3. RESULTS AND DISCUSSION

The raw data collected for this study is presented in Appendix B, Part 1. The concentration data taken at each station during the surveys is summarized in tables within each section, below. The results of the mass flux analyses also are summarized in tables within each section, following. Appendix A-2-1 provides details regarding the net flux for several constituents for each station and each sampling period while Appendix A-2-2 provides graphs of the concentration, flow and flux data.

As described in Section 2.2, above, the net mass transported into (import) or out of (export) a system was calculated for each tidal cycle. These calculations provide an estimate of the pounds per tidal cycle transported by a system. However, the systems vary significantly in size and tidal exchange volume. Therefore, to provide some perspective as to the significance of the mass transport, the net mass transported was divided by the mass carried into the system during the flood portion of the tidal cycle. This provides an estimate of the percent import or export over a tidal cycle. If less than one percent of the incoming mass was transported over a tidal cycle, it was considered to be zero net transport.

During certain tidal cycles the flow volume entering the system during the flooding portion of the tidal cycle was roughly equivalent to that exiting the system under the ebbing portion of the cycle (less than 5% difference in total flow volume). Under these conditions any significant net mass transport of a constituent can be considered to be due to some process within the system and not simply to the unbalanced flow volumes. However, during other tidal cycles the flow volume transported during one portion of the tidal cycle was far greater than that transported during the other. In these cases, any significant mass transport noted may simply be due to the larger volume of water transported during one portion of the cycle and not to any processes in the system. To eliminate the flow imbalance, a flow-weighted mass was calculated for each ebb and flood portion of each tidal cycle by dividing the total mass

$$\text{Mass Flux} = \sum_{i=t_1}^{i=t_2} (Q_i * C_i)\, \delta t$$

where:

Q_i = Flow at time i

C_i = Concentration at time i

δt = Elapsed time from i-1 to i

t_1 = Time at the start of the half tidal cycle

t_2 = Time at the end of the half tidal cycle

This equation determines the mass transported into or out of the system over a half tidal cycle. The net mass for a tidal cycle was determined by subtracting the total mass leaving the system during an ebb tide from the total mass entering the system during the corresponding flood tide.

TABLE 3.1: Concentration Data Summary - Station M1 (in mg/l)

Variable	Number of Samples	Mean	Standard Deviation	Minimum Value	Maximum Value	Coefficient of Variation
MONTH OF NOVEMBER						
$CBOD_5$	26	2.91	0.70	1.80	4.93	24.05
NH_3-N	23	3.68	0.50	2.52	4.54	13.72
NO_3-N	25	1.04	0.33	0.00	1.36	31.38
NO_2-N	23	0.37	0.04	0.29	0.43	9.86
DO	25	7.06	1.15	5.10	9.40	16.26
Salinity*	26	11.88	0.29	11.40	12.80	2.47
Chlorophyll-a	26	26.34	9.98	4.90	44.79	37.88
TKN	23	4.66	0.90	3.13	6.43	19.22
TPO_4	22	0.27	0.07	0.12	0.43	27.78
TSS	26	33.72	7.96	22.40	58.40	23.61
MONTH OF JULY						
$CBOD_5$	49	3.62	0.67	2.00	4.95	18.43
NH_3-N	49	1.30	0.33	0.88	2.02	25.48
NO_3-N	49	0.27	0.28	0.01	1.14	103.26
NO_2-N	49	0.64	0.07	0.48	0.74	10.52
DO	51	4.43	1.69	2.00	8.50	38.20
Salinity*	48	7.86	0.46	7.07	8.51	5.91
Chlorophyll-a	47	26.78	11.87	3.10	58.90	44.33
TKN	49	2.83	0.76	1.11	5.03	26.73
TPO_4	49	1.39	1.33	0.38	6.05	95.56
TSS	50	39.42	13.07	20.80	72.40	33.15

* Note: Salinity in PPT

transported by the total volume of water transported. The flow-weighted mass for the flood and ebb portions of the cycle were compared to determine whether a net increase or decrease in concentration had occurred.

