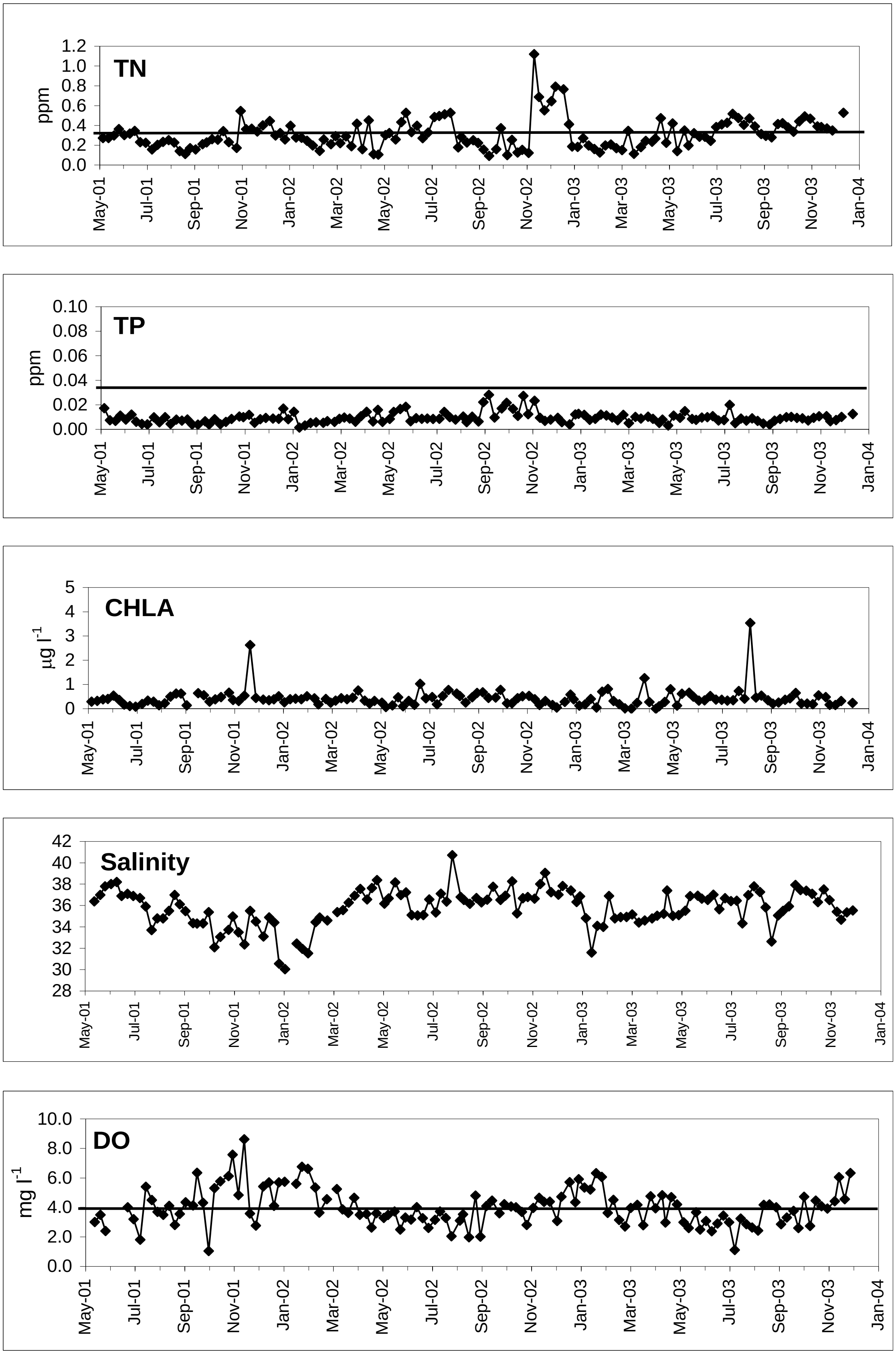


Figure 14

Sta. 3 - Head of 112th Street Canal

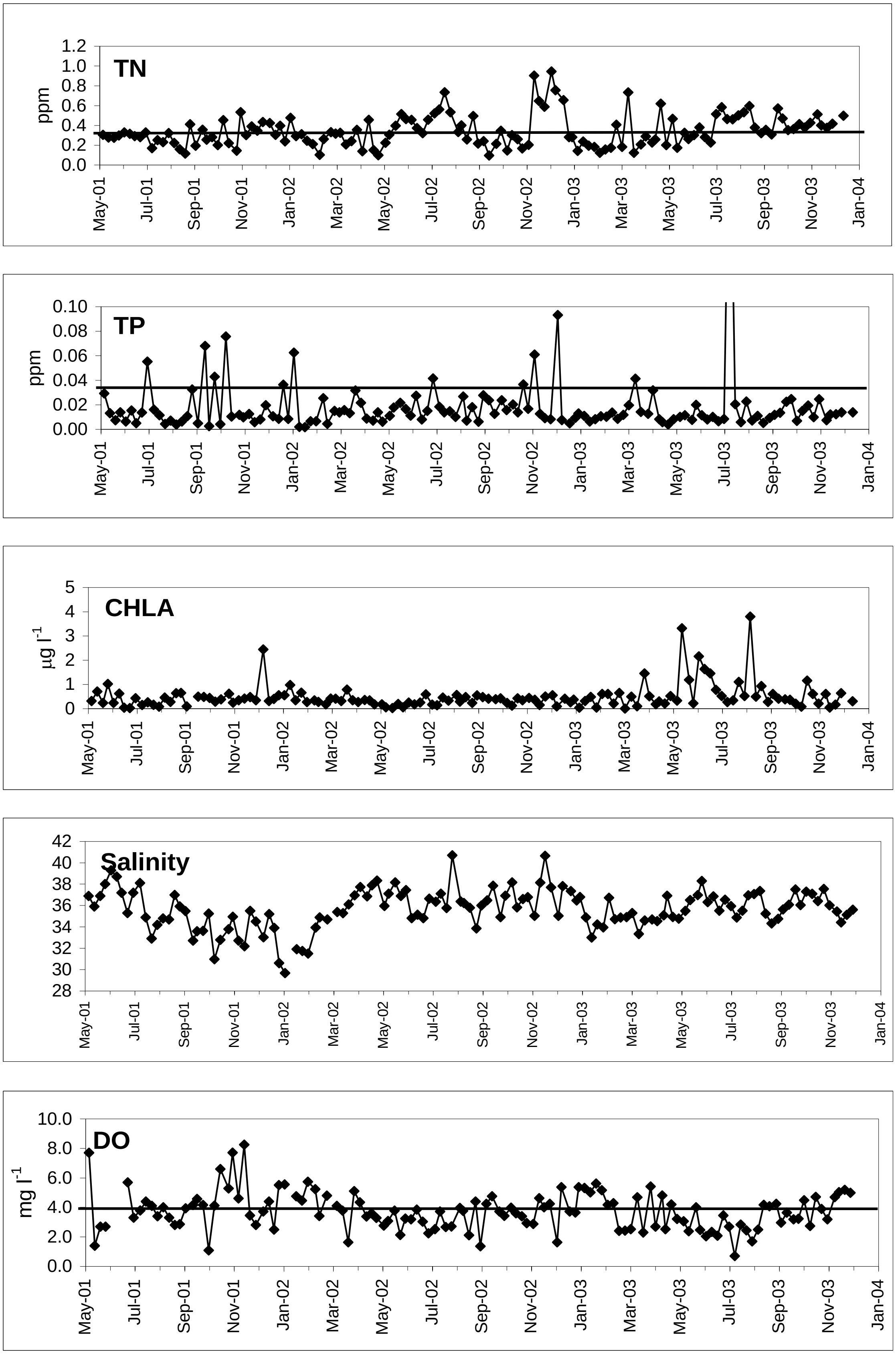


Figure 15

Sta. 4 - Mouth of the 100th Street Canal

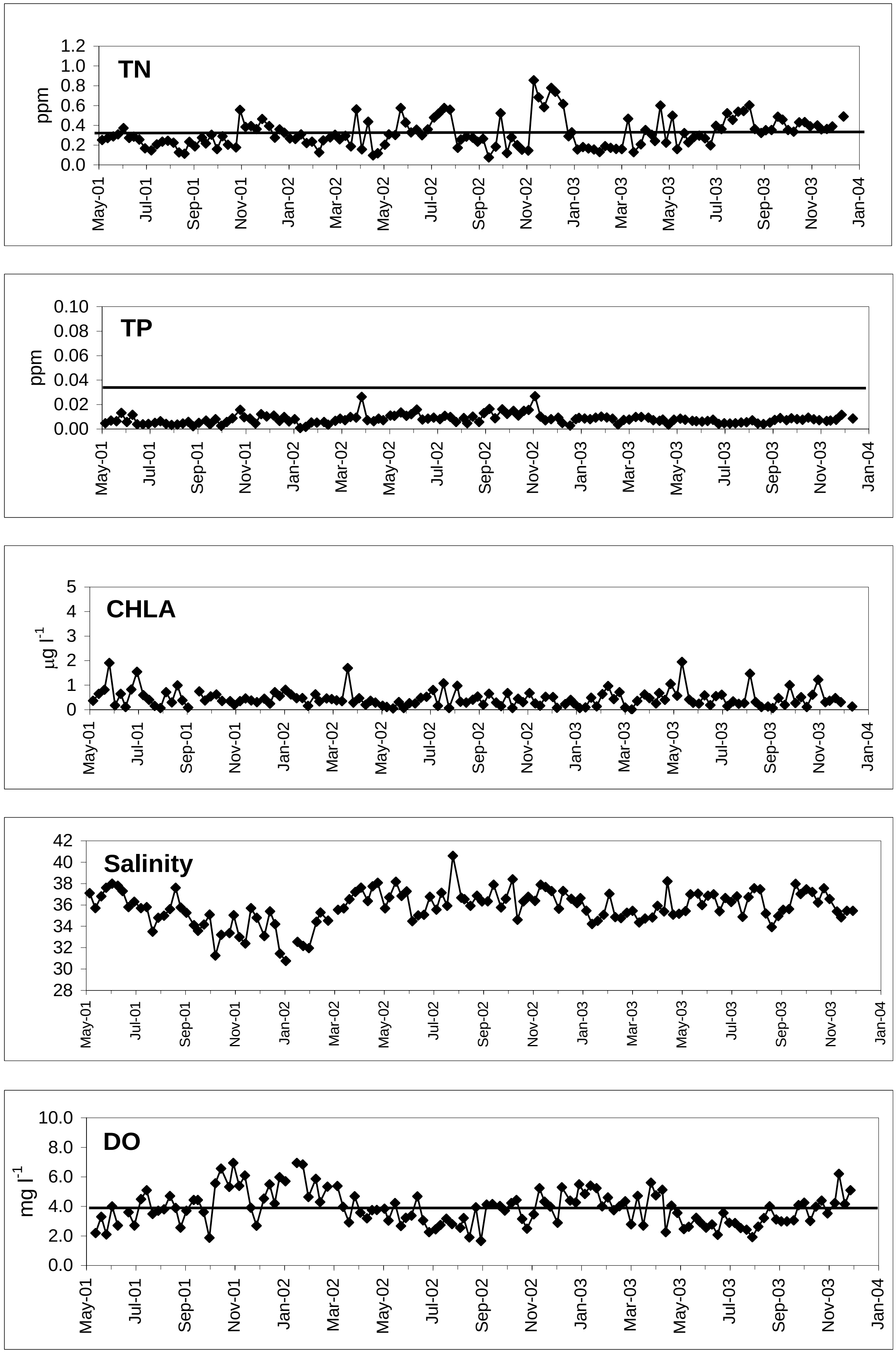


Figure 16

Sta. 5 - Head of the100th Street Canal

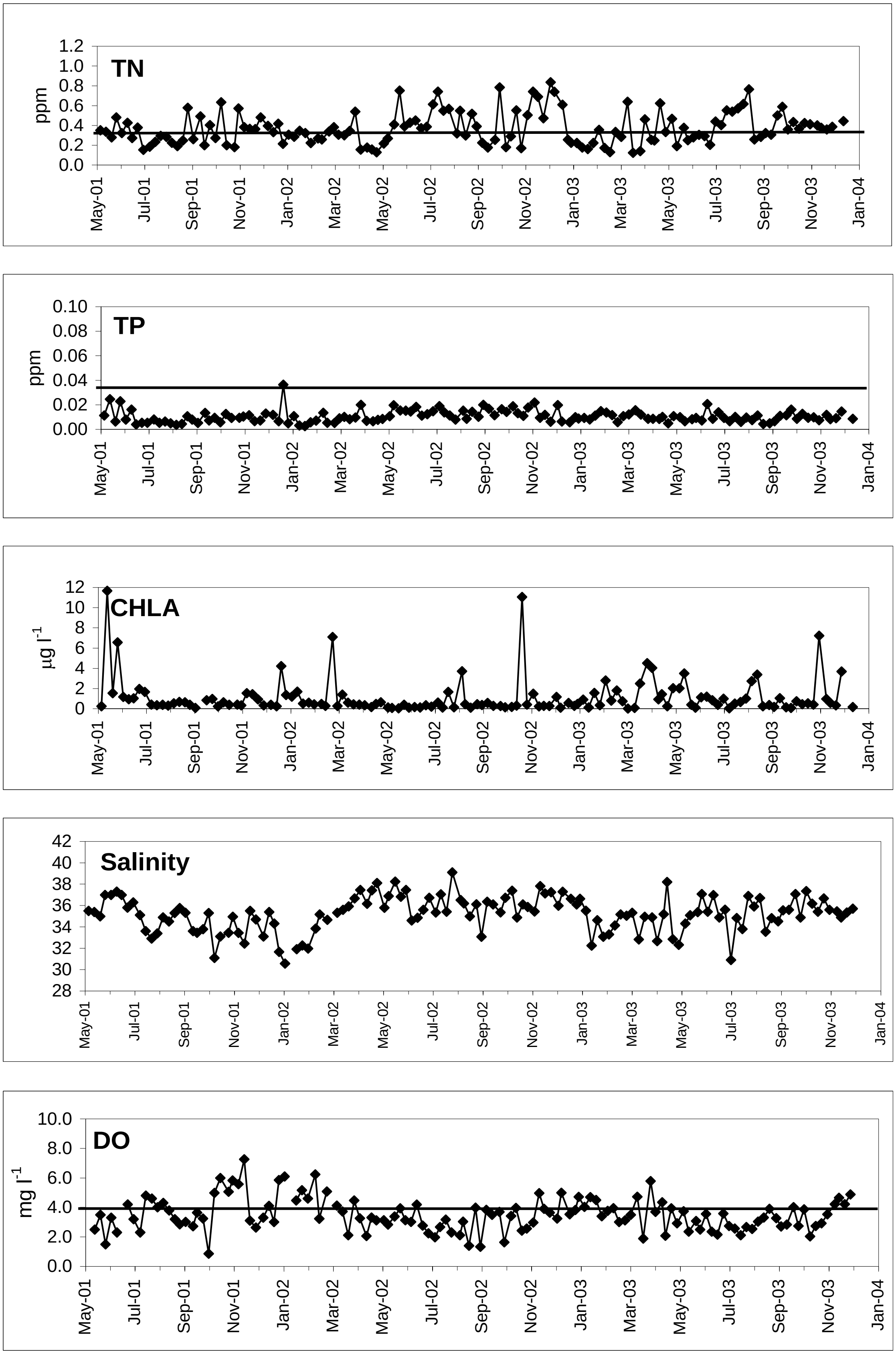
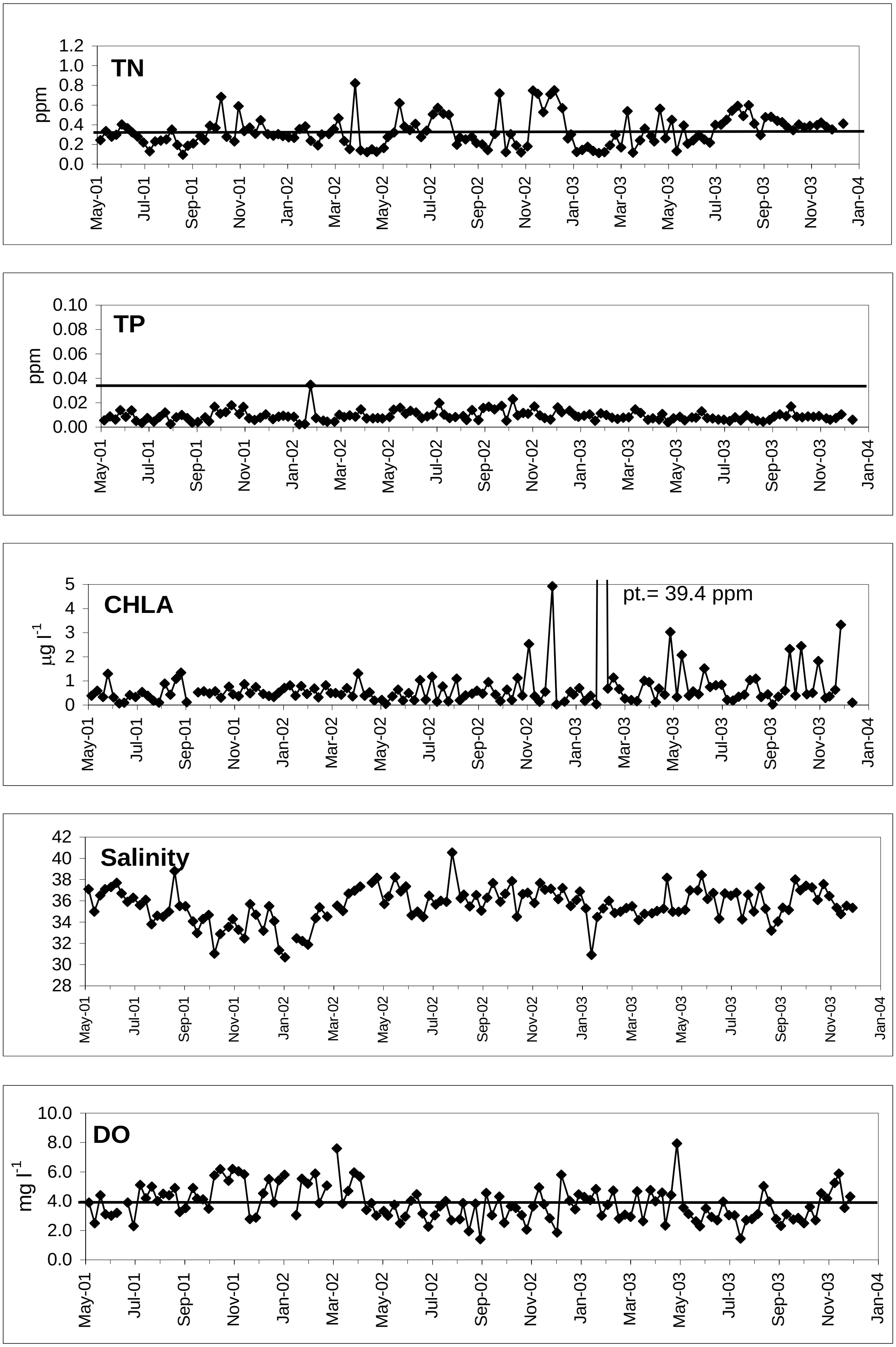


Figure 17

Sta. 6 - Mouth of the 97th Street Canal



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Sta. 7 - Head of the 97th Street Canal