Total net transport was calculated for each sampling period. That is, the data over the entire two- or four-tidal cycle sampling period was combined to provide an estimate of net flow and mass transport. In certain cases, flow balanced over two to four tidal cycles, although it did not balance for each individual cycle. One example which occurred was that a larger flood volume in one tidal cycle was followed by a smaller flood volume and a larger ebb volume in the next cycle.

Data were also collected at Stations M3, S1, S2 and S4 in Sawmill Creek. For Stations M3, S1 and S2, the flow system in the marsh was such that the system did not empty or fill through a single point. It was not possible to relate the concentration at a given time and place to the volume of water that concentration represented. Therefore, it was not possible to determine the mass transport at those locations.

The experiments conducted for this project may be classified as three separate environments: microscale mudflat; microscale marsh; and macroscale wetland. The results are discussed under these headings for each station as follows.

3.1 MICROSCALE MUDFLAT - Station M-1

Concentration data for Station M-1 is summarized in Table 3.1. A summary of the net import and export of mass is presented in Table 3.2, while more detailed tables and figures regarding results are provided in Appendices A-2-1 and A-2-2.

November Data - Comparison of the total flood water volume to total ebb water volume for each tidal cycle during November revealed transport ranging from 2.4% (import) to -39% (export) of the total flood volume entering the system. During the first cycle, net flow import of 18% was recorded. During this cycle, over 18% of the incoming mass of $CBOD_5$, NH_3-N, NO_3-N, NO_2-N, TKN, DO, salinity, TSS and TPO_4 were imported. Clearly, some of this import is due simply to the large net flow import, although the percentage import of each constituent can not be directly related to the percentage import of flow. However, a greater percentage of each of these constituents was imported than the percentage import of flow suggests. This result suggests that processes in the system are contributing to their import, and that the import noted can not all be attributed to the flow imbalance.

Flow-weighted concentrations were calculated for all constituents. These concentrations were determined by dividing the total mass on the flood or ebb tide by the respective volume during that portion of the tide. For each constituent imported above, the flow-weighted concentration was higher during the flood tide than the ebb tide, which suggests the mudflat was a sink for these parameters.

Cycle 2 showed a net flow export of 39%. As expected, all parameters (except chlorophyll-a) were exported. However, less than 36% of the incoming mass of $CBOD_5$, NH_3-N, TKN, DO, TPO_4, and TSS were exported, and $CBOD_5$ and TKN exhibited export of less than 10%. These results suggest that processes in the marsh may actually be contributing to the import of nutrients and that the overall net export may simply be attributable to the large net export of flow. Review of the flow-weighted concentration data revealed higher concentrations during the flood tide than the ebb tide for all constituents except for NO_3-N and salinity. This suggests the mudflat is acting as a sink for all parameters except NO_3-N and salinity. Salinity essentially balanced with a change in flow-weighted concentration between ebb and flood tide of -1.1%. NO_3-N showed a large net export of about 185 pounds, which is 124% of the incoming mass. Even after consideration of the net flow export, this large value suggests a source of NO_3-N in the mudflat system during Cycle 2.

Table 3.2: Summary of Import/Export Of Mass Flux in the Microscale Mudflat Experiment - Station M-1

STATION	DATE	T	CYCLE	FLOW	SALINITY	CBOD5	NH3	NO3	NO2	TKN	TOTAL N	TPO4	DO	CHL-A	TSS
M-1	11/88	D	CYCLE 1	I	I	I	I	I	E	I	I	I	I	E *	I
		N	CYCLE 2	E	E	E **	E	E	E	E **	E	E	E	I	E
		D	CYCLE 3	I *	O	E	I	E	I *	I	I	E **	E	I	I
			NET 1+2	E *	E *	I	I	E **	E	I	I *	E *	I **	I *	O
			NET 1+2+3	O	E *	I **	I	E	E	I	I	E *	E *	I *	I **
M-1	07/89	D	CYCLE 1	O	E **	E **	I	E	E	E **	E	I	E	E **	E
		N	CYCLE 2	O	E *	I	I	E	E	I	I	E	E	I	E
			NET	O	E **	I *	I	E	E	I	I **	I	E	I	E

* Less than 5% of the flood mass was transported

** Less than 10% of the flood mass was transported chlorophyll-a demonstrated export, ranging from 2.3 to 127.2 percent of the incomng mass.