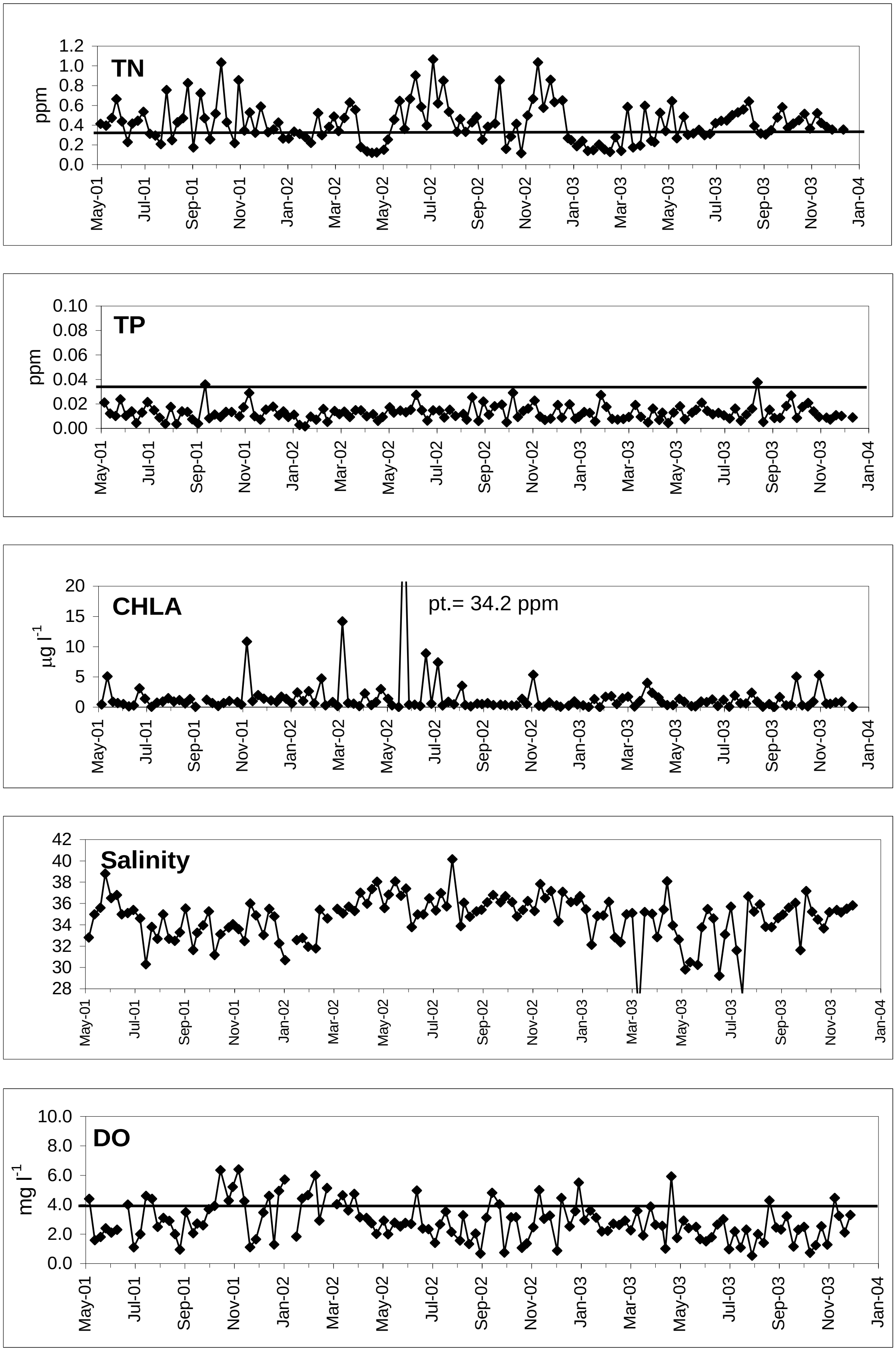


Figure 19

Sta. 8 - Mouth of the 91st Street Canal

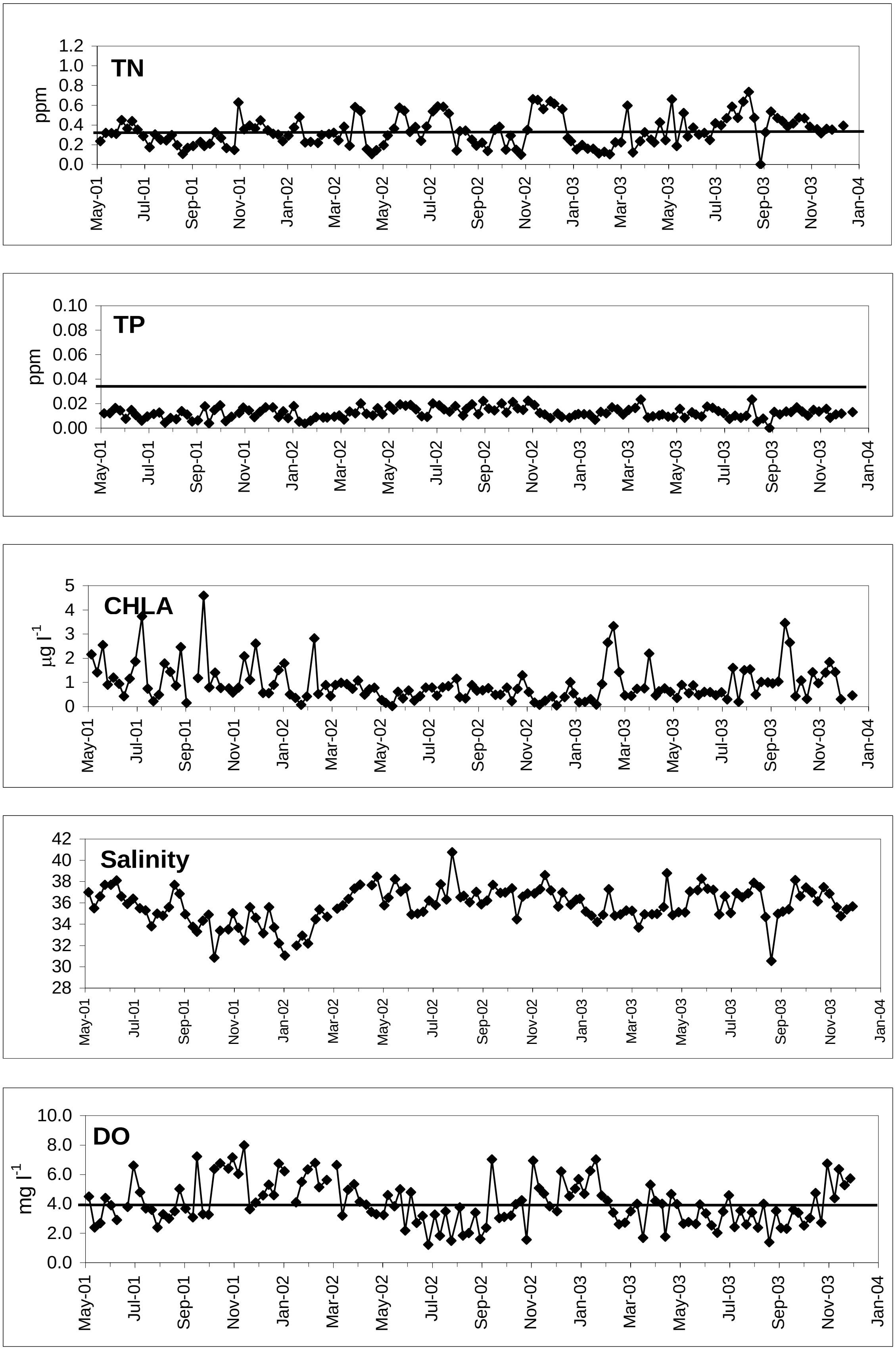


Figure 20

Sta. 9 - Head of the 91st Street Canal

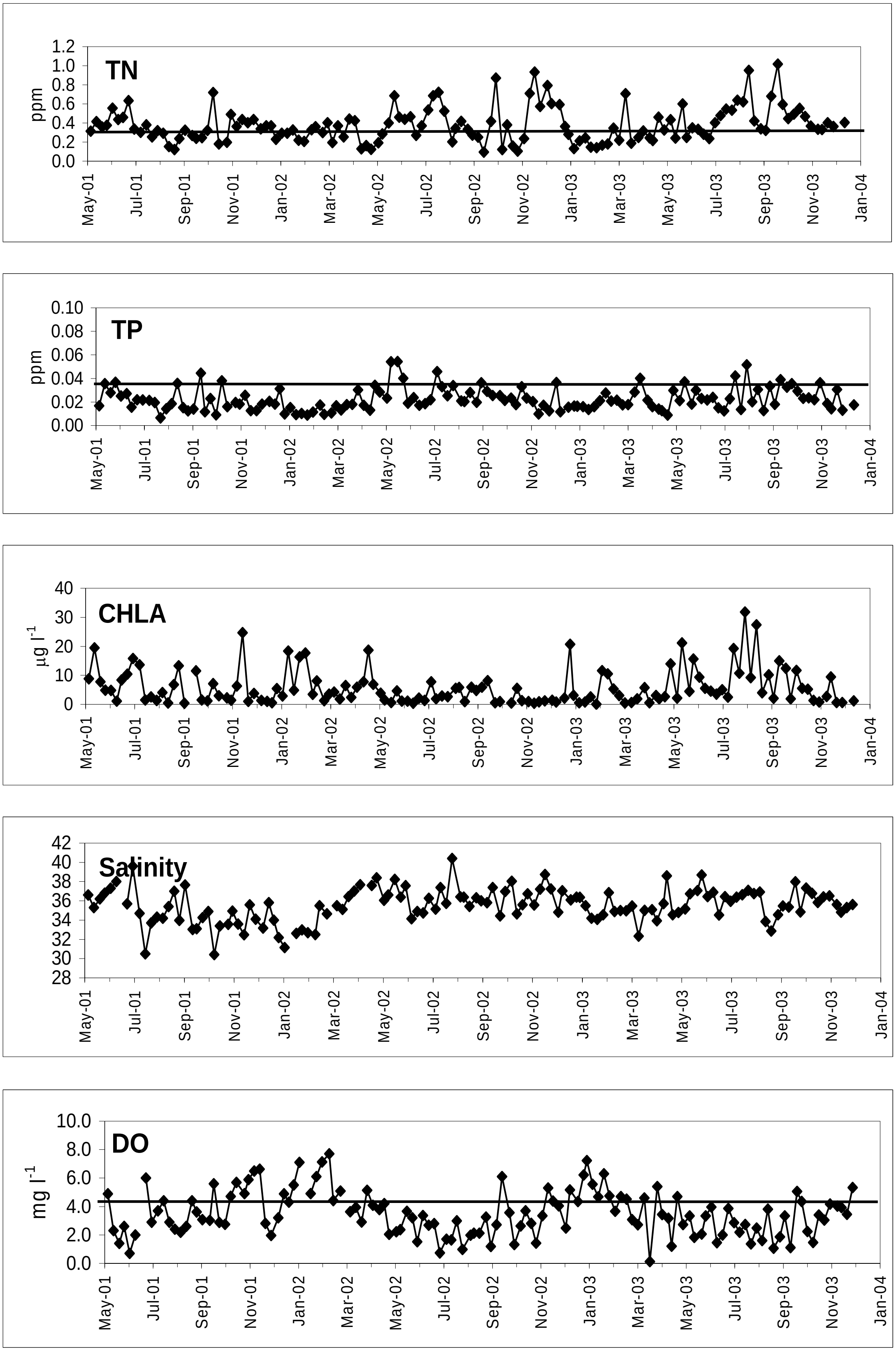


Figure 21

Sta. 2 -Nearshore of 100th Street Canal

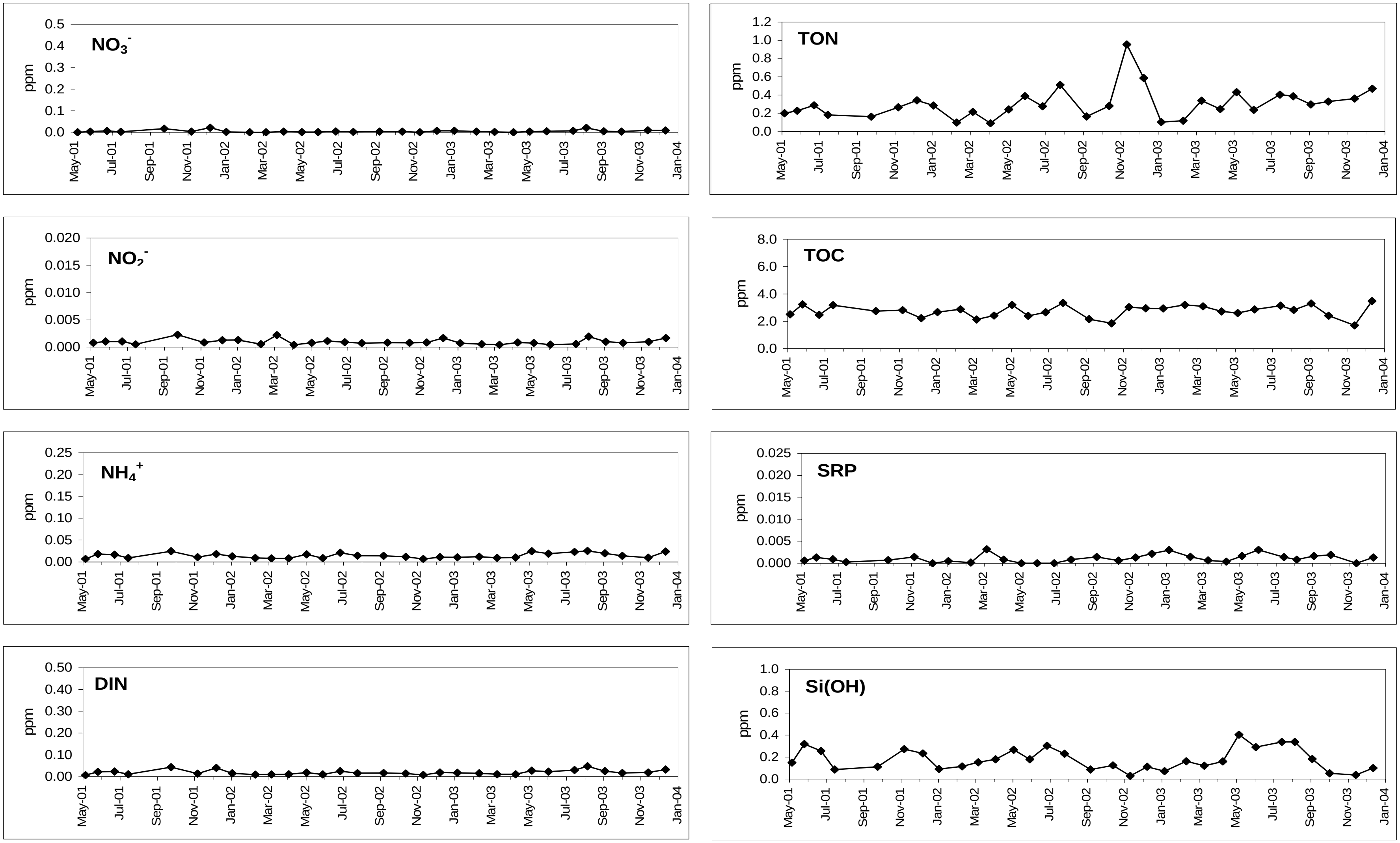


Figure 220

Sta. 1 - Mouth of 112th Street Canal

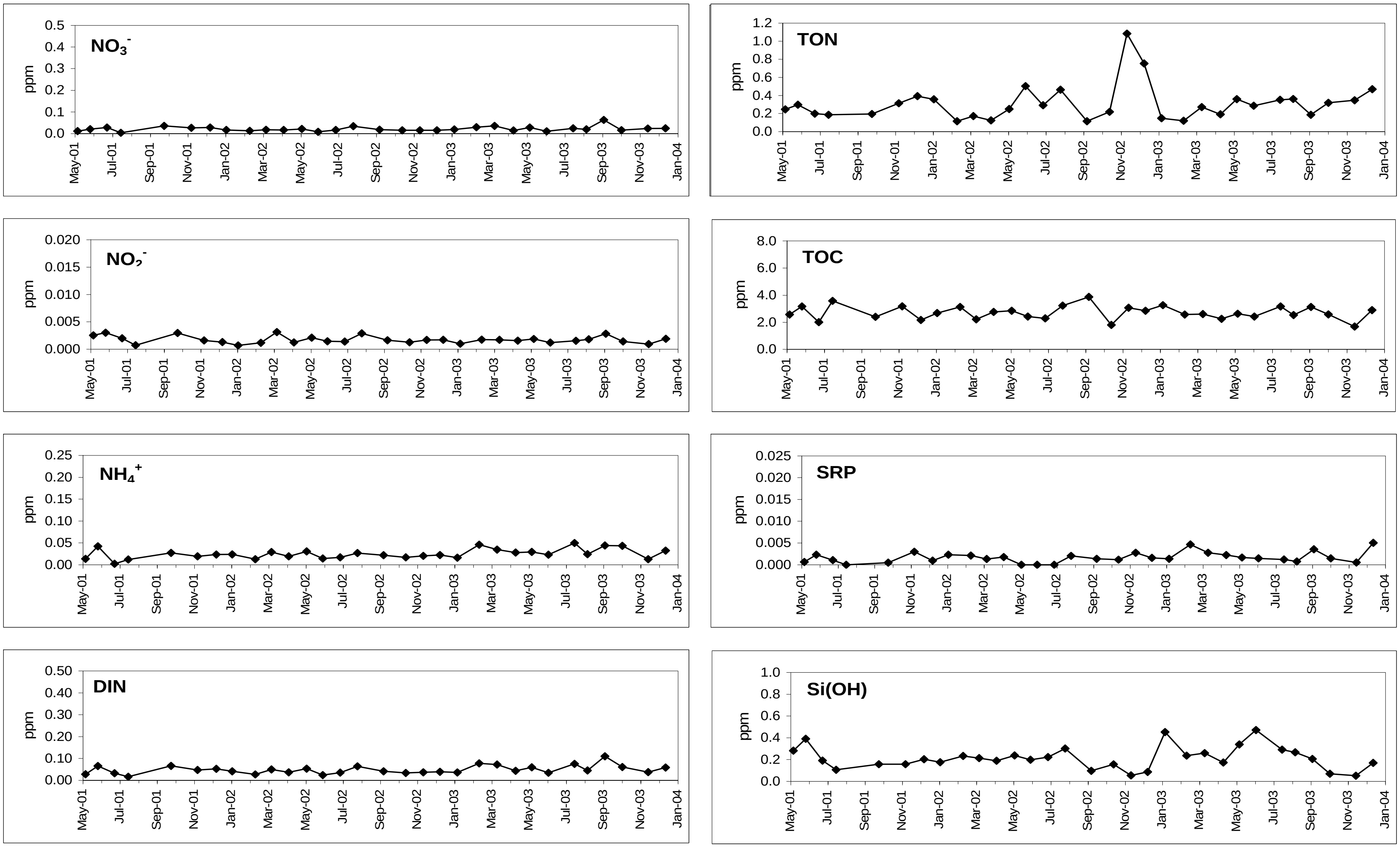


Figure 23

Sta. 3 - Head of 112th Street Canal

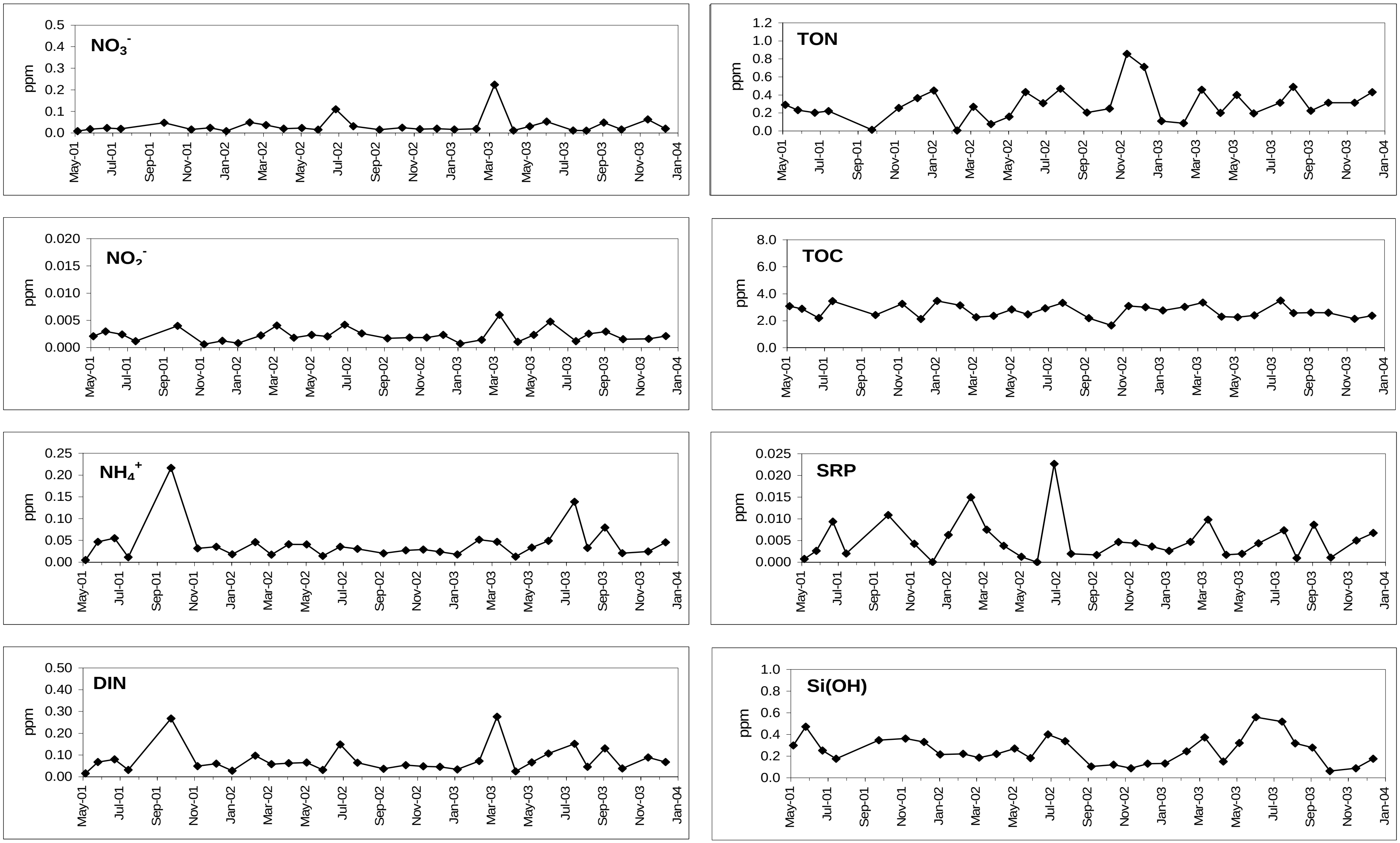


Figure 24

Sta. 4 - Mouth of 100th Street Canal

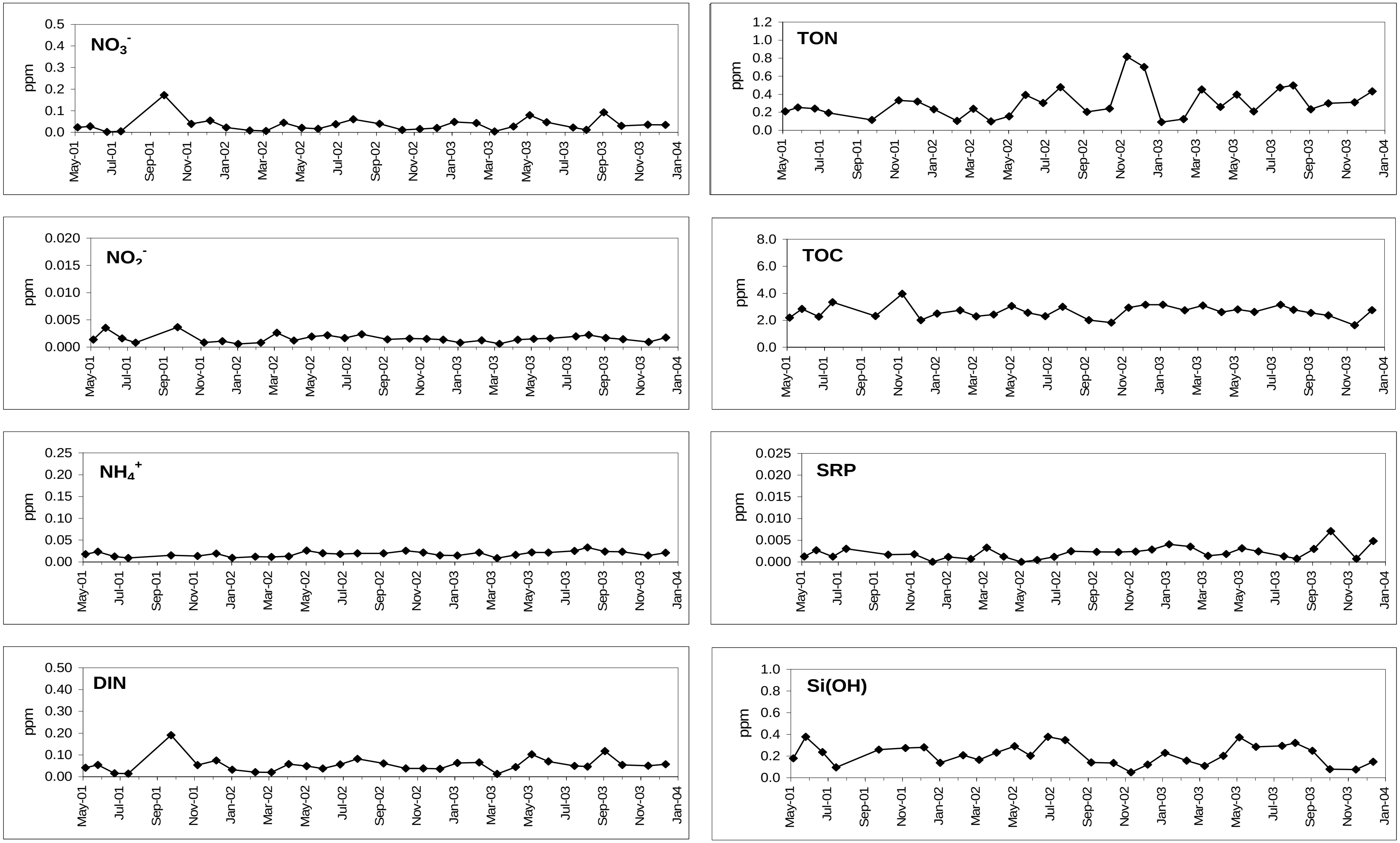
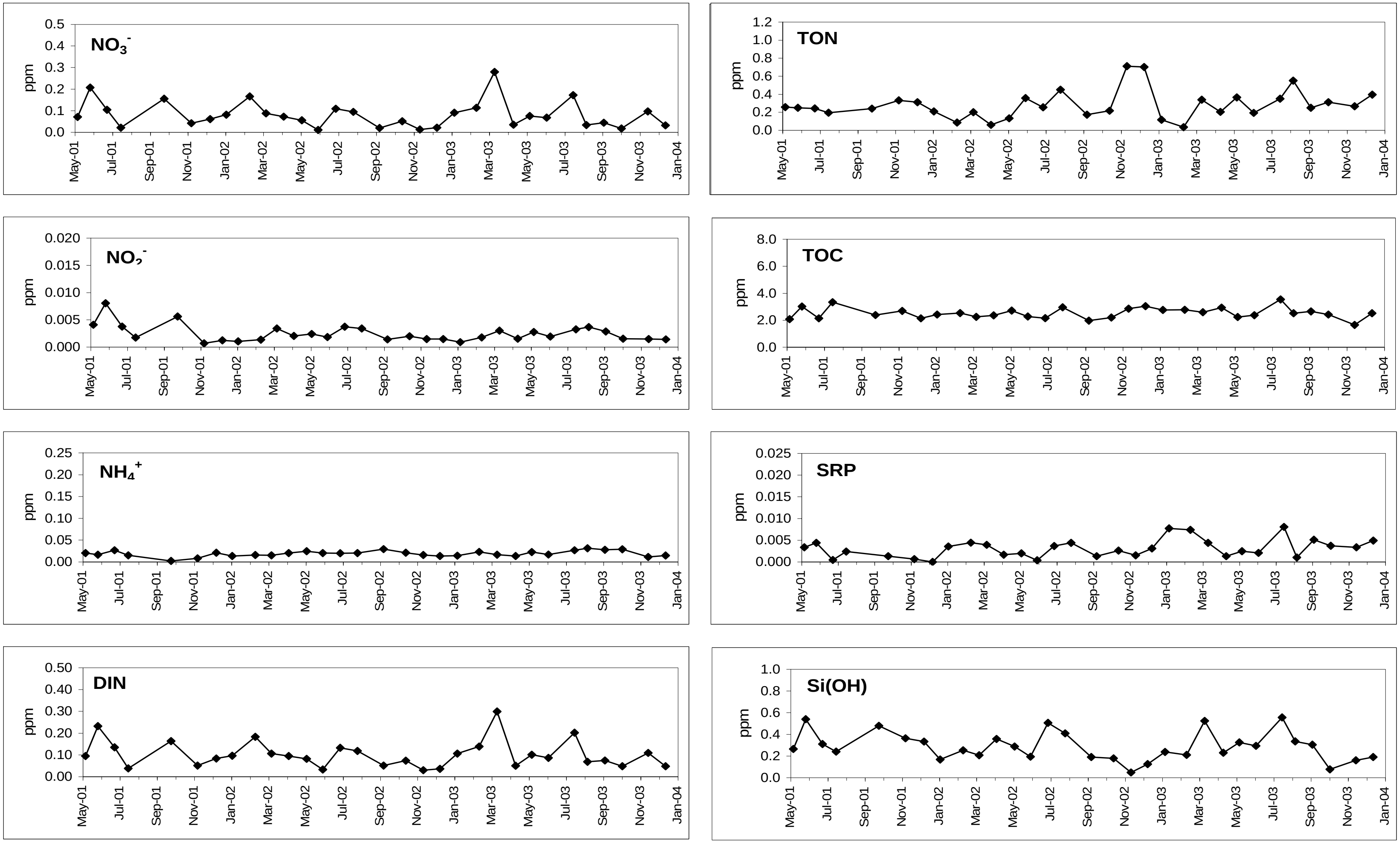