Thus, for the July sampling period, consistent import of NH_3-N and export of NO_3-N, NO_2-N, DO, salinity, and chlorophyll-a occurred. The other constituents showed import over one cycle and export over the other. Salinity, expected to be a conservative tracer in the system, showed net export during both July cycles. During Cycle 2, the export was 2.3% while during Cycle 1, it was 8.2%.

Net Analysis for July - A net analysis of the July data was performed. That is, the total volume of water and mass of each constituent transported during the flood tide was summed over both tidal cycles and compared to the corresponding ebb volume and masses. In this way, the net flow balance was 0.2%. Net import of $CBOD_5$, NH_3-N, TKN, Total N, TPO_4, and TSS occurred. Large net exports of NO_2-N (over 100% of the incoming mass), NO_3-N (66.9% of the incoming mass), and to a lesser extent, DO (38% of the incoming mass) were noted.

Comparison of Sampling Periods - For both the November and July sampling periods, flow balanced when the total flood volume over the entire period was compared to the total ebb volume. Flow also balanced for each individual cycle in July, however, large imbalances in flow were observed for two of the three cycles sampled in November. When the net analyses for November and July were considered, net transport direction was consistent for most parameters with export of salinity, NO_3-N, NO_2-N, and DO and import of $CBOD_5$, NH_3-N, TKN, Total N, and chlorophyll-a. TSS was imported in November and exported in July while TPO_4 showed the opposite pattern. No parameter displayed consistent transport direction for all individual tidal cycles analyzed, although as shown in Table 3.2, many showed consistent results for all but one cycle. The consistent net results for July and November did not suggest a significant seasonal difference in transport direction for most parameters.

For Cycle 3, the incoming and outgoing flows approximately balanced with a net inflow of 139,395 cubic feet which is 2.4% of the total flood volume. The results for the net flux of water quality constituents were export of $CBOD_5$, NO_3-N, DO, and TPO_4 ranging from 7.5% to 21.5% of the incoming mass. This contradicts the results from Cycle 1 and Cycle 2 which suggest processes in the mudflat are resulting in import of $CBOD_5$, DO and TPO_4, when the large flow export during Cycle 2 is considered. NH_3-N, TKN, and TSS were imported, with percentage import ranging from 17.9 to 24.2 percent. The results over the three cycles in November are consistent import for NH_3-N and TKN (when the large export of flow during Cycle 2 is taken into account), but are inconsistent for the other parameters.

November Net Analysis - A net analysis of all three complete tidal cycles in November was done in which the flood volume and the flood mass for each constituent were summed over all three cycles and compared to the respective ebb totals. The net analysis revealed a flow balance of 0.4%, indicating no net transport of flow. Cycle 2, which showed the greatest percentage flow imbalance also had the smallest flow volume. The ebb dominance in Cycle 2 was balanced in volume by the flood dominance during Cycle 1. The net analysis revealed import of $CBOD_5$, NH_3-N, TKN, Total N, chlorophyll-a and TSS and export of NO_3-N, NO_2-N, and TPO_4. Very slight export of DO and salinity (less than 2%) were noted.

July Data - For Cycle 1, flows essentially balanced (0.3% import). NH_3-N and TPO_4 were imported at 35.2% and 47.3% of their incoming mass, respectively. Export of $CBOD_5$, NO_3-N, NO_2-N, TKN, DO, TSS, and chlorophyll-a was noted which varied from 5.2% to 113.4% of the flooding mass.