Figure 25

Sta. 5 - Head of 100th Street Canal



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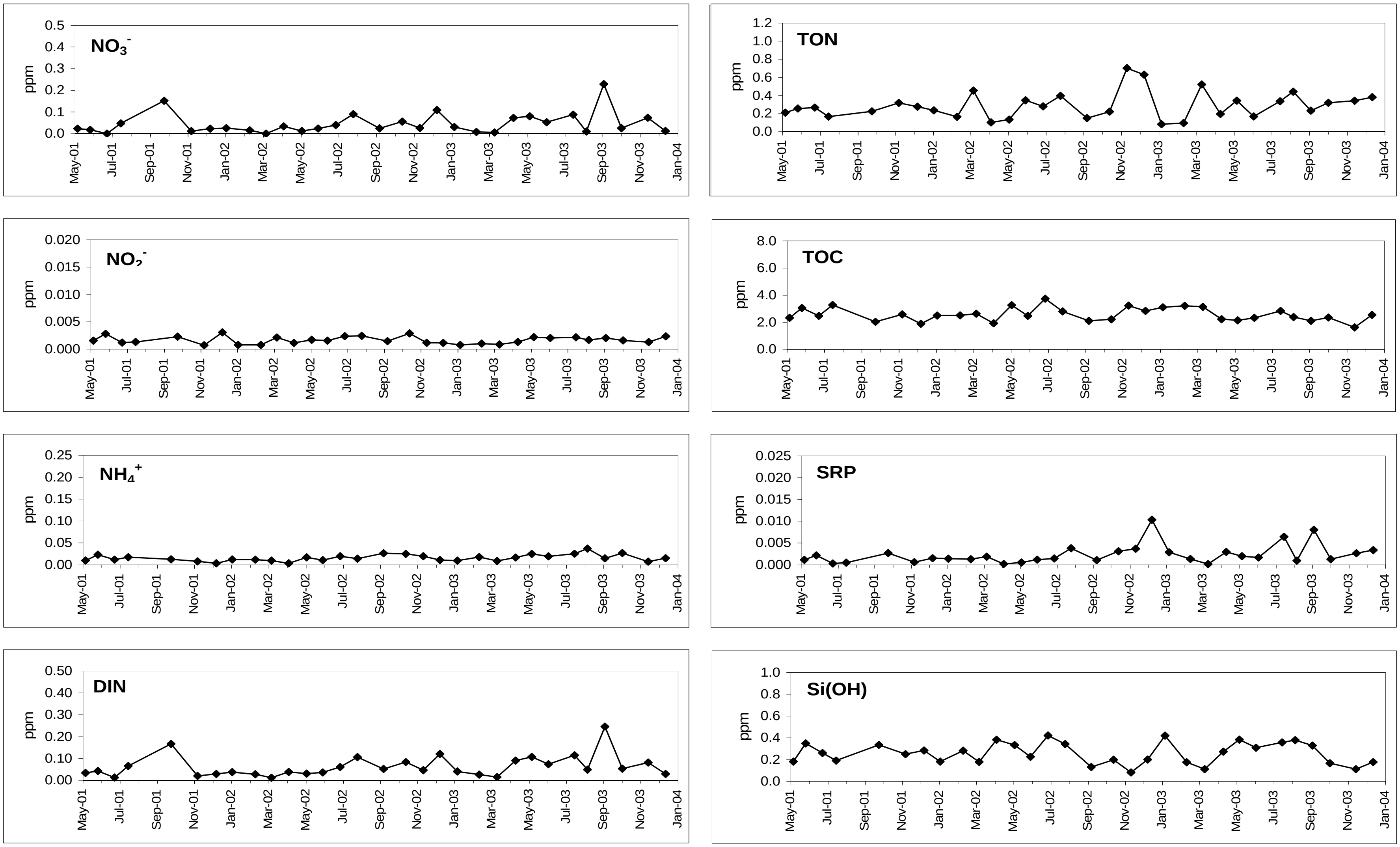
Sta. 6 - Mouth of 97th Street Canal



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Sta. 7 - Head of 97th Street Canal

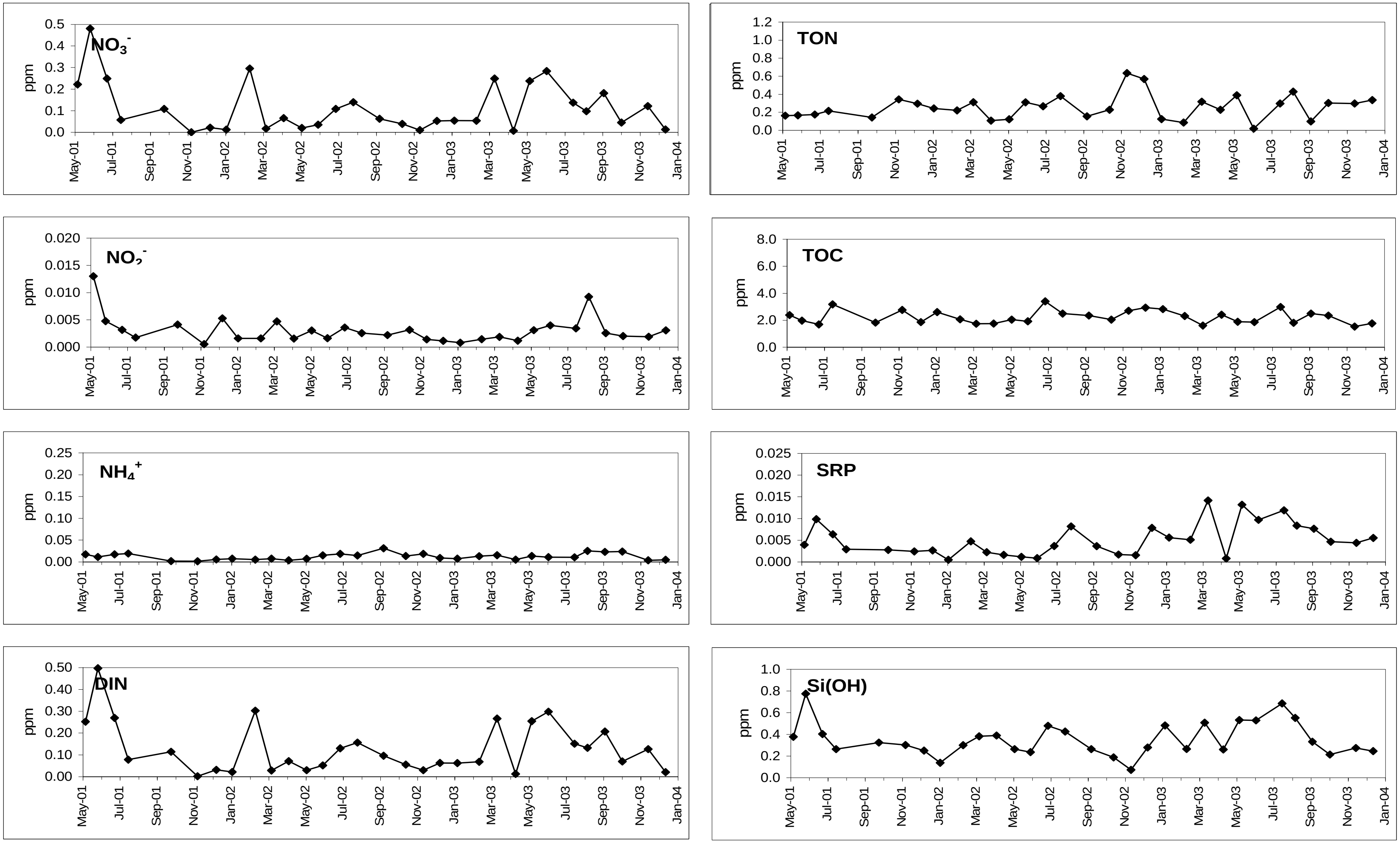


Figure 28

Sta. 8 - Mouth of 91st Street Canal

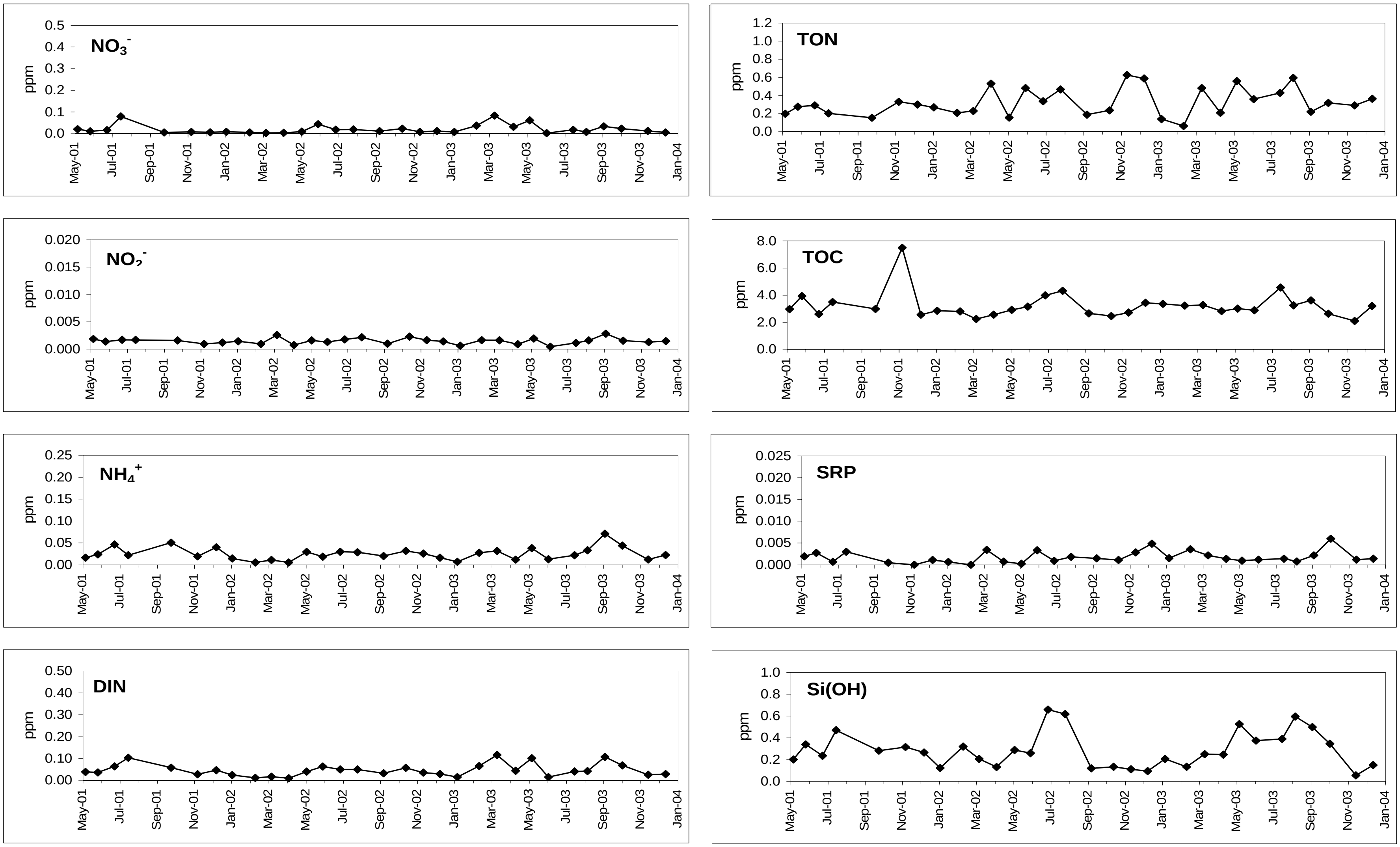


Figure 29

Sta. 9 - Head of 91st Street Canal

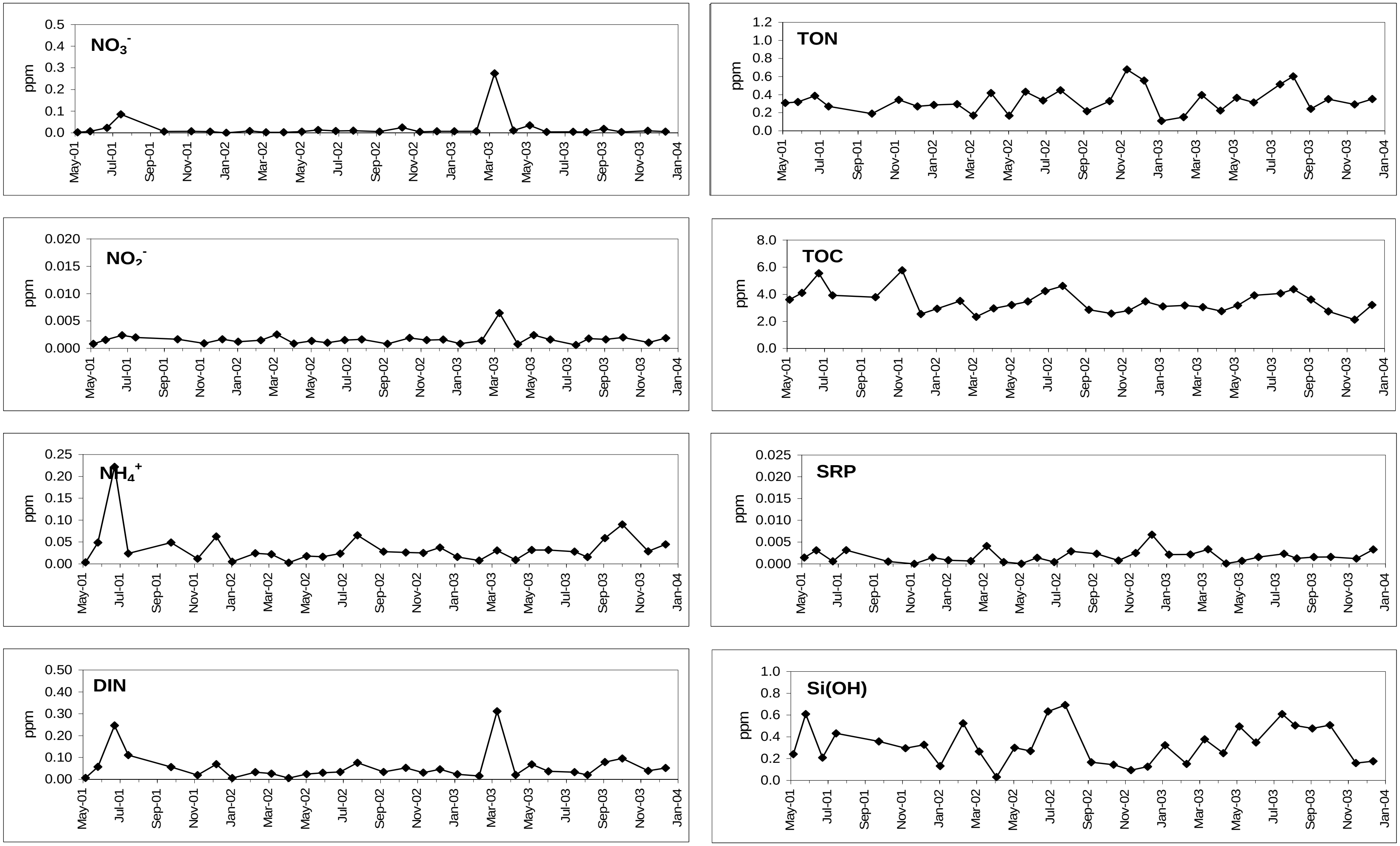
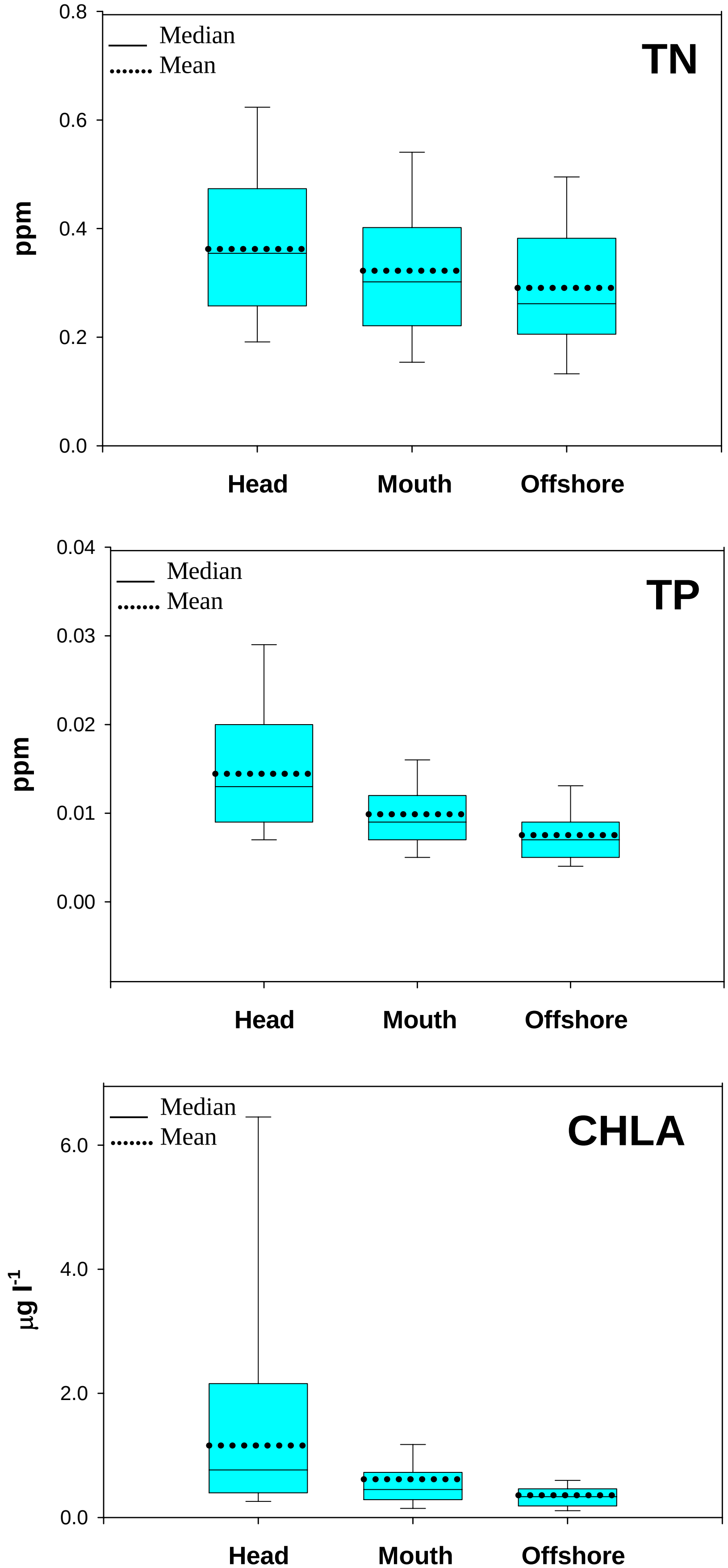


Figure 30



Median
Mean
TN
ppm
0.0
0.2
0.4
0.6
0.8
Head
Mouth
Offshore
Median
Mean
TP
ppm
0.00
0.01
0.02
0.03
0.04
Head
Mouth
Offshore
Median
Mean
CHLA
µg l-1
0.0
2.0
4.0
6.0
Head
Mouth
Offshore

Figure 31

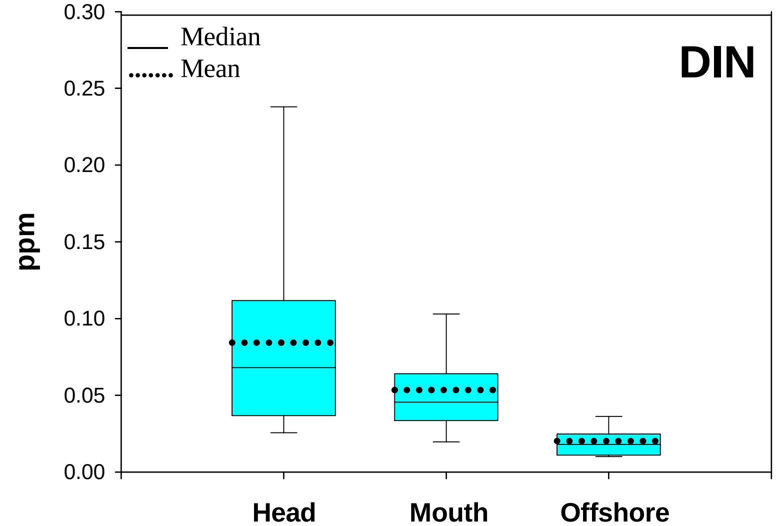


Figure 32

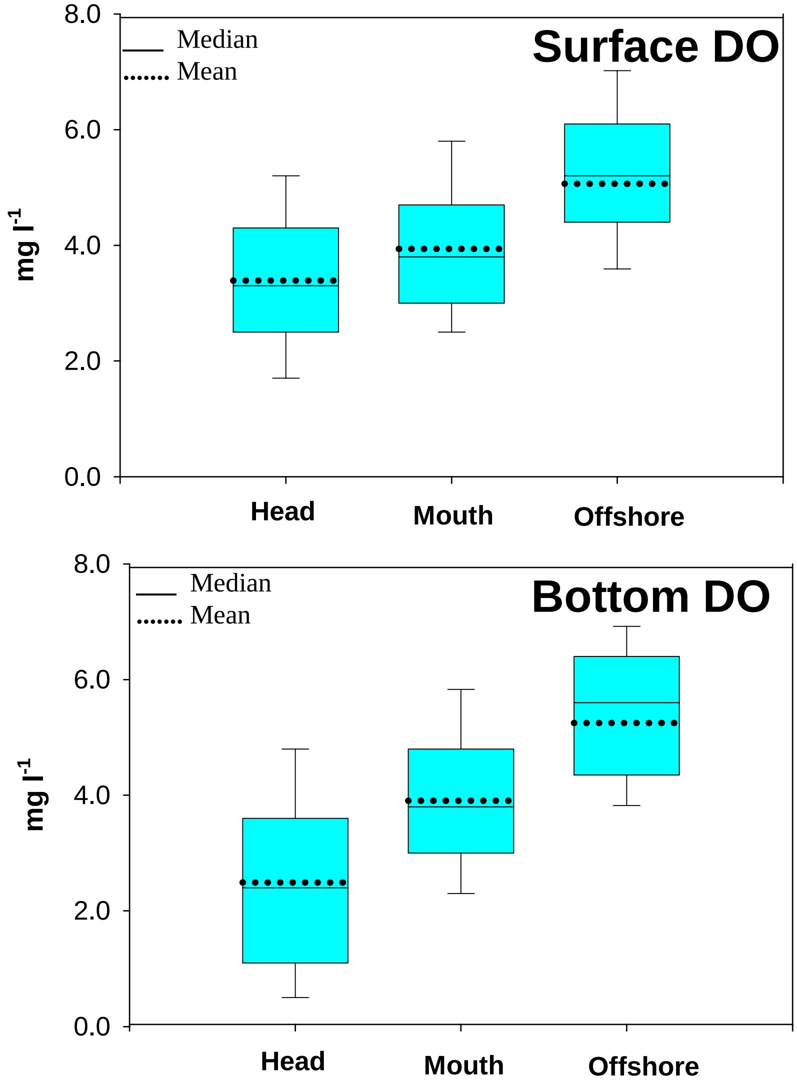


Figure 33

Sta. 10- Mouth of the 112th Street Canal

Sta. 13- Mouth of the 91st Street Canal

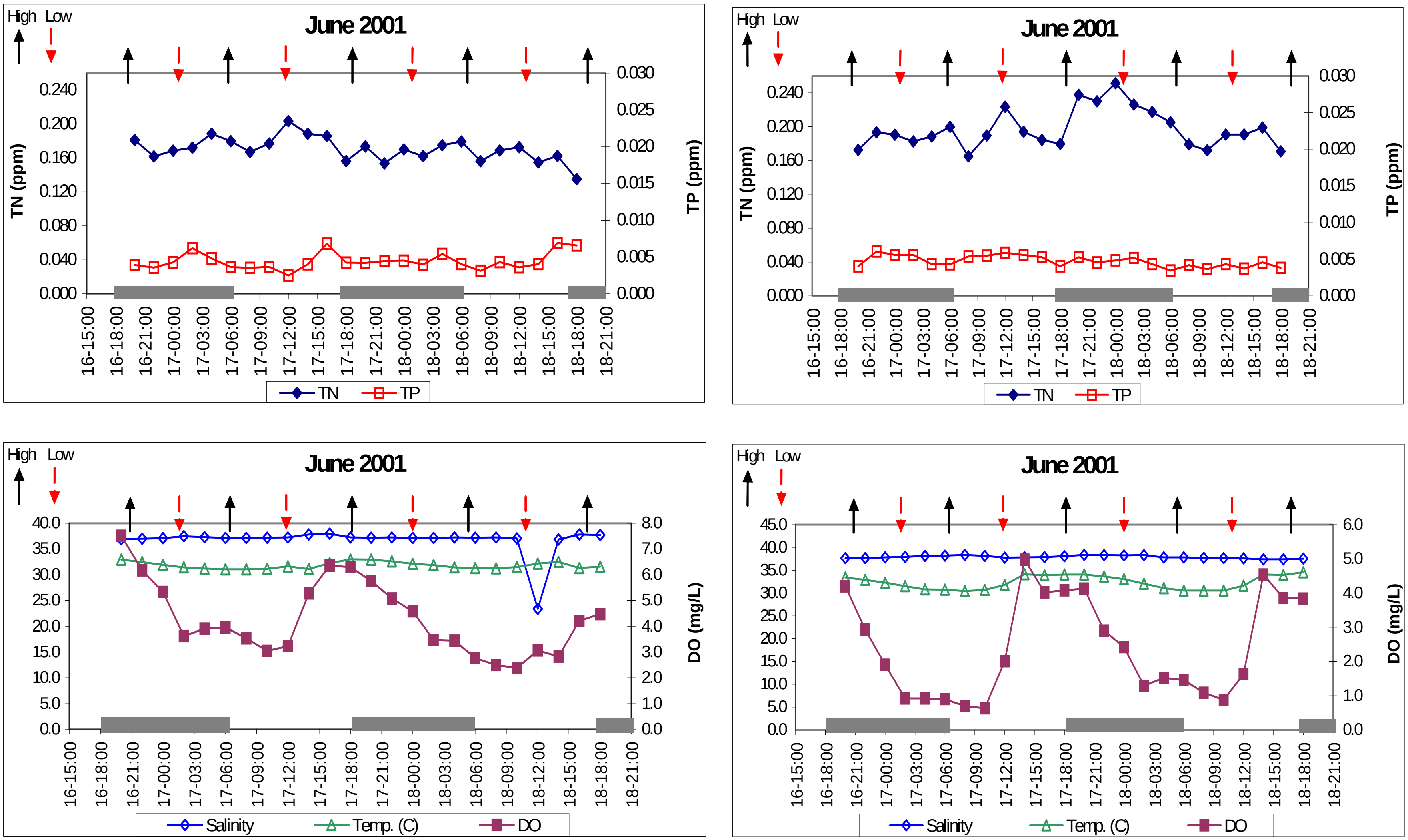


Figure 34. June 2001 Diurnal Sampling (ISCO)