Flow also essentially balanced during Cycle 2 (0.2% import). During that cycle, import of $CBOD_5$, NH_3-N, TKN, and TSS was observed, ranging from 11.9 to 35 percent of the flooding mass. However, NO_3-N, NO_2-N, DO, salinity, TPO_4, and tidal cycles in November. This amounts to roughly 377 pounds per day or 10.8 pounds of NH_3-N per acre of mudflat per day. In July, approximately 353 pounds of NH_3-N were transported over two tidal cycles which translates to roughly 10.2 pounds per acre per day. Thus, the results of NH_3-N transport for November and July were remarkably consistent and did not show any seasonal differences. Individual cycles conformed to these transport directions, with a few exceptions. Based on the noted import of NH_3-N and export of NO_3-N and NO_2-N, the mudflat may have been importing NH_3-N from the flooding waters of Sawmill Creek and transforming the NH_3-N to NO_3-N and NO_2-N.

Total Inorganic Nitrogen (NH_3-N + NO_3-N + NO_2-N) was exported during November (119.49 lbs.) but imported during July (-181.1 lbs.). The July results are dominated by export of NO_2-N (-435.4 lbs.). As discussed elsewhere in the report, the mass of NO_2-N is unexpectedly large.

The pattern of nutrient transport observed in the Sawmill Creek mudflat is not reflected in the few available papers discussing mudflat/estuarine nutrient dynamics. In Connecticut, Welsh (1980) found that the mudflat she studied was a source of DO. She also found it was was a sink for NH_3-N, NO_3-N and NO_2-N in July and August, and a source of these nutrients in late October. In the other studies NH_3-N typically was exported while NO_3-N and NO_2-N were imported at lower salinities and exported at higher salinities. The lack of literature in systems with similar hydrodynamic and chemical conditions as the Hackesnsack River, as well as the difficulties noted in Section 1.3, preclude a complete comparison of these results to other studies.

Again, it must be remembered that the results presented in this section represent one short-term study and certainly can not be considered definitive. Additional data would be needed to determine if the conclusions reached herein are truely representative of the Sawmill Creek mudflat.

On the basis of these results, the mudflat appears to provide a source of DO to the tidal waters that inundate it, although it is only a very slight source in November. It is also a source of NO_3-N and NO_2-N and a sink for NH_3-N, $CBOD_5$, TKN and total nitrogen.

The source of DO in the mudflat may be physical reaeration of the water as it flows over the shallow mudflats, photosynthetic activity, a combination of these, or some other process. It is not possible to determine the source of the DO in the system based on the available data. No diurnal pattern was noted in the DO data. In fact, the only cycle which showed import of DO was a day cycle. However, as noted in Section 1.2, the uptake of DO during respiration tends to be far less significant than the production of DO during photosynthesis. In addition, physical reaeration is probably the key factor in DO production.

Over the three tidal cycles in November, approximately 127 pounds of DO were transported which is roughly 85 pounds per day or 2.4 pounds per acre per day. Over the two cycles in July, approximately 1,160 pounds of DO were exported or roughly 33.3 pounds per acre per day. These results may suggest that although the direction of transport does not vary with the season, the magnitude is far greater during the summer months. However, it must be noted that the November data were inconsistent and flows did not always balance. These results are not unexpected. The waters flowing into the marsh onto the mudflat in November would probably be better oxygenated than those in July. Thus, the same processes may not cause as great an increase in DO concentrations in November as in July. Thus, further data are needed to explore seasonal differences.

The net analyses for both sampling periods (comparison of total flood mass to total ebb mass over the entire sampling period) indicated import of NH_3-N and TKN and export of NO_3-N and NO_2-N. About 565 pounds of NH_3-N were imported over three

3.2 MICROSCALE MARSH - STATION M-2

Concentration data for Station M2 are summarized in Table 3.3 and a summary of the import or export of mass in the system is provided in Table 3.4. Appendices A-2-1 and A-2-2 contain more detailed tables and figures regarding net transport at this station.

November Data - During Cycle 1, flows balanced (-0.2%). Import occurred for $CBOD_5$, NH_3-N, and TKN and export occurred for NO_3-N, DO, salinity, TPO_4, and TSS. The largest net percentage transport was TPO_4 and NO_3-N at 36.7% and 15.1%, respectively.

During Cycle 2, a flow balance of 0.7% (import) was found. Export of NO_3-N, salinity, TPO_4, chlorophyll-a, and TSS and import of $CBOD_5$, NH_3-N, TKN and DO was observed. TPO_4 and chlorophyll-a demonstrated export of more than 50% of the incoming mass; DO showed import of about 34% of the incoming mass.

During Cycle 3, flow balanced. During this cycle $CBOD_5$, NH_3-N, TKN, TPO_4 and TSS were imported, while NO_3-N, DO, salinity, and chlorophyll-a were exported. The most significant imports were 30.7% of the incoming mass of $CBOD_5$, 18.9% of NH_3-N, 30.5% of TSS and 16.8% of TKN.

Cycle 4 showed slight export of flow of -1.5%. DO, salinity, TPO_4 and TSS were exported while the other constituents were imported. The constituents demonstrating the largest transport, based on percentage of the incoming mass, were DO at 23.7%, TPO_4 at 33.7% and chlorophyll-a at 53.9%.

Overall, for the November sampling period, consistent import over all four tidal cycles was observed for $CBOD_5$, NH_3-N, and TKN. Salinity showed consistent export over all four tidal cycles while DO, TPO_4 and NO_3-N demonstrated export during three out of four cycles.

TABLE 3.3: Concentration Data Summary - Station M2 (in mg/l)

Variable	Number of Samples	Mean	Standard Deviation	Minimum Value	Maximum Value	Coefficient of Variation
			MONTH OF NOVEMBER			
$CBOD_5$	32	2.07	0.66	0.80	4.35	32.16
NH_3-N	33	2.51	0.55	1.70	4.41	22.11
NO_3-N	33	1.17	0.11	1.02	1.48	9.56
NO_2-N	33	0.40	0.30	0.31	0.46	8.33
DO	34	5.97	1.20	3.60	9.10	20.01
Salinity*	34	12.44	0.87	9.79	14.40	7.01
Chlorophyll-a	34	15.87	8.37	1.42	32.71	52.75
TKN	33	3.56	0.76	2.69	6.14	21.41
TPO_4	33	0.26	0.09	0.10	0.44	34.70
TSS	34	46.92	14.91	22.30	76.00	31.78
			MONTH OF JULY			
$CBOD_5$	54	2.32	0.83	0.80	4.85	35.83
NH_3-N	53	0.99	0.29	0.13	1.46	29.80
NO_3-N	53	0.25	0.31	0.00	1.81	123.62
NO_2-N	53	0.47	0.28	0.06	0.90	59.31
DO	53	2.39	0.76	1.20	4.10	31.85
Salinity*	52	8.46	1.32	7.07	16.10	15.64
Chlorophyll-a	47	15.81	10.65	2.94	51.60	67.35
TKN	53	2.69	0.86	1.48	4.48	31.83
TPO_4	53	0.92	0.60	0.22	2.32	65.85
TSS	54	96.27	96.86	23.20	427.00	100.62
			MONTH OF AUGUST			
$CBOD_5$	46	2.80	0.72	1.60	5.10	25.82
NH_3-N	46	0.90	0.42	0.35	1.89	46.97
NO_3-N	46	0.46	0.32	0.03	1.00	68.45
NO_2-N	46	0.43	0.31	0.04	0.90	72.02
DO	46	3.18	1.45	1.20	6.70	45.77
Salinity*	46	11.99	1.08	9.96	14.65	9.02
Chlorophyll-a	46	14.11	10.86	2.35	55.50	76.97
TKN	46	2.01	0.94	1.00	7.11	46.66
TPO_4	46	0.89	0.56	0.40	3.58	62.35
TSS	46	62.97	71.80	14.00	517.00	114.01