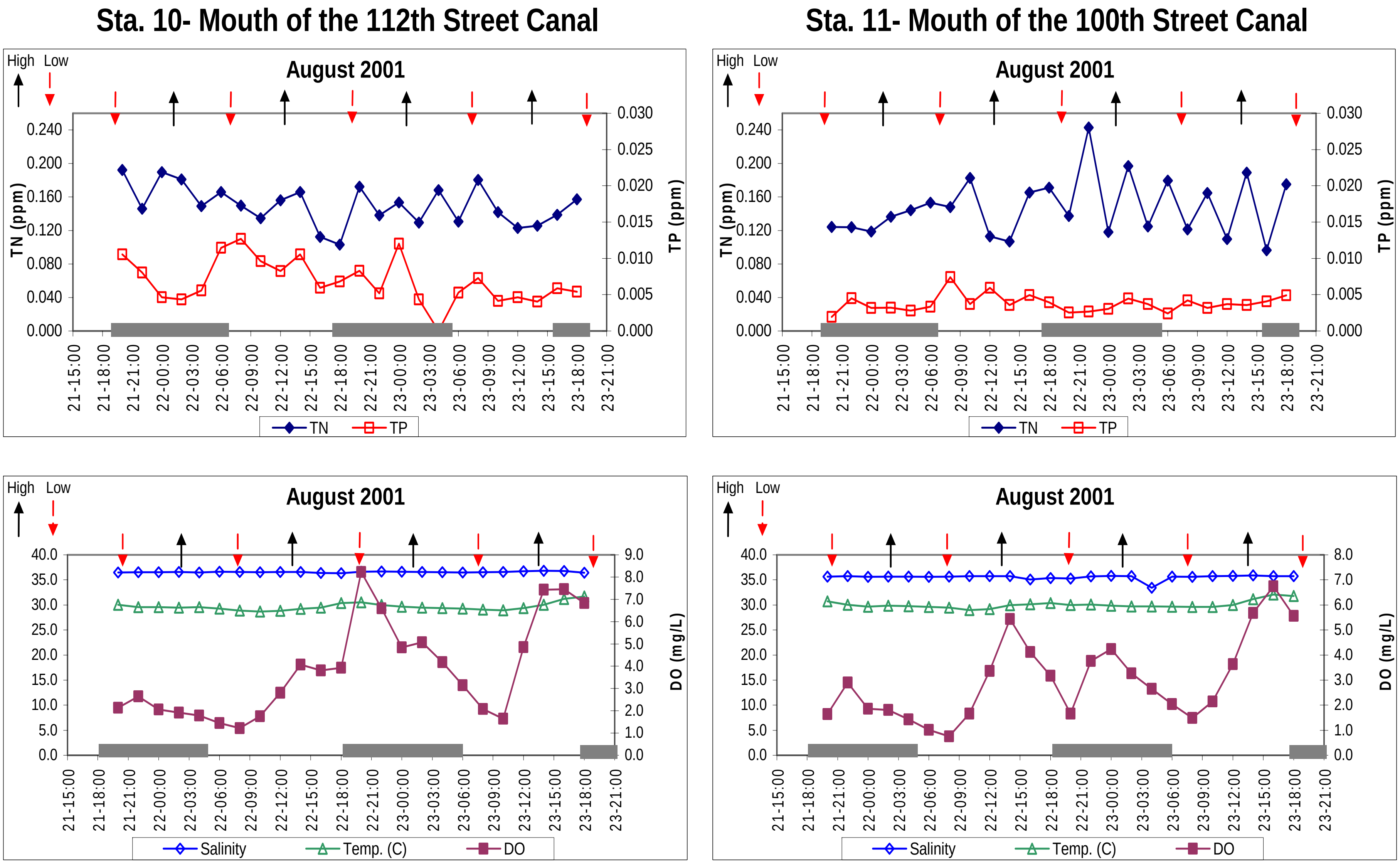
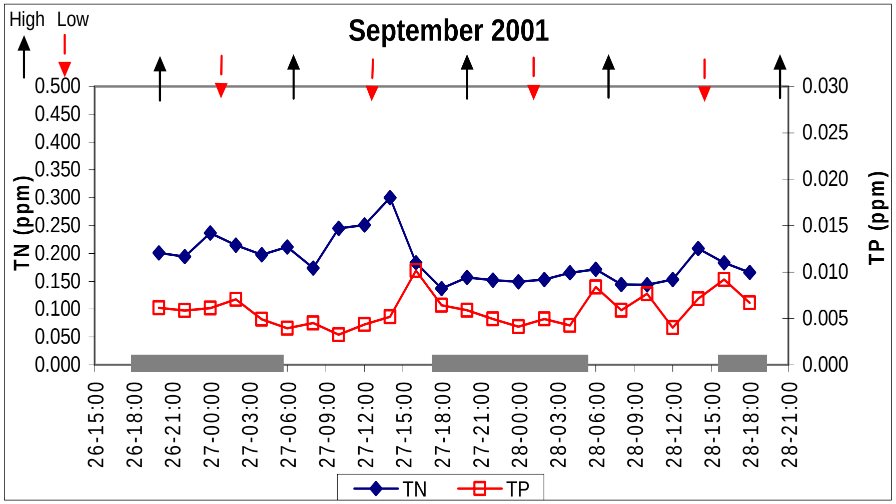
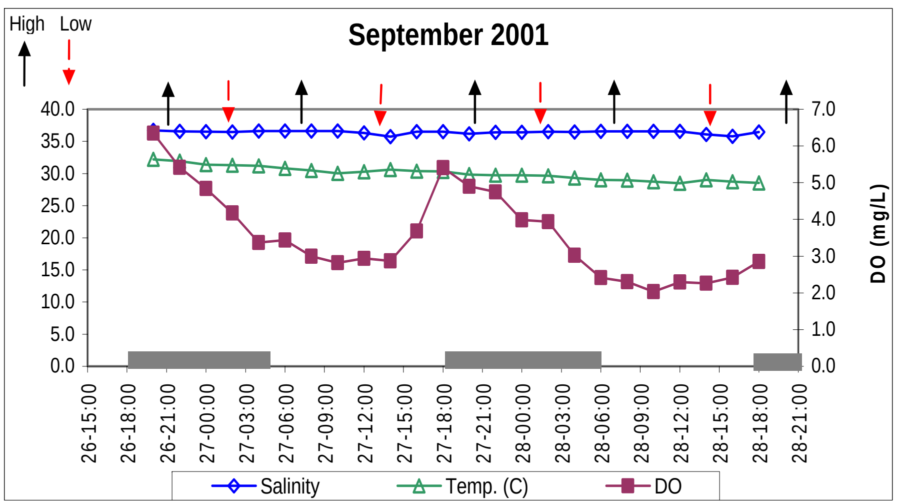


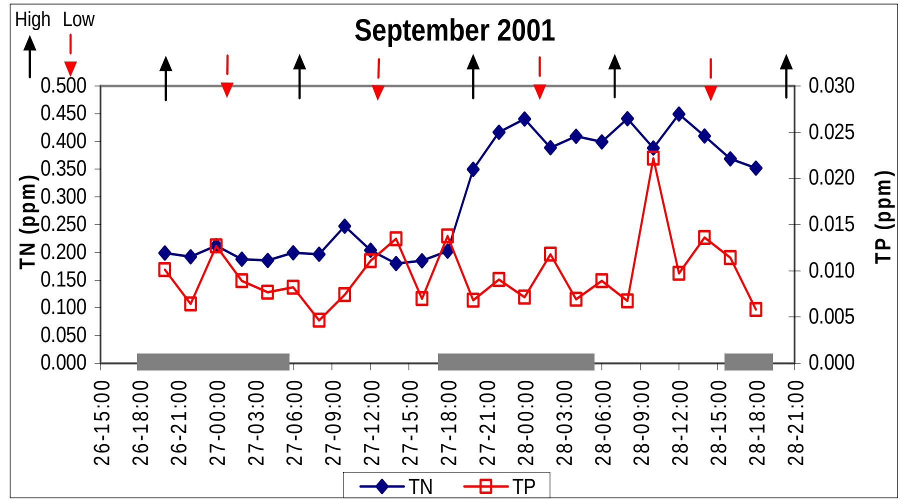
Figure 35. August 2001 Diurnal Sampling (ISCO)

Sta. 12- Mouth of the 97th Street Canal





Sta. 13- Mouth of the 91st Street Canal



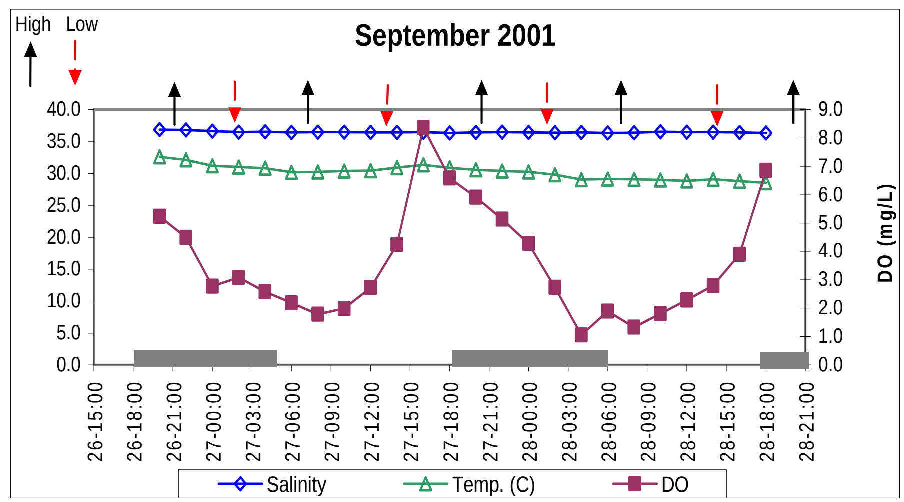


Figure 36. September 2001 Diurnal Sampling (ISCO)

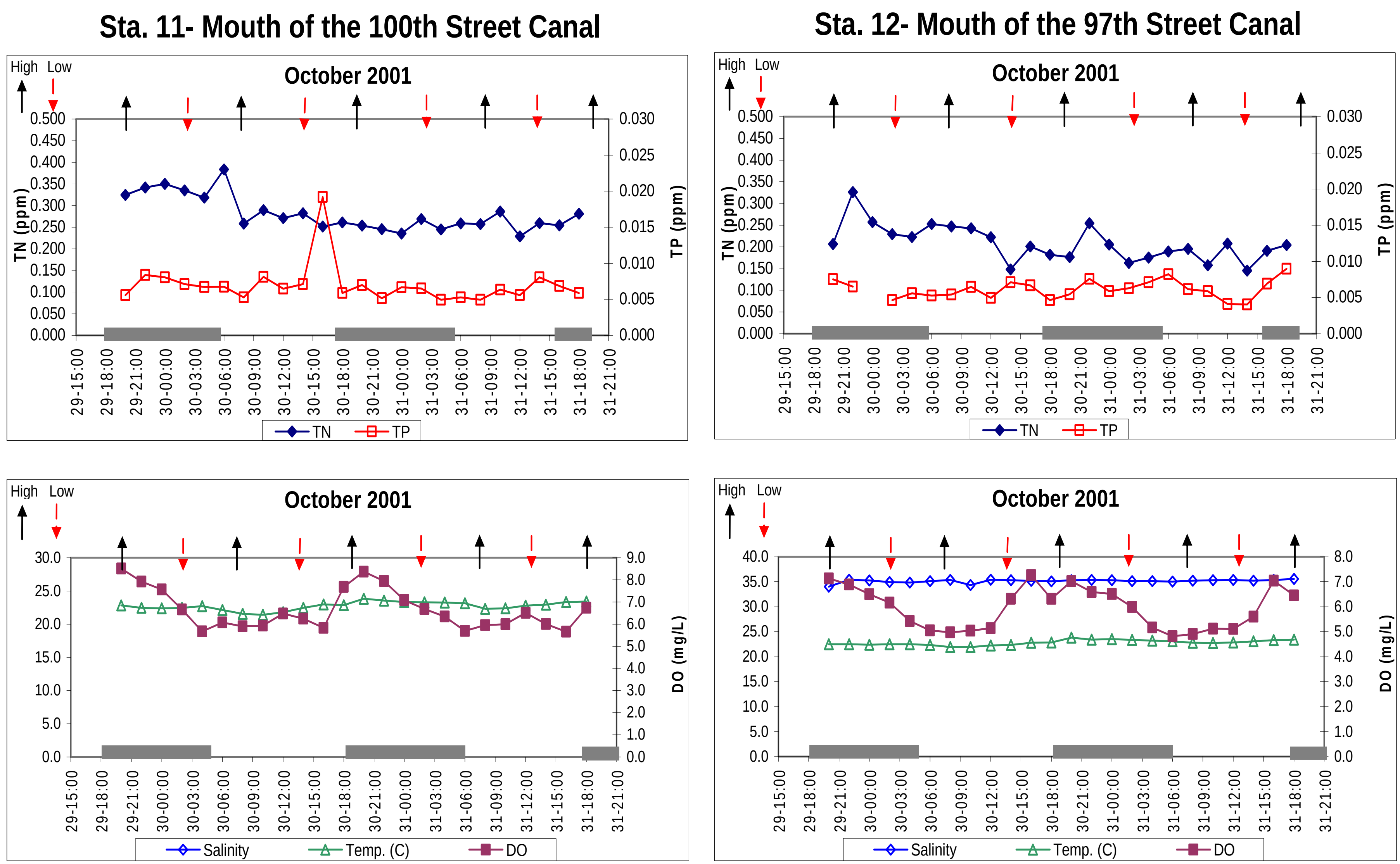


Figure 37. October 2001 Diurnal Sampling (ISCO)

Sta. 10- Mouth of the 112th Street Canal

Sta. 13- Mouth of the 91st Street Canal

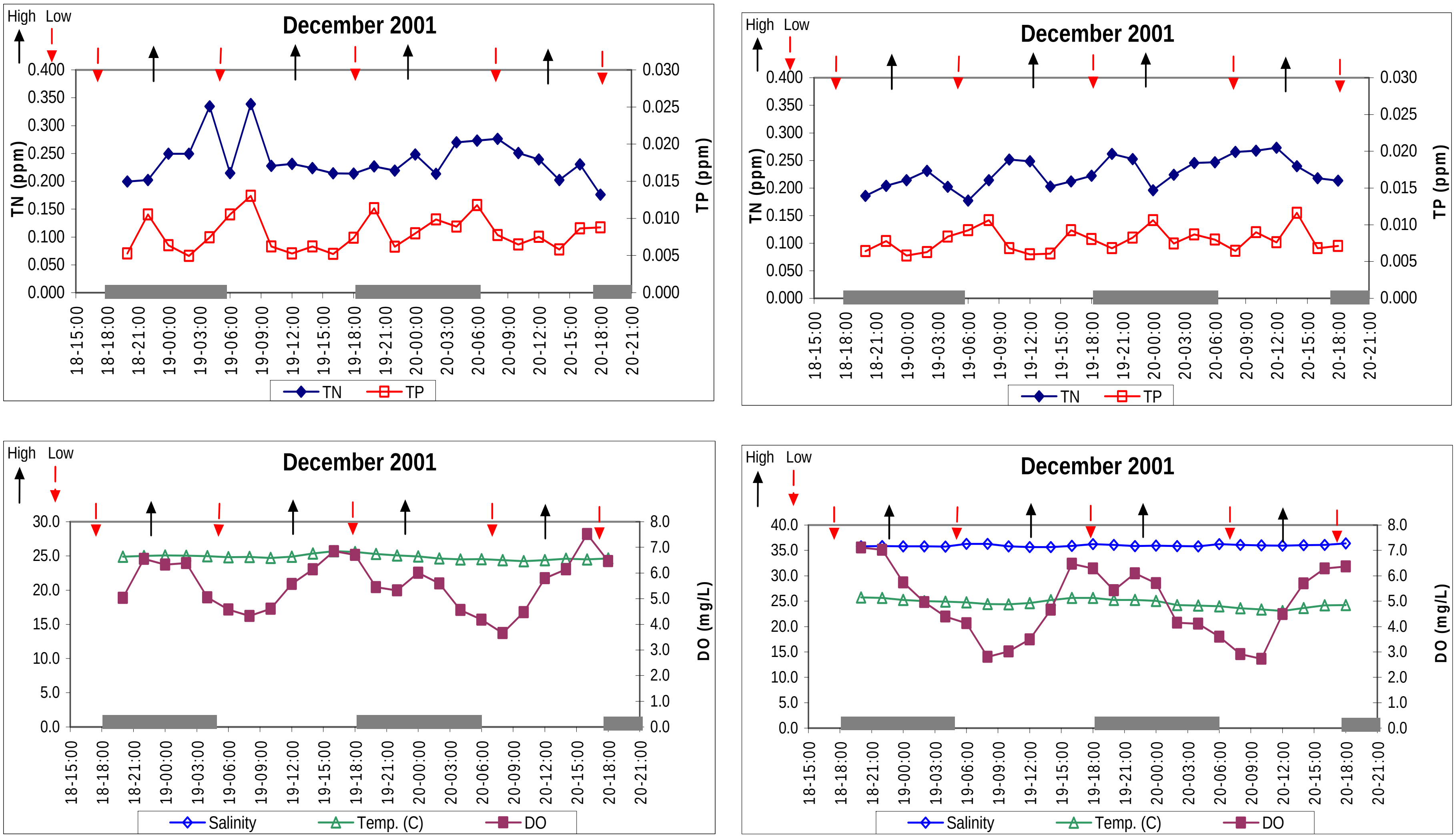


Figure 38. December 2001 Diurnal Sampling (ISCO)

Sta. 12- Mouth of the 97th Street Canal

Sta. 13- Mouth of the 91st Street Canal

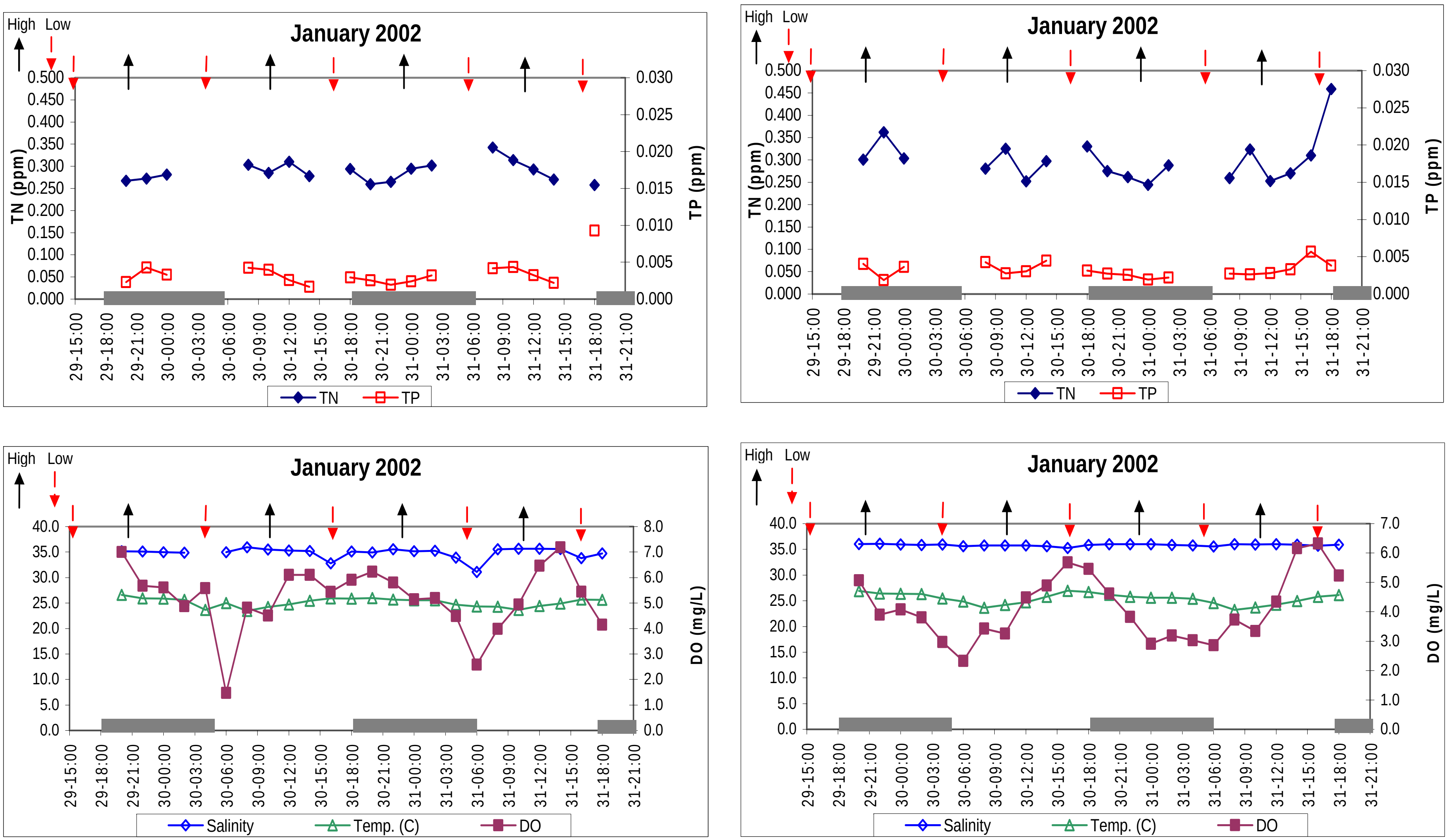


Figure 39. January 2002 Diurnal Sampling (ISCO)