* Note: Salinity in PPT

Table 3.4: Summary of Import/Export Of Mass Flux in the Microscale Marsh Experiment - Station M-2

STATION	DATE	T	CYCLE	FLOW	SALINITY	BOD5	NH3	NO3	NO2	TKN	TOTAL N	TPO4	DO	CHL-A	TSS
M-2	11/88	D	CYCLE 1	O	E *	I	I **	E	I *	I	I *	E	E *	O	E **
		N	CYCLE 2	O	E *	I	I	E	E **	I	I	E	I	E	E *
		D	CYCLE 3	O	E *	I	I	E	E *	I	I **	I	E *	E	I
		N	CYCLE 4	O	E *	I	I	I *	O	I	I **	E	E	I	E
			NET	O	E *	I	I	E	E *	I	I	E	I *	E **	I **
M-2	07/89	D	CYCLE 1	O	E *	E **	I	E	I	I	I	E	E	I	E *
		N	CYCLE 2	O	E	I **	I	I	I	I	I	E	E *	O	I
			NET	O	E	O	I	E	I	I	I	E	E	I	I
M-2	08/89	D	CYCLE 1	O	E **	E	I	I	I **	E *	I *	I	E	E	I
		N	CYCLE 2	O	E *	I	E	I **	I	I	I	E *	I	I	I **
			NET	O	E *	E *	E *	I	I **	I	I	I *	E	E **	I **

M1 = TIDAL MUDFLAT EMBAYMENT STATION
M2 = TIDAL MARSH IMPOUNDMENT STATION

O = CHANGE IN MASS ≤ 1.0%
* = CHANGE IN MASS ≤ 5.0%
** = CHANGE IN MASS ≤ 10.0%

D = DAYTIME
N = NIGHTTIME

Net Analysis for November - A net analysis of the entire sampling period was conducted which compared the total flood mass for all four cycles to the total ebb masss. This analysis revealed import of $CBOD_5$, NH_3-N, TKN, Total N and TSS. Surprisingly, DO also showed net import even though it demonstrated export on three of four individual cycles. Export of salinity, NO_3-N, NO_2-N, TPO_4, and chlorophyll-a were noted, although the salinity export was generally less than 5%.

July Data - Comparison of flood and ebb flows for the first tidal cycle showed export of 0.6% of the incoming flow. Import occurred for NH_3-N, NO_2-N, and TKN. Export was noted for the other variables with 101.1% of the incoming NO_3-N mass flowing out of the system. DO showed net export of about 72.2% of the incoming mass or about 19 pounds. With the exception of $CBOD_5$ (6.4%) and salinity and TSS (approximately 3%), the other constituents showed net transport in the range of 20% to 35% of the incoming mass.

Flows also balanced for Cycle 2. During that cycle $CBOD_5$ was imported as were NH_3-N, NO_3-N, NO_2-N, TKN, and TSS. The other constituents were exported. Thus, over the two cycles consistent import was seen for NH_3-N, NO_2-N, and TKN and consistent export for DO, TPO_4, and salinity. It should be noted that the net mass of DO exported during Cycle 1 was about 19 pounds or about 71% of the incoming mass while during Cycle 2 less than 1 pound (1.8%) of DO was exported.

Net Analysis for July - A net analysis was conducted for the July data, comparing the sum of the mass transported during the flood tide in both cycles to that transported during the ebb tide for each constituent. The results showed export of salinity of more than 10%, as well as export of NO_3-N, TPO_4, and DO and import of NH_3-N, NO_2-N, TKN, total N, chlorophyll-a, and TSS. These results generally were consistent with the results for the individual tidal cycles.

August Data - The flow balanced within 69 cubic feet for each cycle in August. During the first cycle, NH_3-N, NO_3-N, NO_2-N, TPO_4, and TSS were imported. During the second cycle, $CBOD_5$, NO_3-N, NO_2-N, TKN, DO, and TSS were imported; the constituents not listed were exported. Thus, only NO_3-N, NO_2-N, salinity and TSS showed a consistent transport pattern during the two cycles.

Net Analysis for August - A net analysis comparing total flood mass over both August cycles to total ebb mass revealed export of salinity, $CBOD_5$, NH_3-N, DO and chlorophyll-a and import of the other parameters. The net transport of salinity, $CBOD_5$, NH_3-N, and TPO_4 represented less than 5% of the incoming mass.

Comparison of Sampling Periods - Comparing the July and August data, import of NO_2-N and Total N and export of salinity were the only consistencies in transport direction over all four tidal cycles. However, comparison of the net analyses (combining both tidal cycles for each month) revealed consistent import of TKN, TSS, NO_2-N and Total N and consistent export of DO and salinity. The other parameters showed export during one sampling period and import during the other.

Comparison of all three sampling periods revealed that flow was balanced and salinity exported in each of the eight tidal cycles. During most of the cycles, export of salinity accounted for less than 5% of the incoming mass. For all other parameters, transport direction was inconsistent in at least one tidal cycle. However, comparison of the net results (combining two tidal cycles in July and August and all four in November) among the sampling periods revealed net import of TKN, Total N and TSS for all three periods. As shown in Table 3.2, the other parameters showed inconsistent results with no discernible seasonal pattern across all parameters. NH_3-N, NO_3-N, and TPO_4 showed the same transport direction for November and July but the opposite for August, while NO_2-N and DO showed the same pattern for July and August with the opposite result in November. Thus, no clear seasonal pattern was revealed.

An unusual pattern was noted in the data, in that a larger net mass of NO_2-N than NO_3-N was transported on both the ebb and flood tides in July and August. This was caused by the higher concentrations of NO_2-N measured in the system over much of the July and August sampling periods. The typical relationship between NO_3-N and NO_2-N in natural waters is that NO_3-N concentrations are higher than NO_2-N concentrations because NO_2-N is usually oxidized quickly to NO_3-N. The reason for the unusual pattern at Station M2 can not be determined from the available data.

In reviewing the seasonal data, it is important to recall that slightly different methods were used to sample the marsh during the November, 1988 sampling period than during July and August, 1989. As discussed in Section 2.3, above, during November, sampling occurred only when the marsh surface was covered with water. The methods were refined in July and August so that sampling occurred throughout the tidal cycle. As expected, flows did not balance as well for the November sampling period as they did for the summer sampling. Thus, the July and August data should be considered more reliable than the November data.

Based on the net results for each sampling period described above, the marsh is a source of DO in the summer months and a slight sink in November, although in three of the four indiviual cycles in November the marsh was a source of DO. The marsh is also a sink for ammonia in two of three periods (July and November) and a slight source in the other; a source of nitrate in those same two periods and a sink in the other; and a sink for TKN and Total N in all three periods. Salinity shows a small, but consistent, export.

The DO results suggest reaeration of flooding waters under summer conditions. This is likely the result of both physical and biochemical processes, with physical processes more important. The export of DO during the summer months amounts to about 19.9 pounds over two tidal cycles or approximately 6.2 pounds per acre per day in

July and about 10.9 pounds over two tidal cycles in August or approximately 3.4 pounds per acre per day.

The import of NH_3-N and export of NO_3-N in November and July suggests that nitrification may have occurred in the marsh. The opposite pattern was noted in August, when NO_3-N was imported and NH_3-N was exported. However, NH_3-N was imported during Cycle 1 in August which is consistent with the July and November results. Cycle 2 showed the opposite pattern, as did the net analysis for August. During Cycle 2 in August, a much smaller total mass of ammonia was imported on the flood tide than in any other summer cycle (approximately 8 pounds compared to an average of 12.9 pounds for the other three summer cycles). The mass exported in the ebb flow was 11.2 pounds, larger than the average ebb mass of 10.1 pounds for the other three cycles but still smaller than the average inflow of 12.9 pounds.