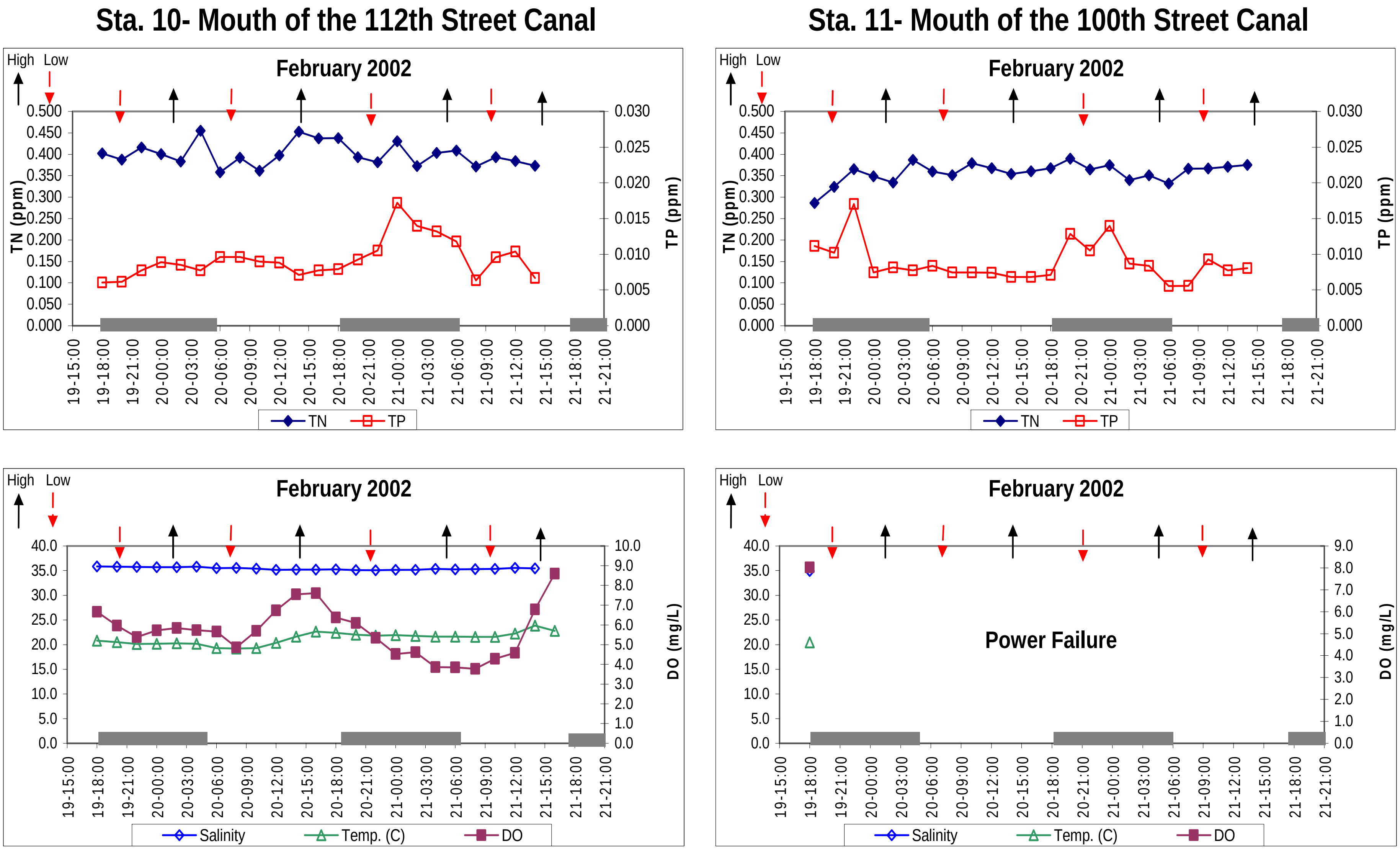


Figure 40. February 2002 Diurnal Sampling (ISCO)

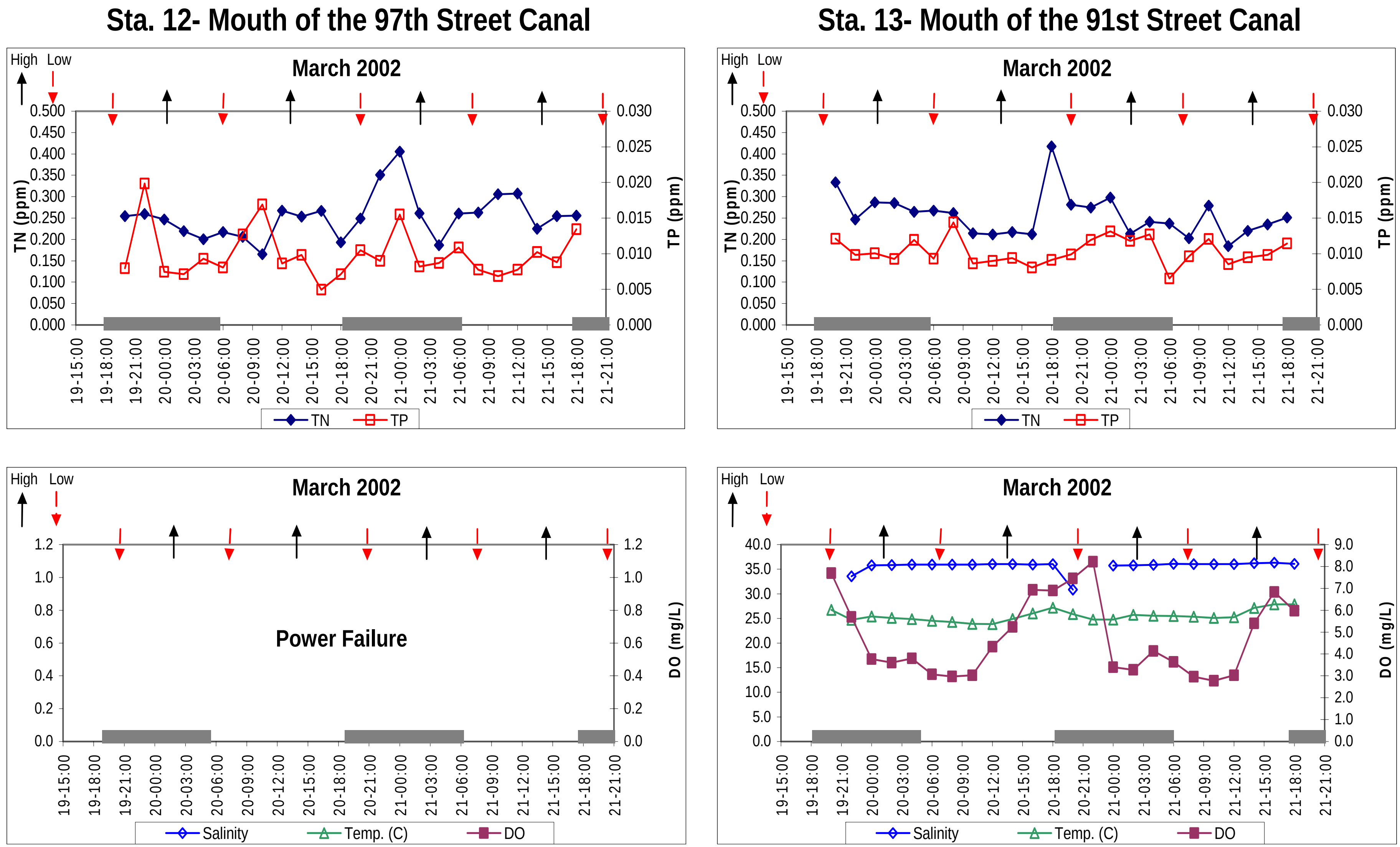
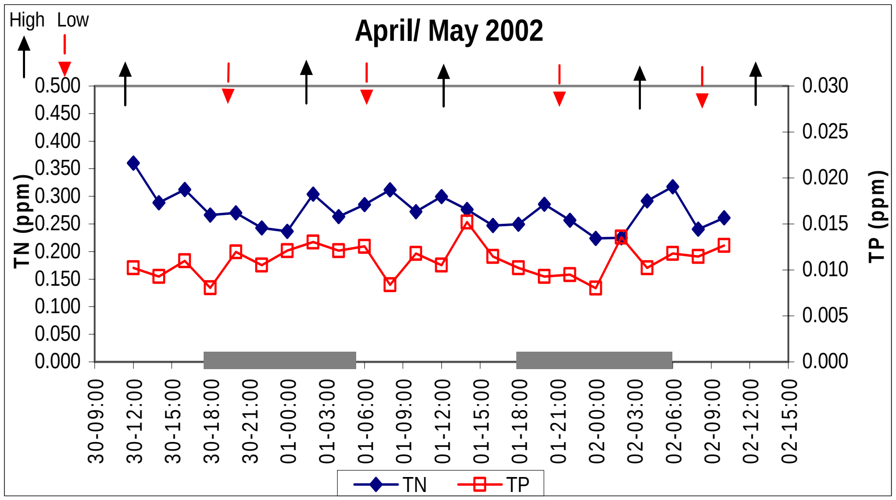
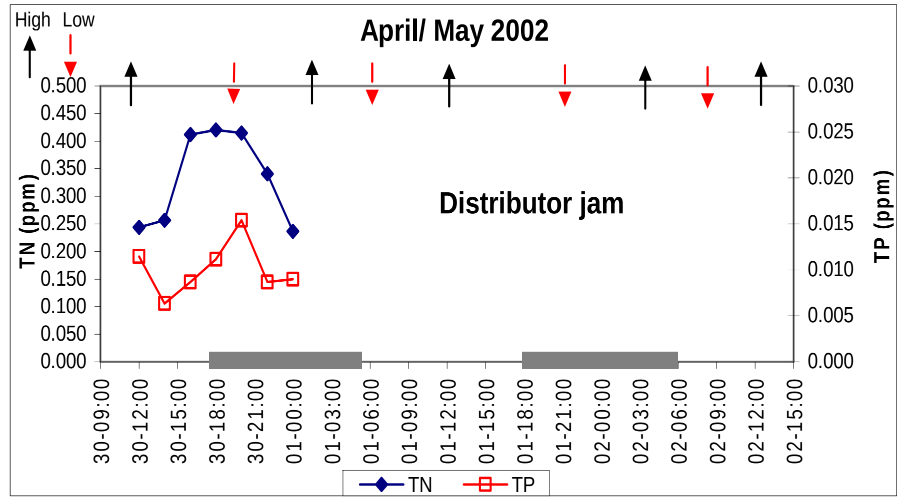


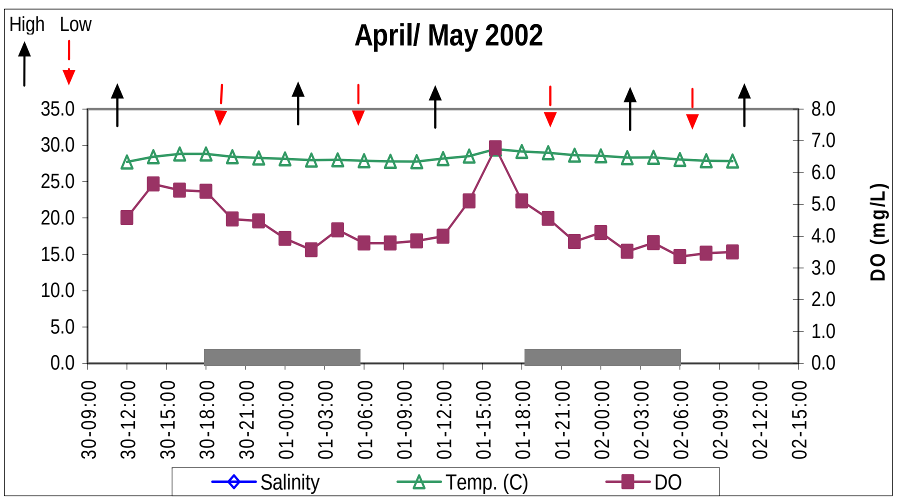
Figure 41. March 2002 Diurnal Sampling (ISCO)

Sta. 10- Mouth of the 112th Street Canal

Sta. 11- Mouth of the 100th Street Canal







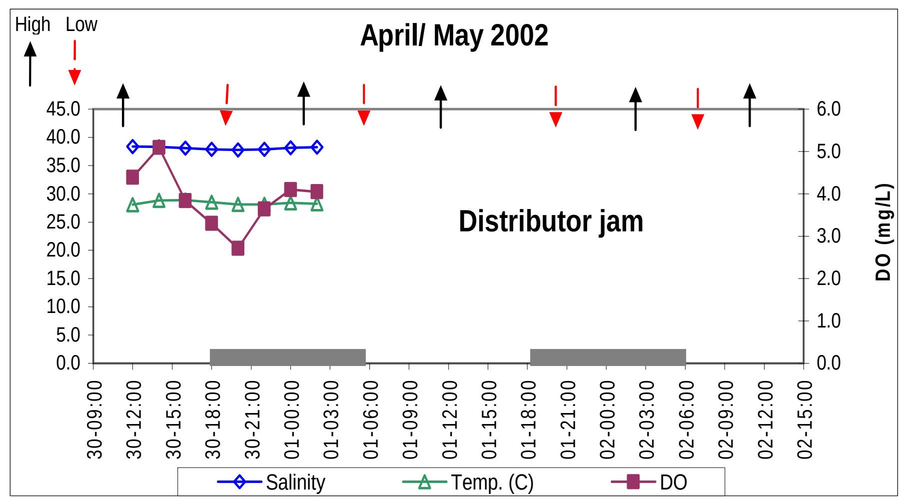


Figure 42. April/ May 2002 Diurnal Sampling (ISCO)

Sta. 12- Mouth of the 97th Street Canal

Sta. 13- Mouth of the 91st Street Canal

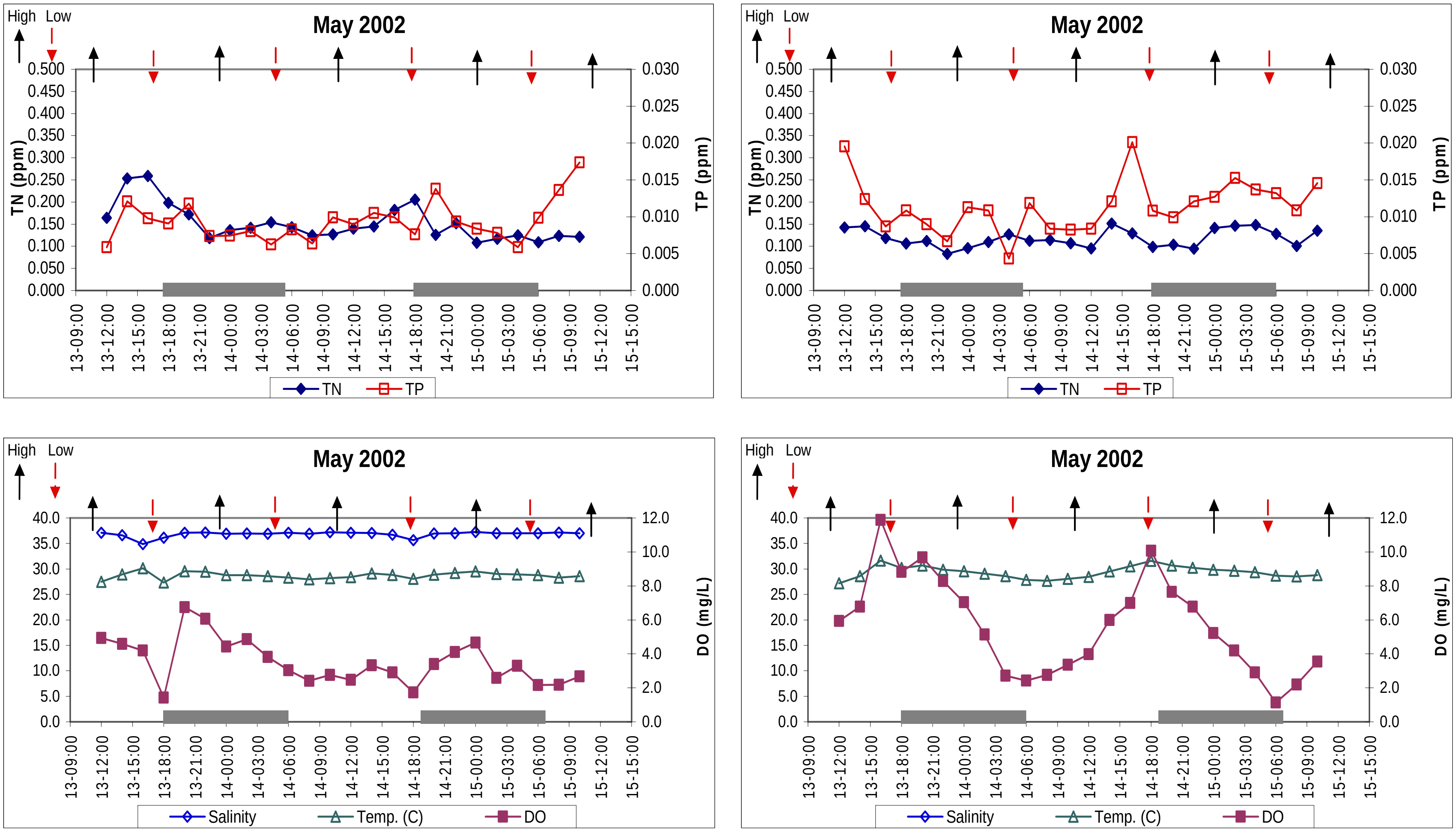


Figure 43. May 2002 Diurnal Sampling (ISCO)

Sta. 10- Mouth of the 112th Street Canal | **Sta. 11- Mouth of the 100th Street Canal**

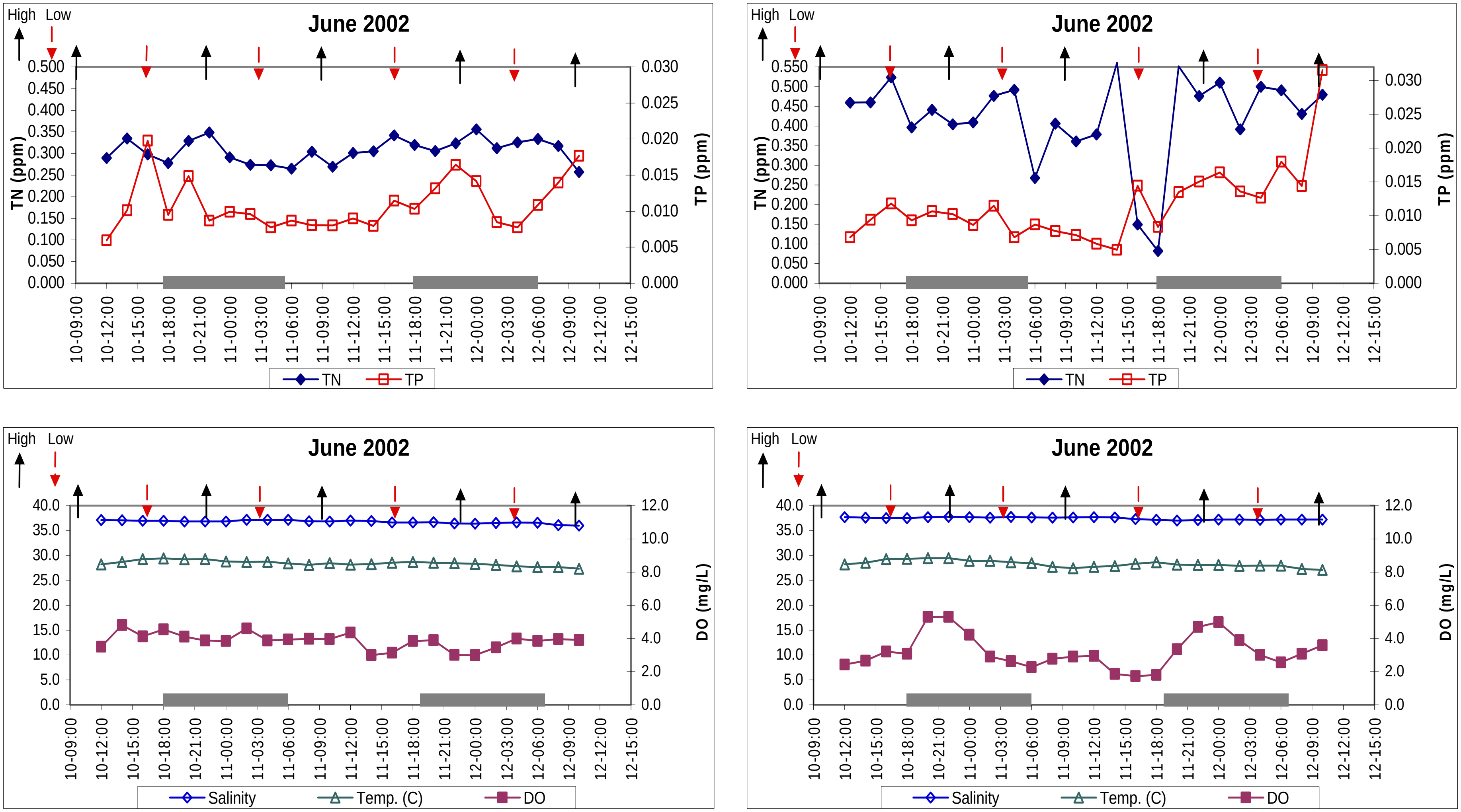
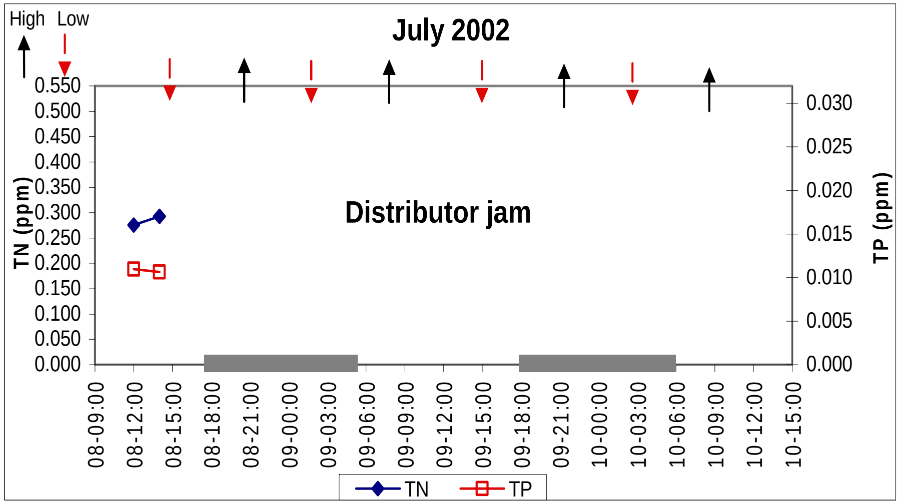
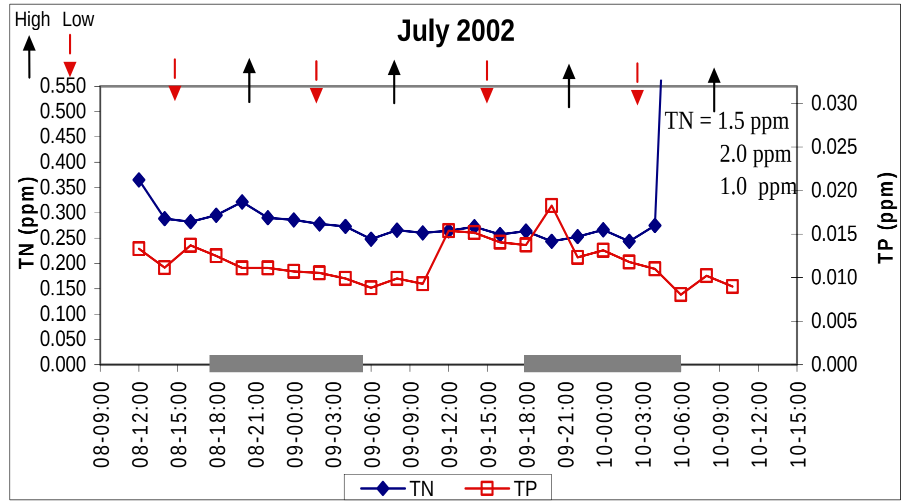


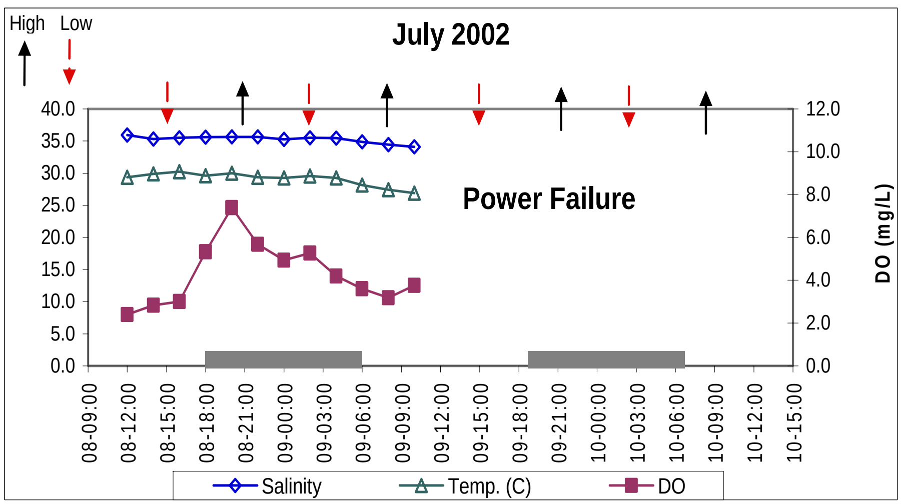
Figure 44. June 2002 Diurnal Sampling (ISCO)

Sta. 12- Mouth of the 97th Street Canal



Sta. 13- Mouth of the 91st Street Canal





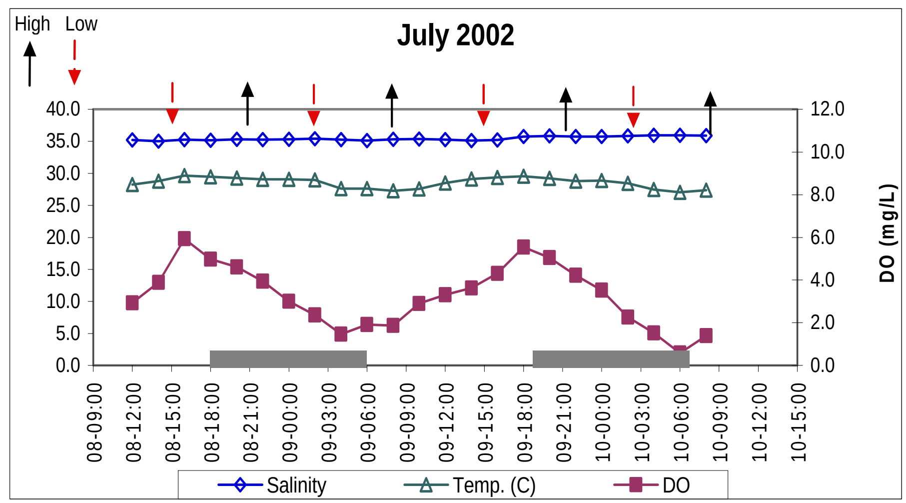
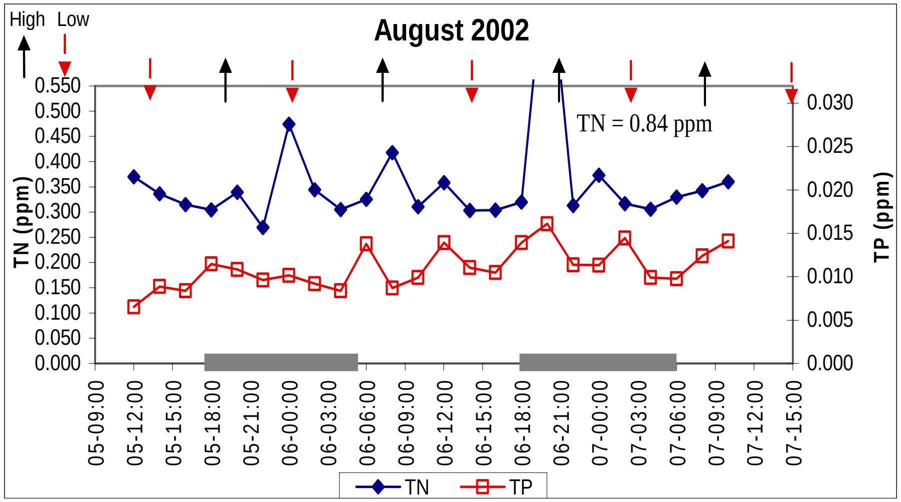
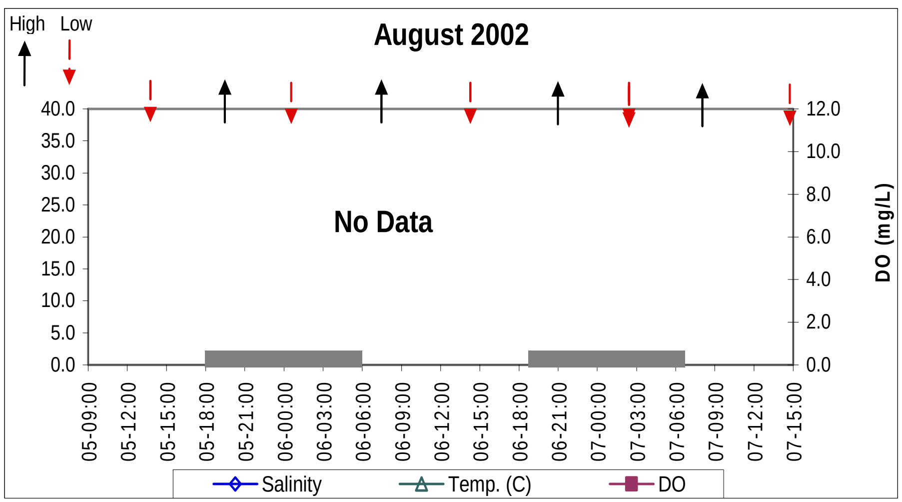


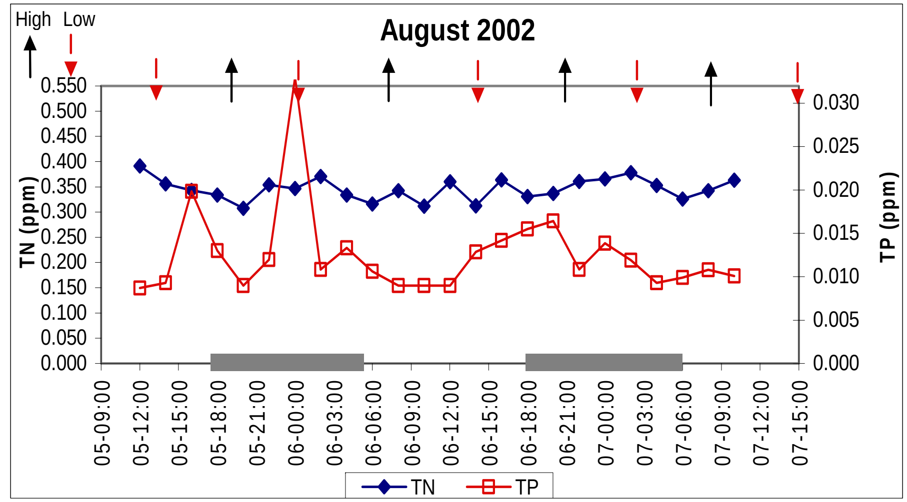
Figure 45. July 2002 Diurnal Sampling (ISCO)

Sta. 10- Mouth of the 112th Street Canal





Sta. 11- Mouth of the 100th Street Canal



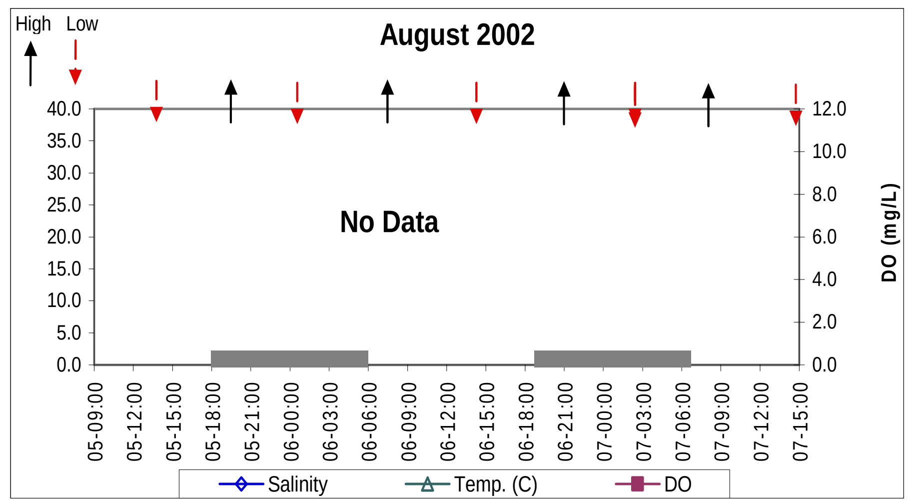
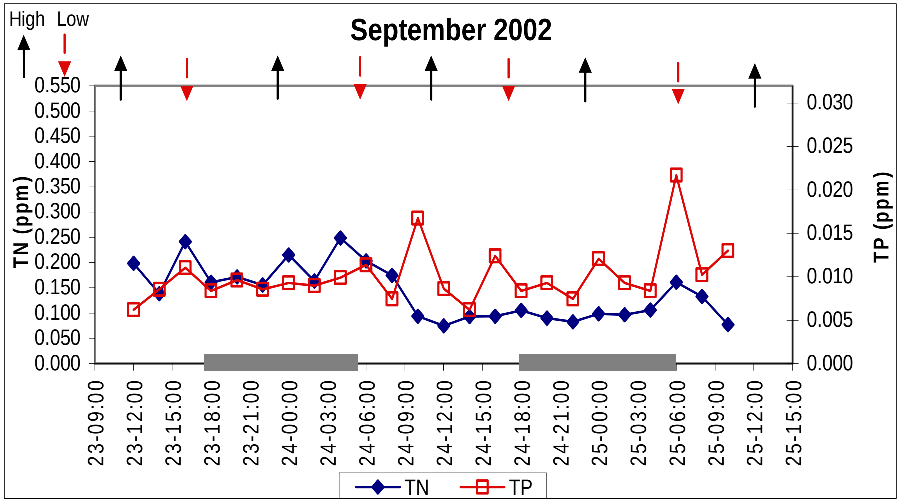
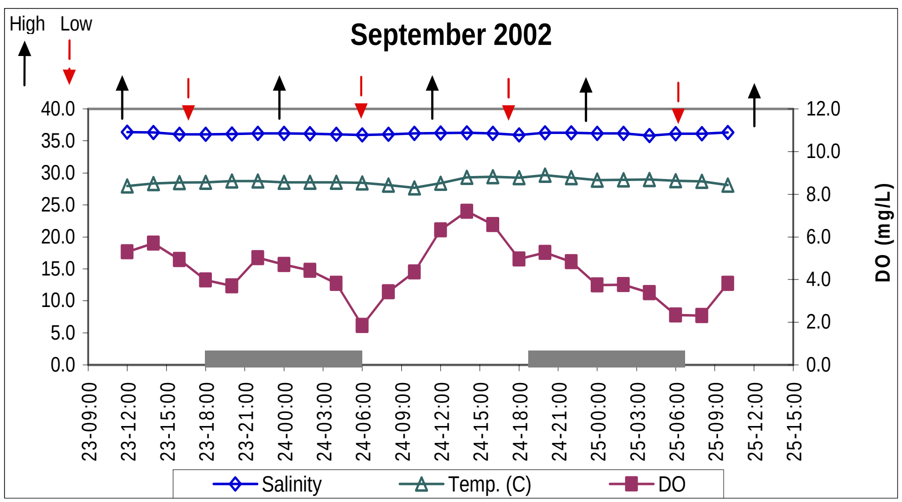


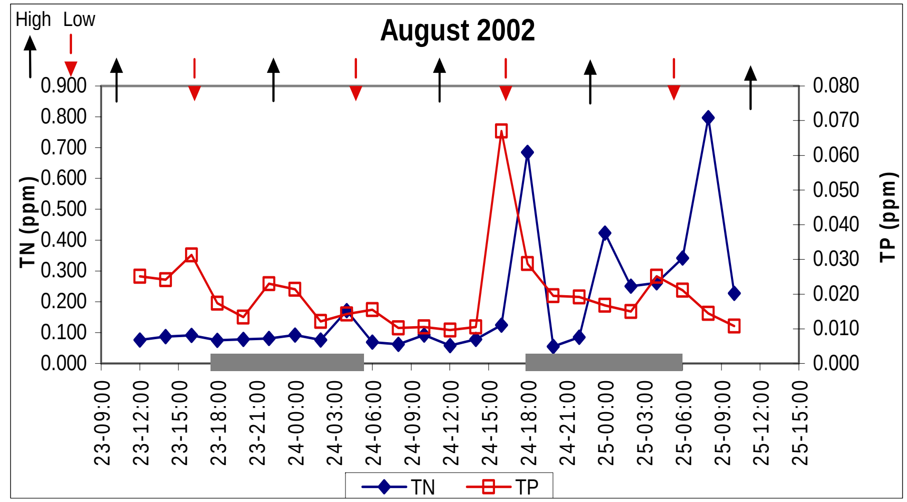
Figure 46. August 2002 Diurnal Sampling (ISCO)

Sta. 12- Mouth of the 97th Street Canal





Sta. 13- Mouth of the 91st Street Canal



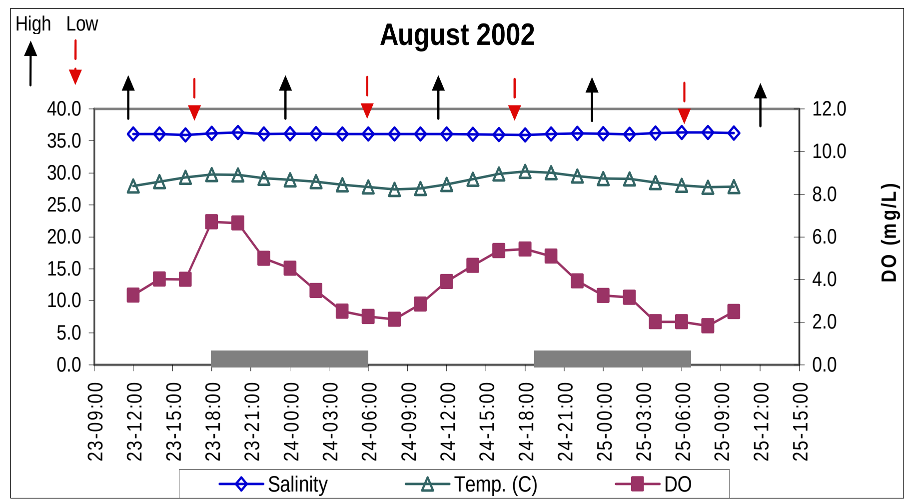


Figure 47.September 2002 Diurnal Sampling (ISCO)

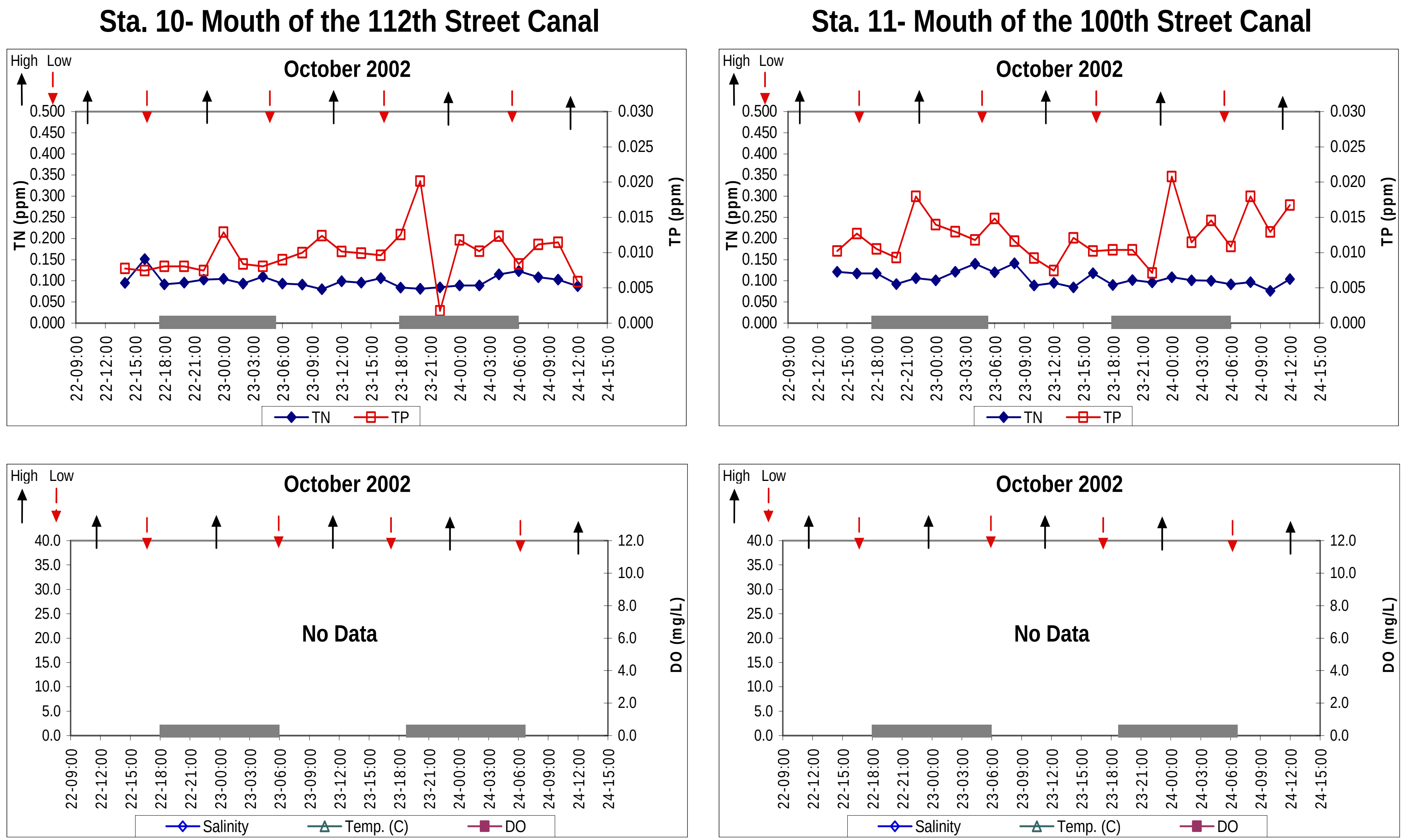
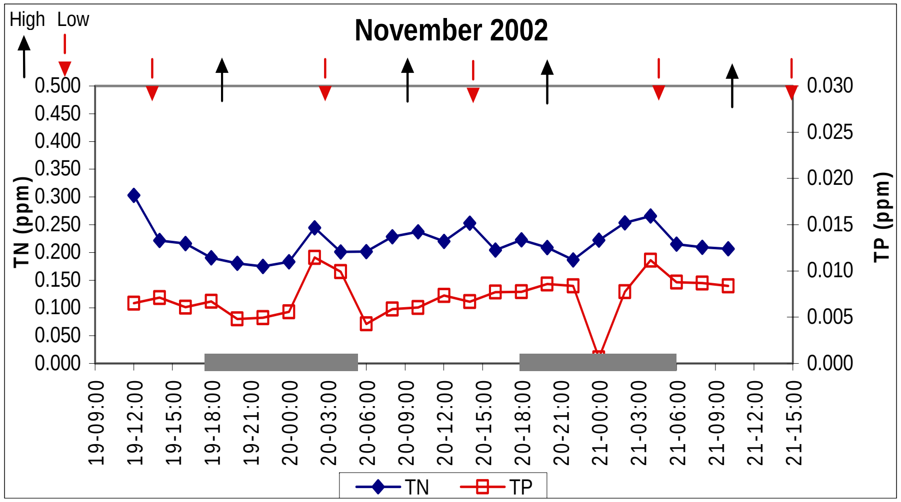
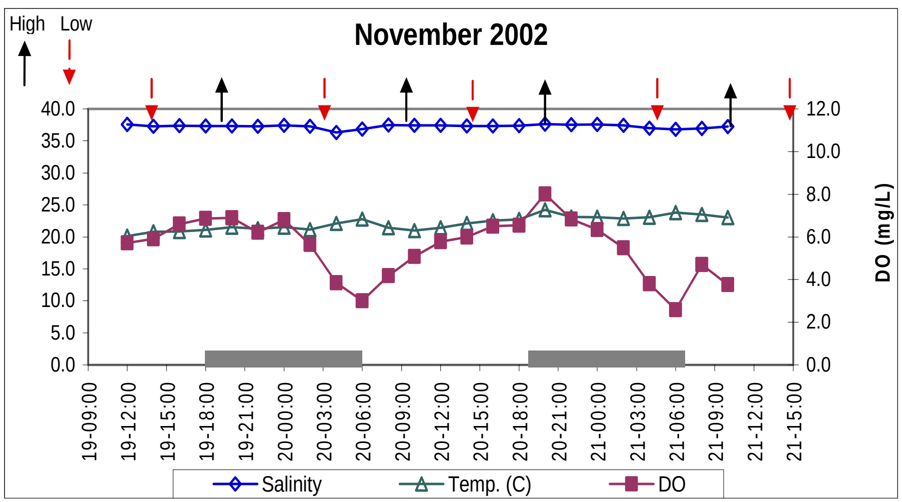


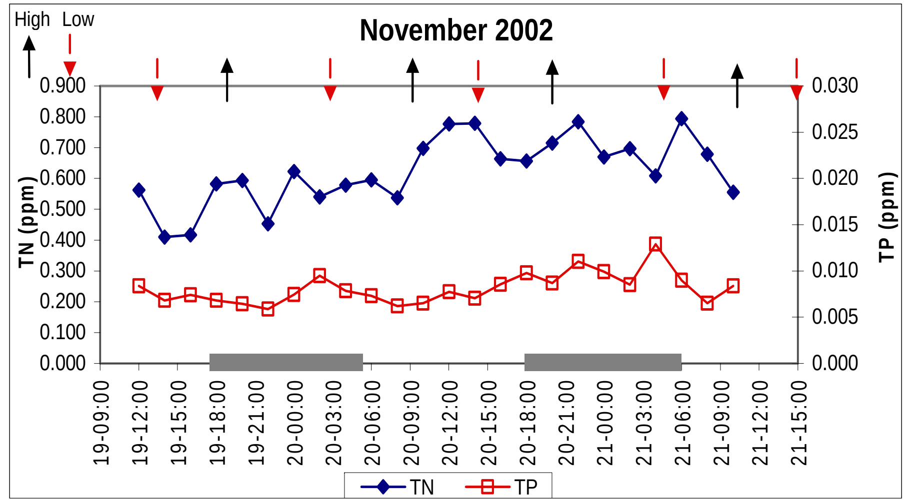
Figure 48. October 2002 Diurnal Sampling (ISCO)

Sta. 12- Mouth of the 97th Street Canal





Sta. 13- Mouth of the 91st Street Canal



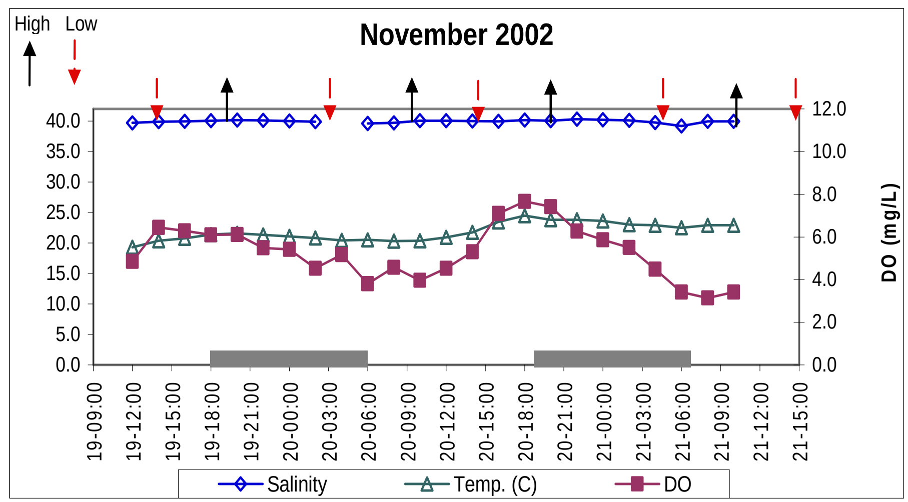
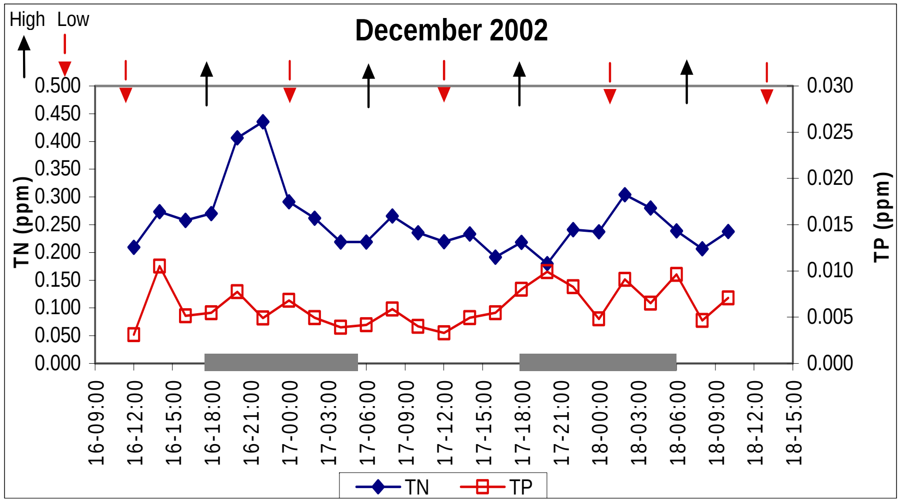
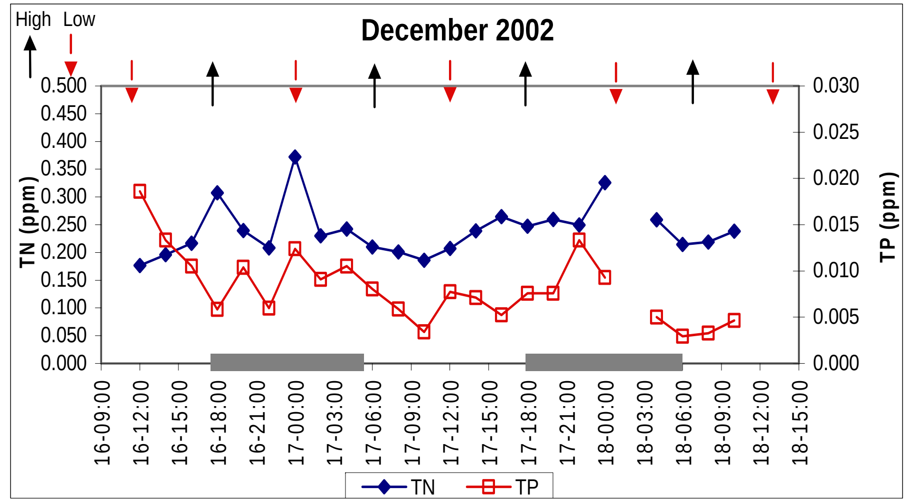


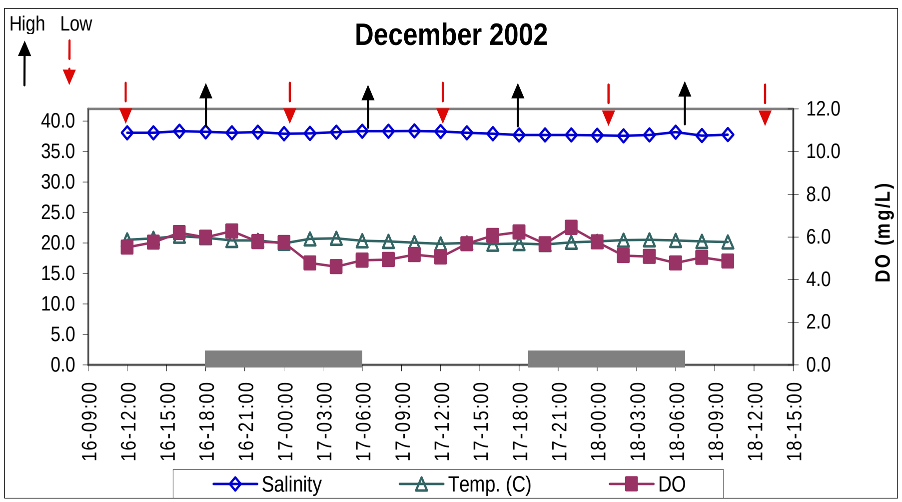
Figure 49. November 2002 Diurnal Sampling (ISCO)

Sta. 10- Mouth of the 112th Street Canal

Sta. 12- Mouth of the 97th Street Canal







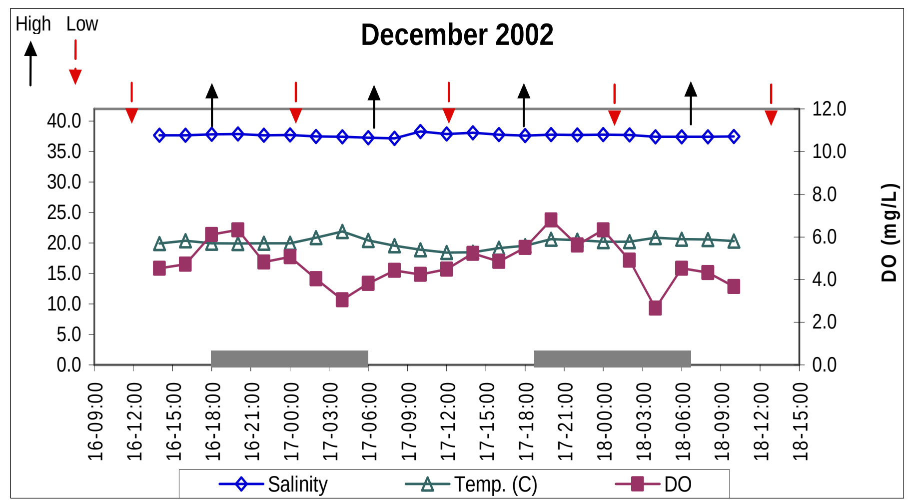


Figure 50. December 2002 Diurnal Sampling (ISCO)

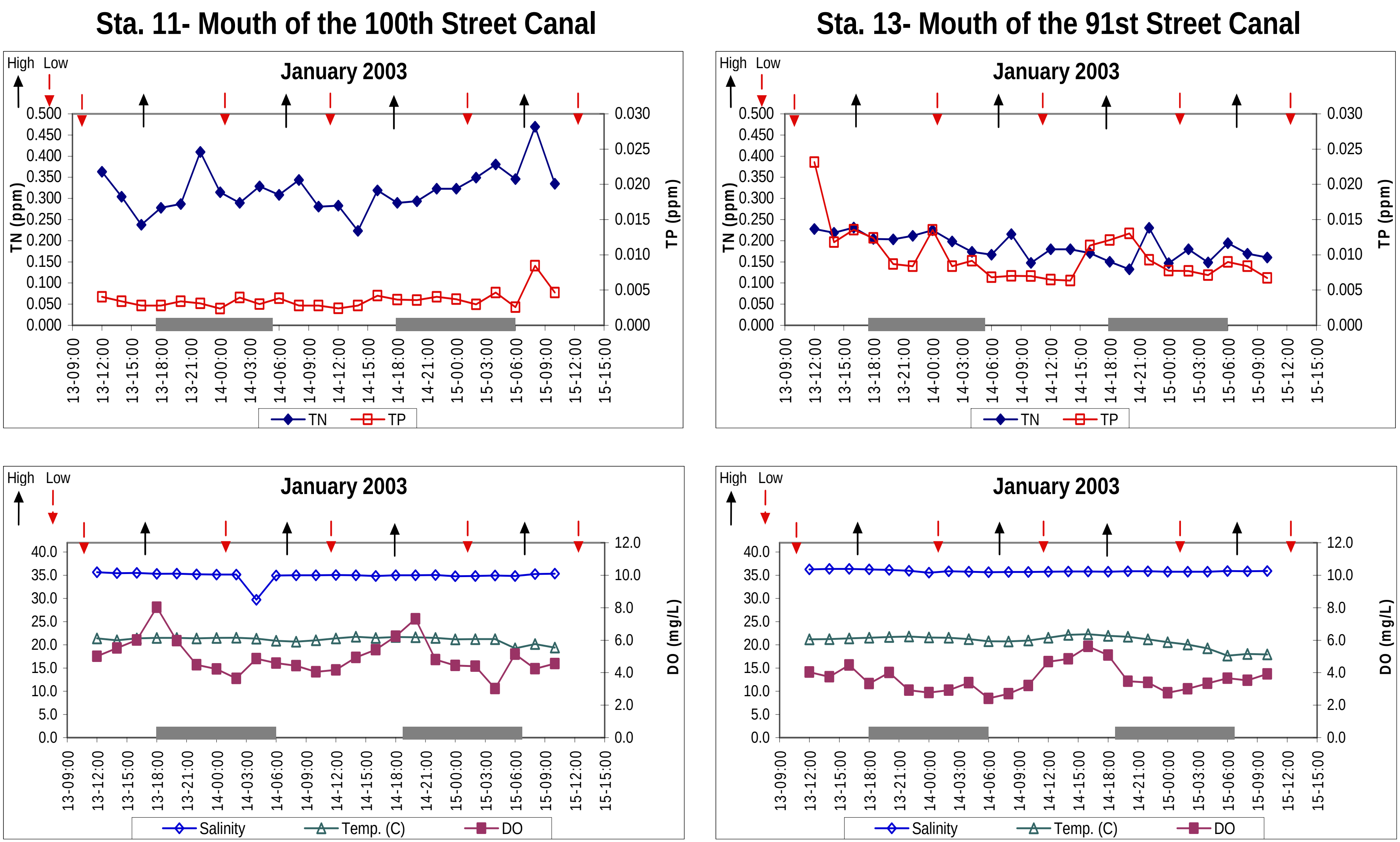


Figure 51. January 2003 Diurnal Sampling (ISCO)

Sta. 10- Mouth of the 112th Street Canal

Sta. 11- Mouth of the 100th Street Canal

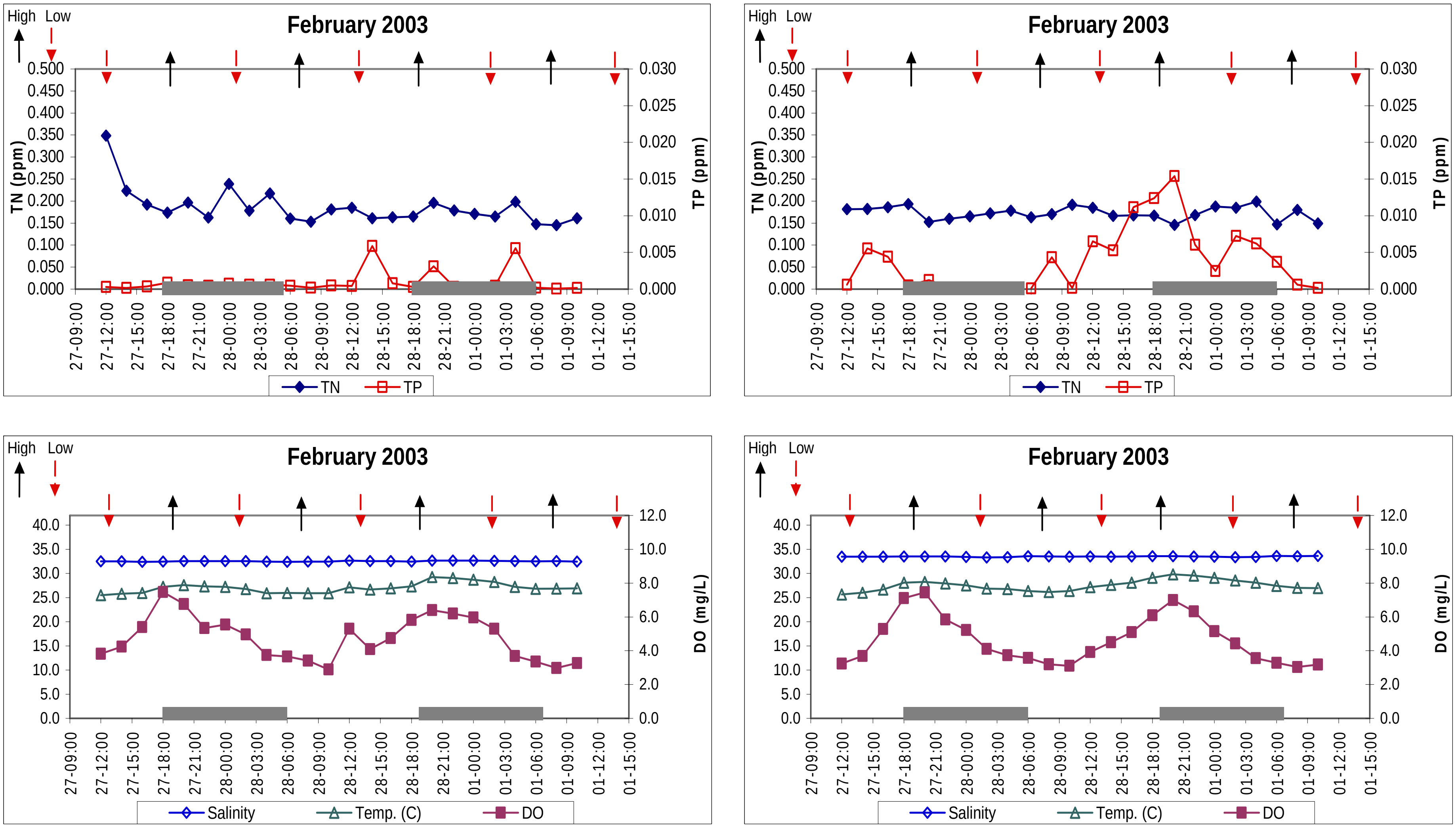


Figure 52. February 2003 Diurnal Sampling (ISCO)

Sta. 12- Mouth of the 97th Street Canal

Sta. 13- Mouth of the 91st Street Canal

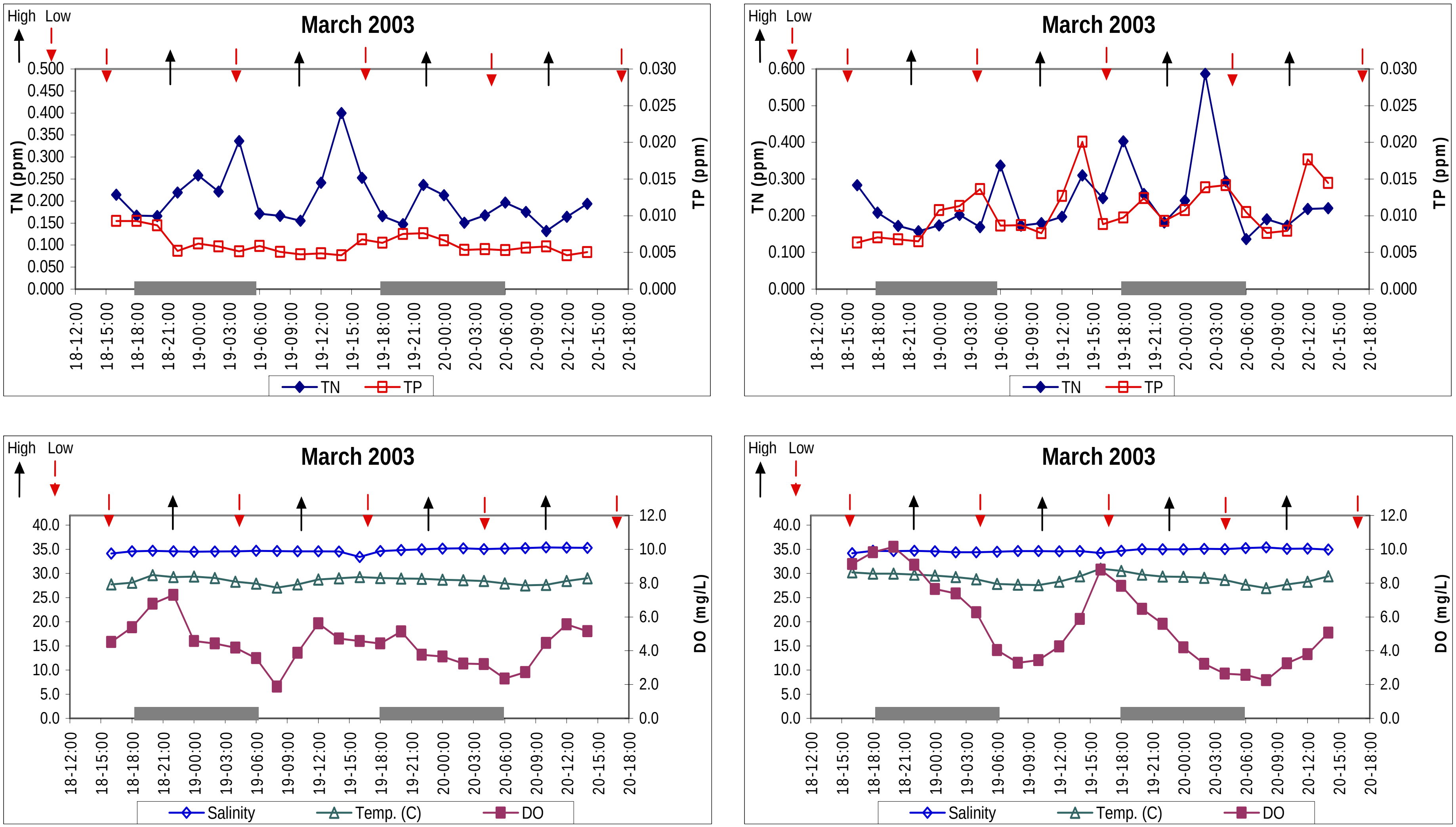
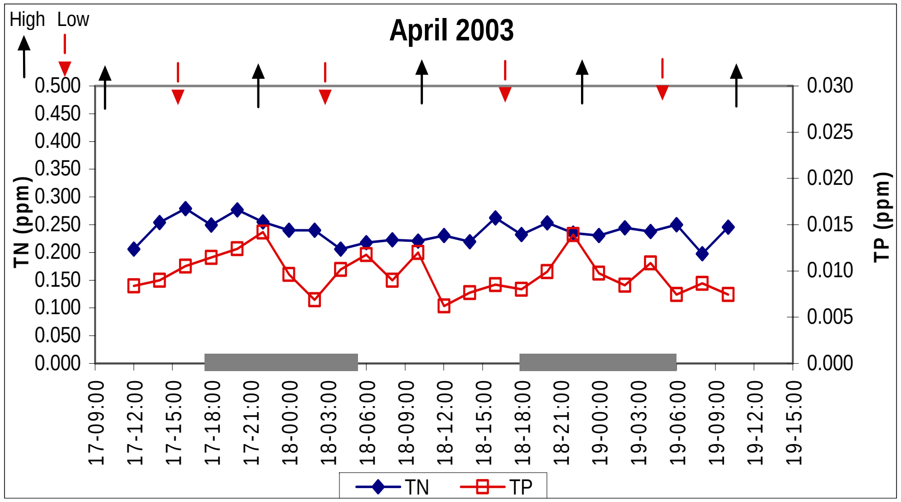
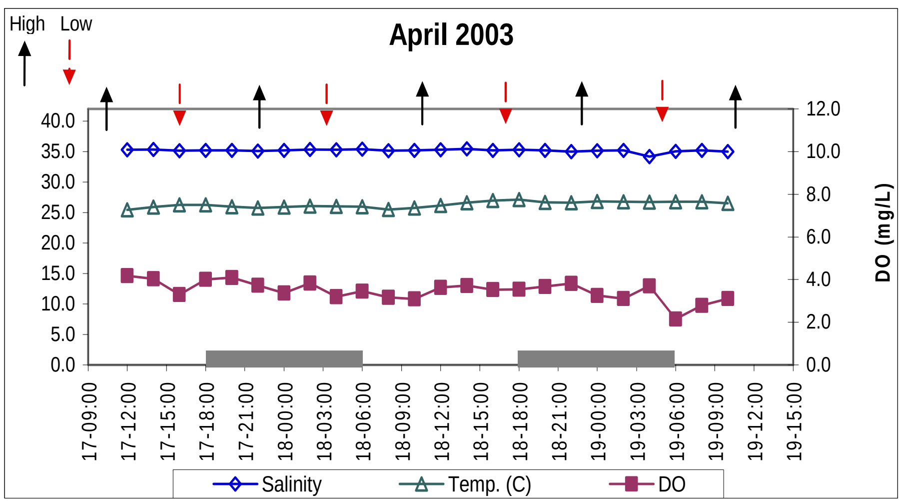


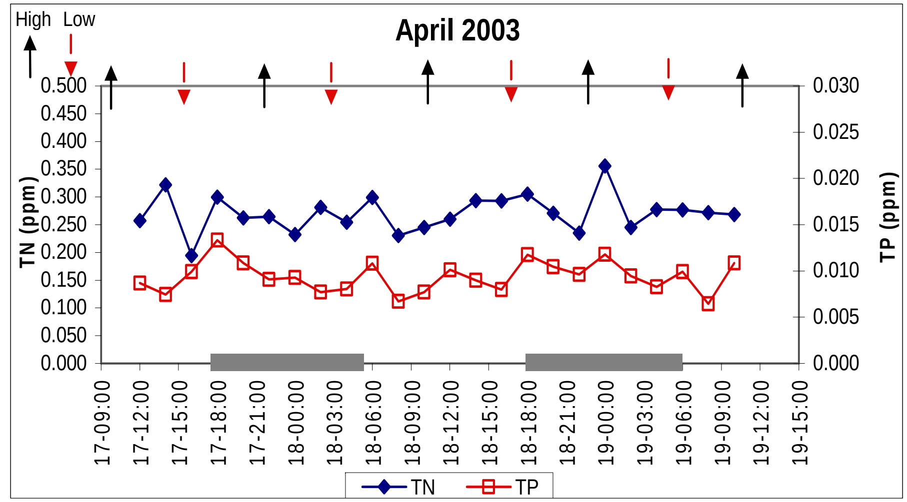
Figure 53. March 2003 Diurnal Sampling (ISCO)

Sta. 10- Mouth of the 112th Street Canal





Sta. 11- Mouth of the 100th Street Canal



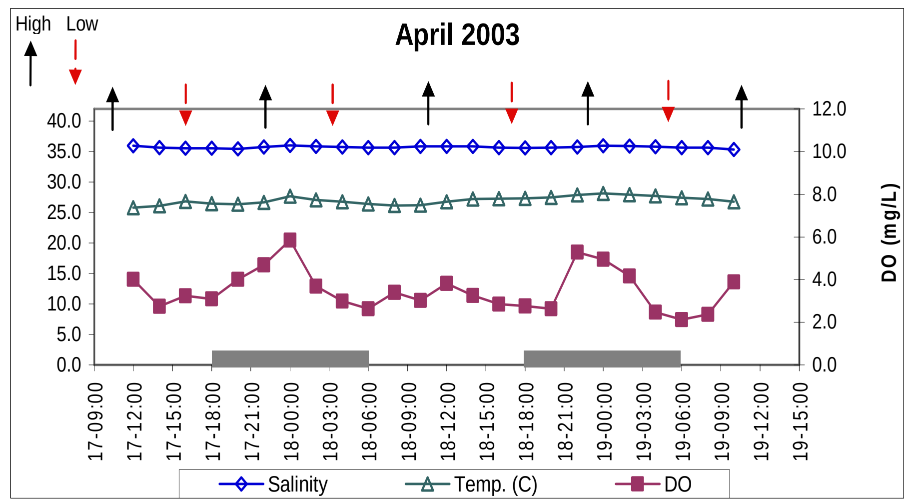
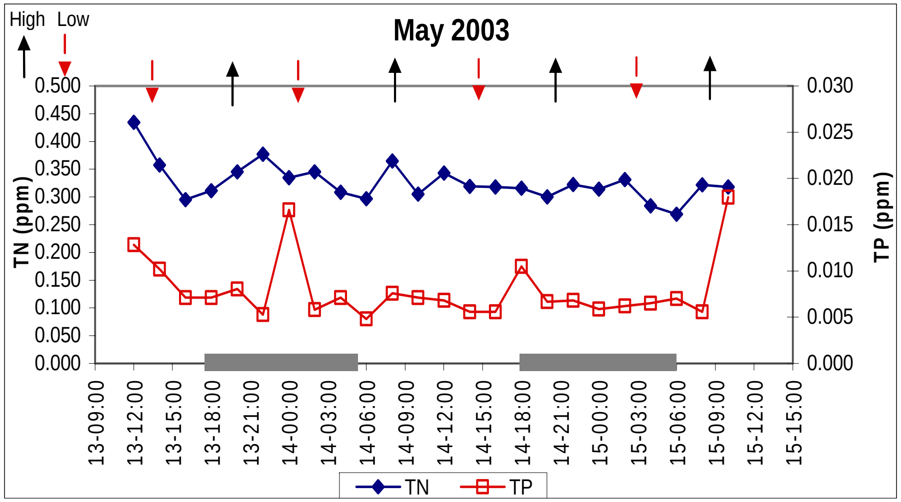
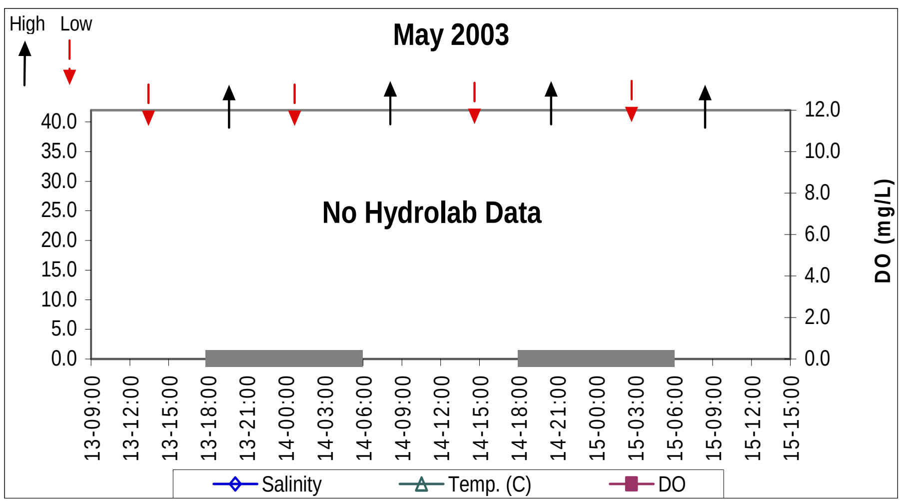


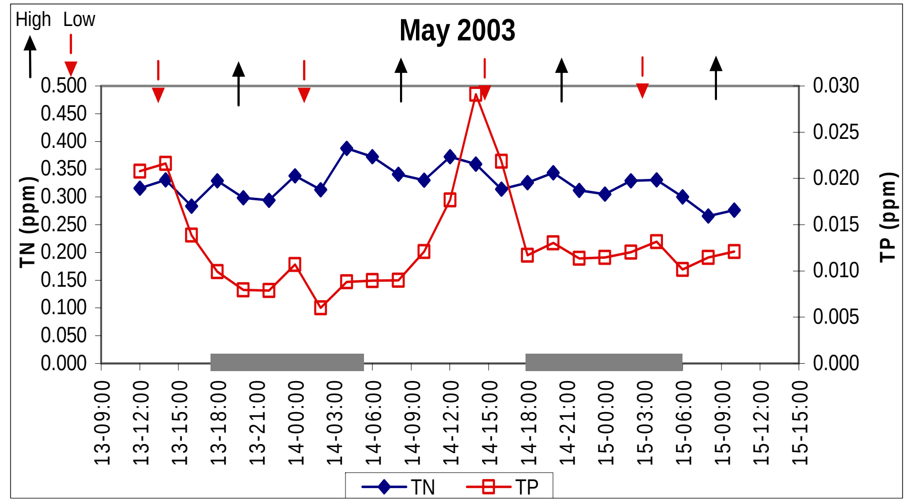
Figure 54. April 2003 Diurnal Sampling (ISCO)

Sta. 12- Mouth of the 97th Street Canal





Sta. 13- Mouth of the 91st Street Canal



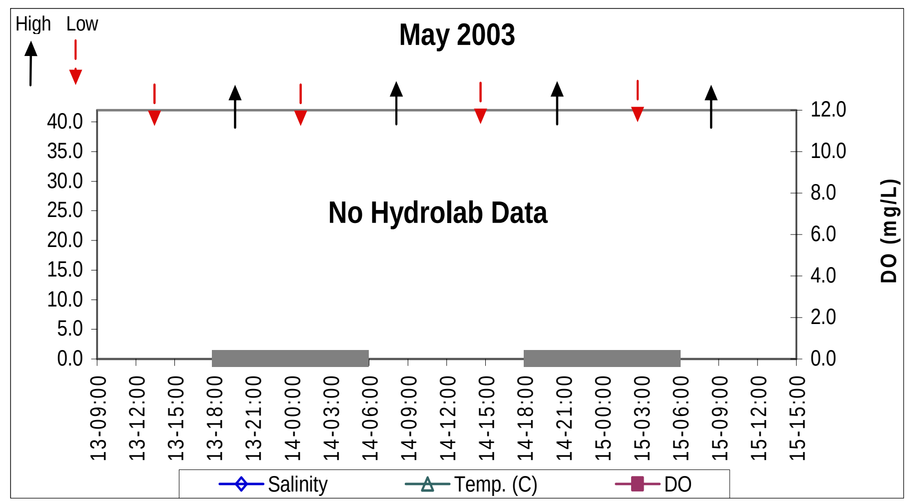
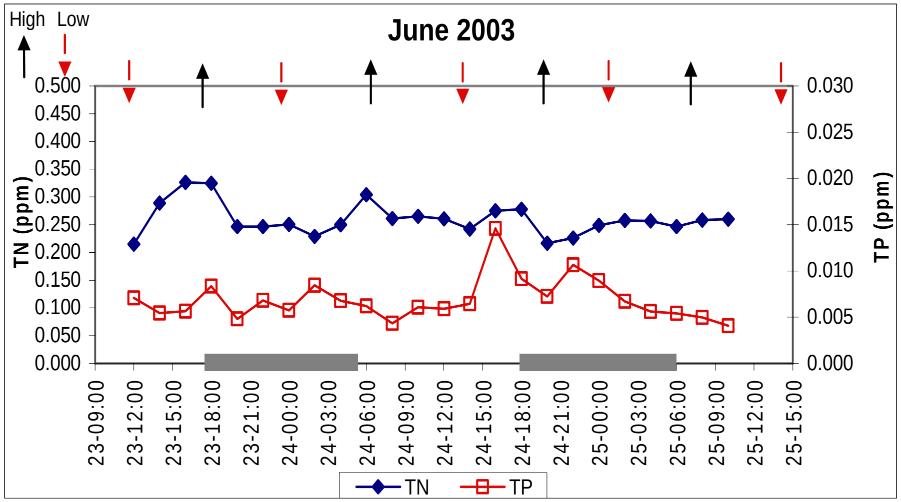
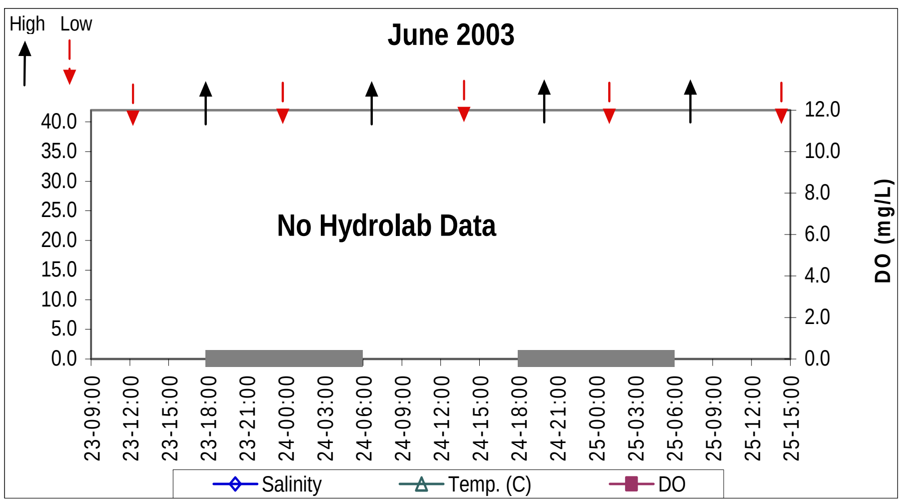


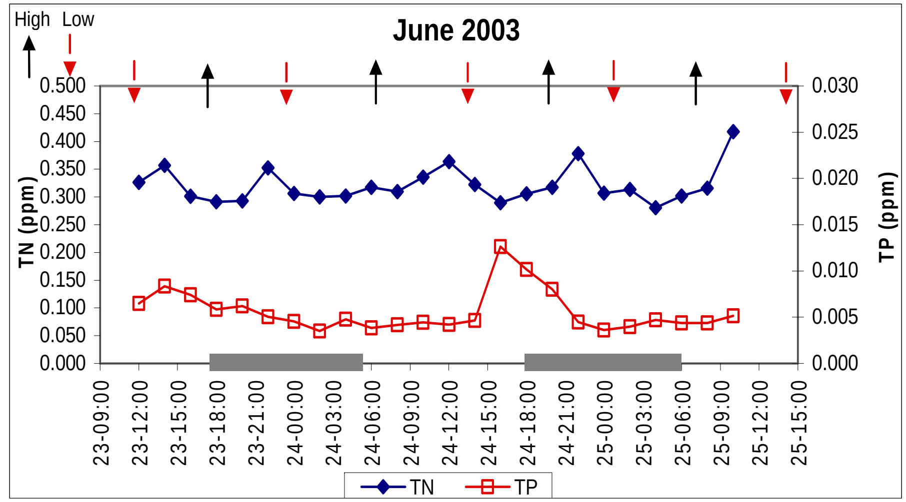
Figure 55. May 2003 Diurnal Sampling (ISCO)

Sta. 10- Mouth of the 112th Street Canal





Sta. 11- Mouth of the 100th Street Canal



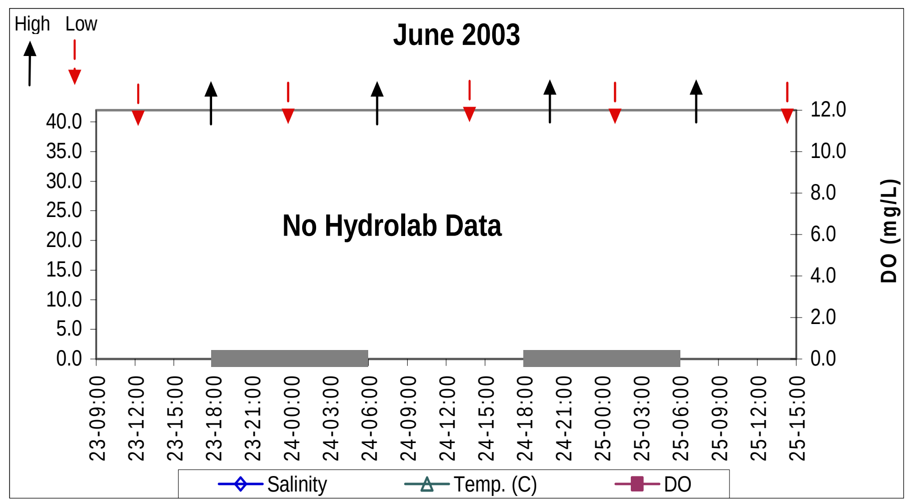


Figure 56. June 2003 Diurnal Sampling (ISCO)

Sta. 12- Mouth of the 97th Street Canal

Sta. 13- Mouth of the 91st Street Canal

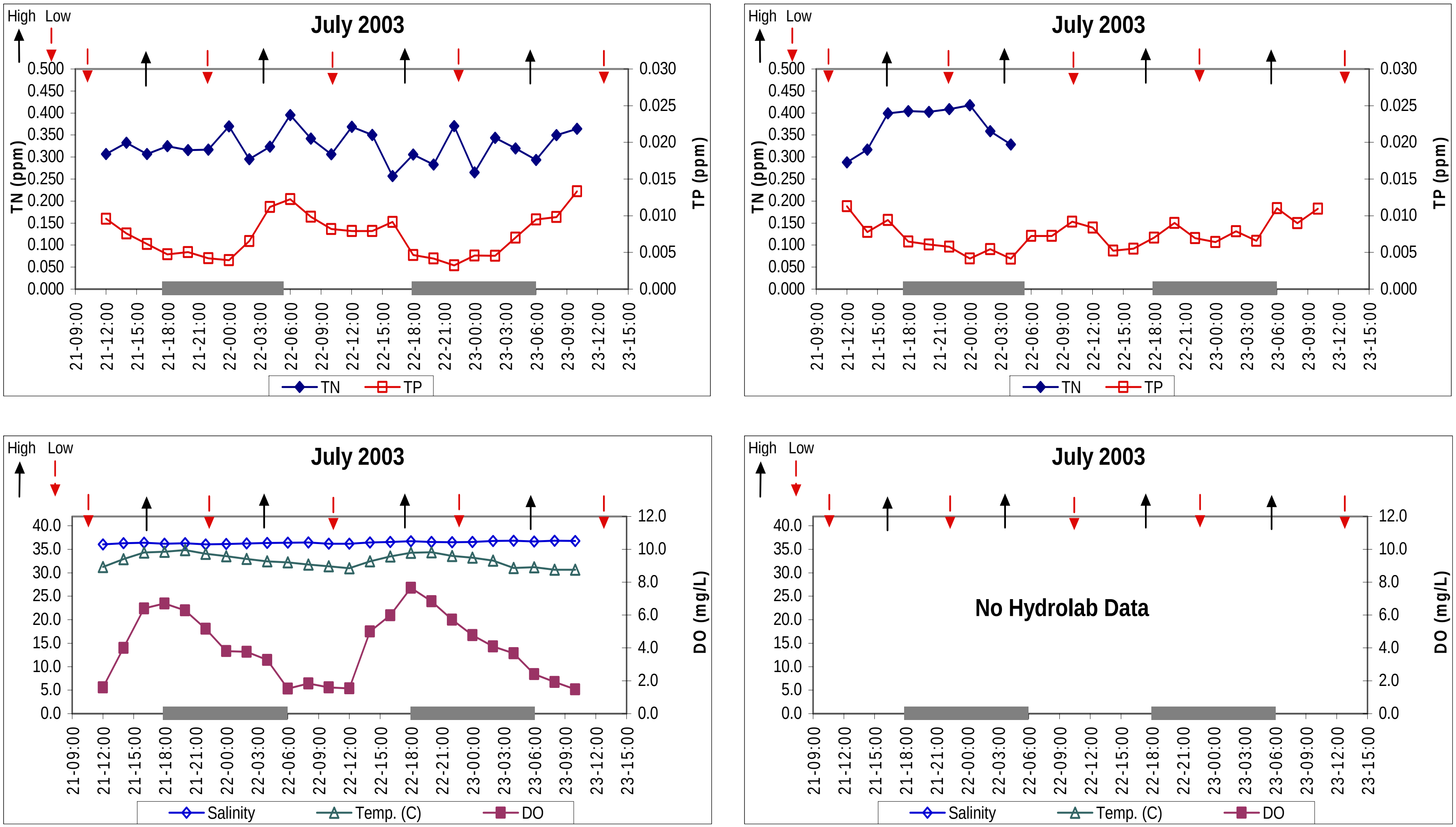
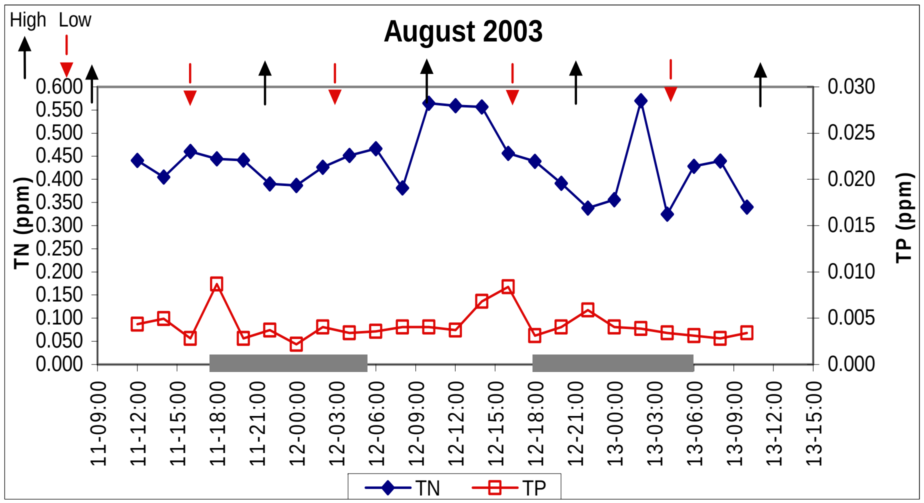


Figure 57. July 2003 Diurnal Sampling (ISCO)

Sta. 11- Mouth of the 100th Street Canal



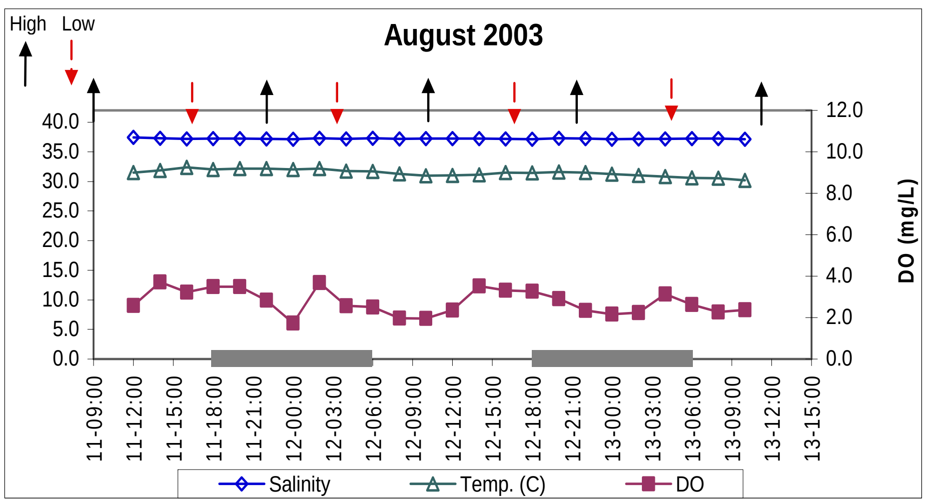


Figure 58. August 2003 Diurnal Sampling (ISCO)

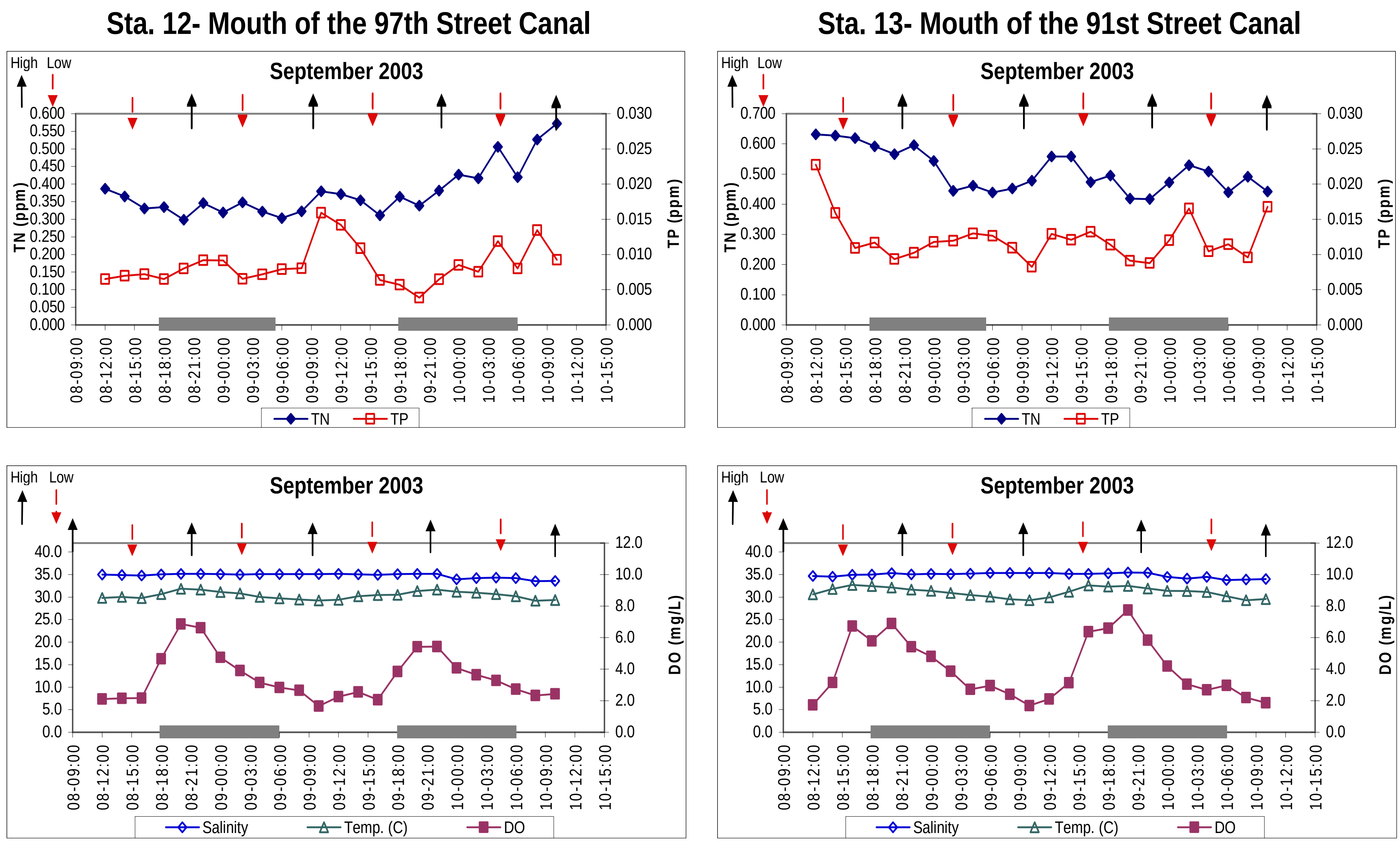
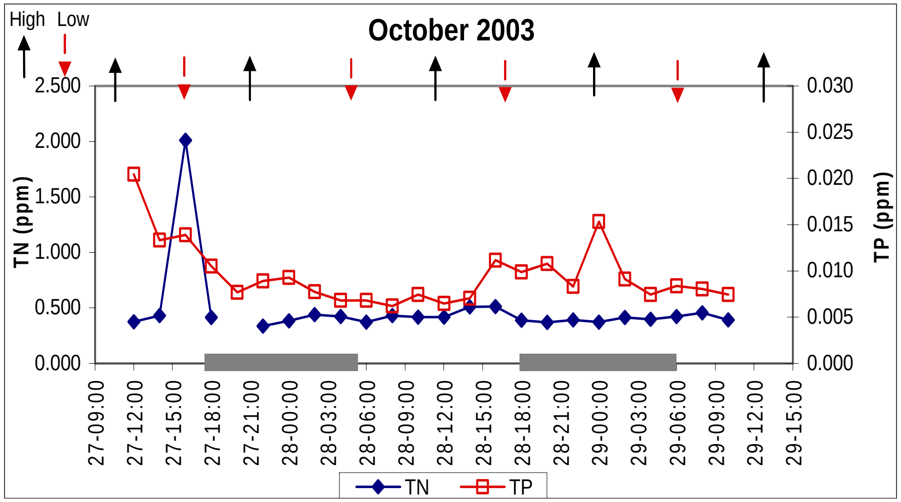


Figure 59. September 2003 Diurnal Sampling (ISCO)

Sta. 11- Mouth of the 100th Street Canal



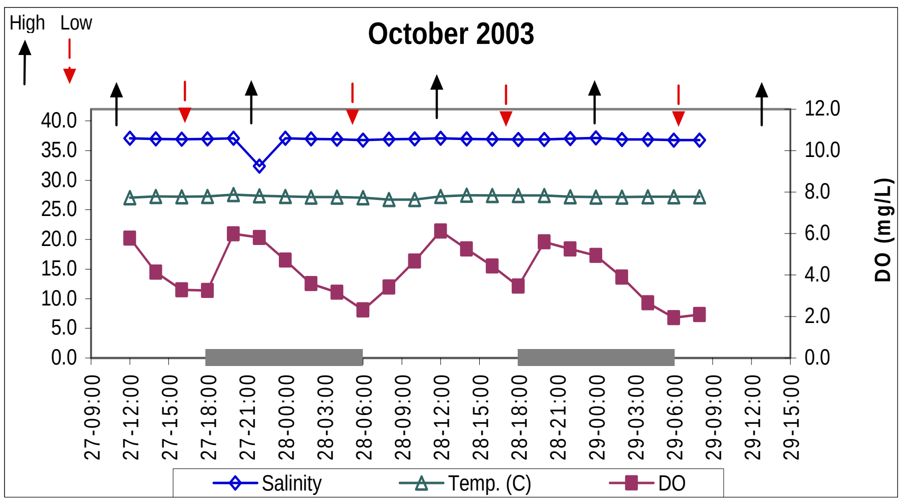


Figure 60. October 2003 Diurnal Sampling (ISCO)

Sta. 12- Mouth of the 97th Street Canal **Sta. 13- Mouth of the 91st Street Canal**

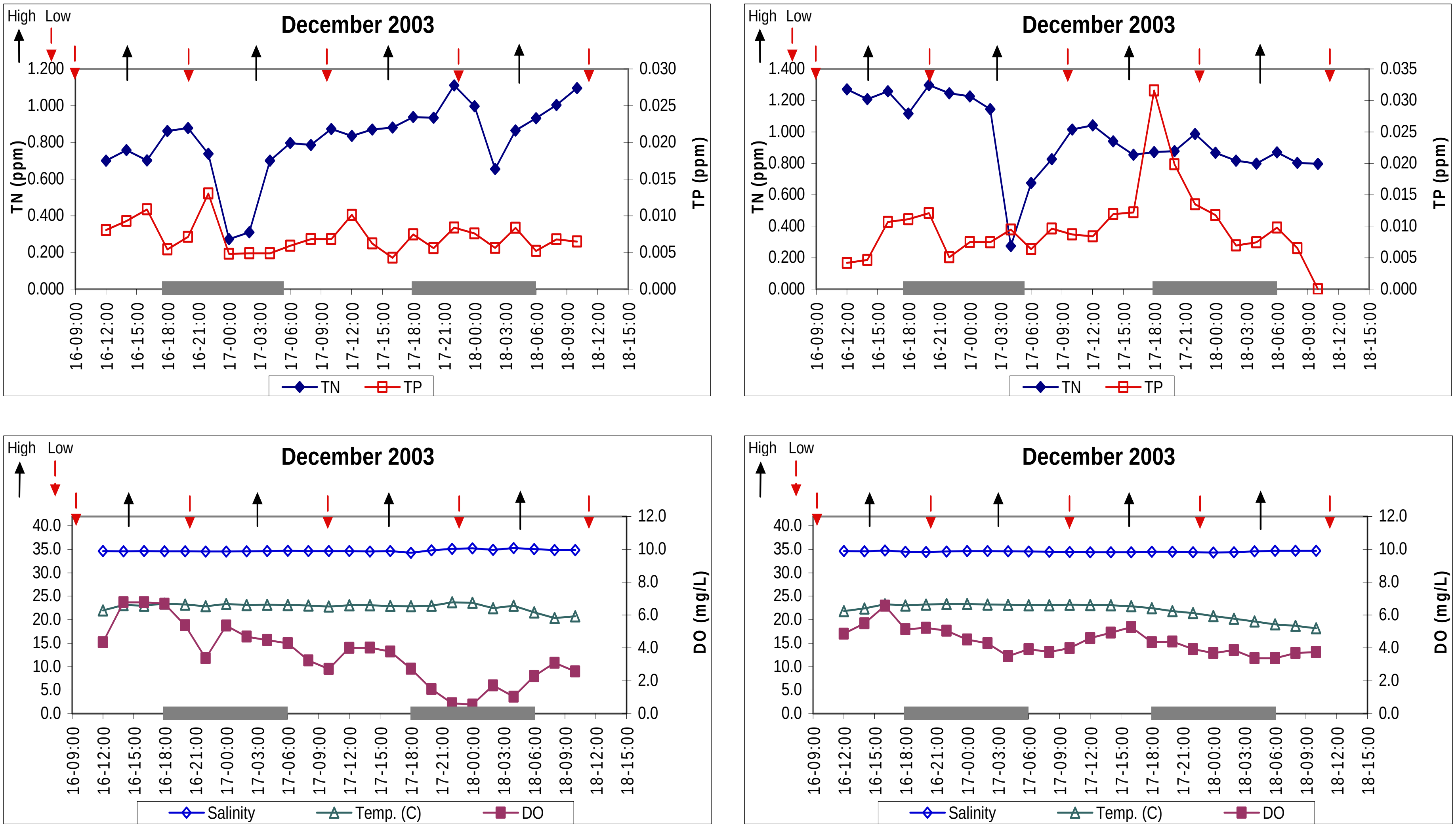


Figure 61. December 2003 Diurnal Sampling (ISCO)