As noted above, the NO_3-N/NO_2-N concentrations for the summer months had an unusual pattern. In the first three summer cycles, NO_2-N concentrations were larger than NO_3-N concentrations under both flood and ebb conditions. In five of the six half-tidal cycles during that period, the total mass of NO_2-N transported was more than double the total mass of NO_3-N. However, during Cycle 2 in August the expected pattern occurred with the total mass of NO_3-N transported two to three times the total mass of NO_2-N. The total mass of NO_3-N plus NO_2-N transported in August was in the same range as that in July. Thus, Cycle 2 in August differs from the other three summer cycles in transport dynamics of NH_3-N and NO_3-N/NO_2-N. That cycle also indicated an import of DO of almost 40%, compared to consistent export of DO during the other three summer cycles. Although flow balanced during Cycle 2 in August, the total volume flooding the system was 12.5% less than during Cycle 1 in August and about 17.6% less than the average flood volume in July.

Clearly, the hydrodynamics and chemistry of Cycle 2 in August were vastly different from those in Cycle 1 in August and in both cycles in July, which were all quite similar. The fact that these differences occured for flow and for several quality parameters suggest some actual phenomenom, as opposed to error in measurement of some specific data. However, without additional data, it is not possible to even speculate on the reason for this variation.

Ignoring Cycle 2 in August for the moment, then, NH_3-N was imported by the marsh. A total of about 8.3 pounds of NH_3-N was imported to the marsh over the three summer cycles, which is about 5.5 pounds per day or about 1.7 pounds per acre of marsh per day. The NO_3-N results are less consistent, although net export occurred in July, import occurred in Cycle 1 during August. The same pattern of NH_3-N and NO_3-N transport was observed in November when about a total of about 16 pounds of NH_3-N was transported over 4 cycles. This is roughly equivalent to 8 pounds per day or 2.5 pounds per acre per day. These results must be considered preliminary estimates, particularly because of the inconsistent data in August.

Total N was imported over all tidal cycles in the marsh. This is primarily because TKN was imported and TKN dominates the Total N calculations. Total Inorganic N (NH_3-N + NO_3-N + NO_2-N) was imported during November (10.3 lbs.), July (7.7 lbs.) and August (3.53 lbs.).

3.3 MESOSCALE EXPERIMENTS

3.3.1 Sawmill Creek - Station S3

Table 3.5 summarizes the concentration data at Station S3 while Table 3.6 summarizes the mass transport results. Appendices A-2-1 and A-2-2 provide further detailed tables and figures regarding these results.

November Data - For Cycle 1, comparison of the total volume of flow during the flood tide to that during the ebb tide revealed a net export of 0.1%, that is flows essentially balanced. Export of $CBOD_5$, NH_3-N, NO_2-N, TKN, Total N, DO, TPO_4,

TABLE 3.5: Concentration Data Summary - Station S3 (in mg/l)

Variable	Number of Samples	Mean	Standard Deviation	Minimum Value	Maximum Value	Coefficient of Variation
MONTH OF NOVEMBER						
$CBOD_5$	24	2.29	1.06	1.10	5.58	46.21
NH_3-N	24	2.83	0.90	1.25	4.49	31.63
NO_3-N	24	1.47	1.92	0.95	10.47	130.19
NO_2-N	24	0.40	0.05	0.22	0.44	13.01
DO	24	5.31	1.52	3.00	9.30	28.56
Salinity*	24	12.73	1.19	11.60	17.10	9.39
Chlorophyll-a	24	12.30	6.72	1.10	27.84	54.64
TKN	24	3.90	1.28	2.03	6.90	32.92
TPO_4	24	0.27	0.08	0.10	0.39	31.42
TSS	24	43.93	15.51	27.20	84.00	35.31
MONTH OF JULY						
$CBOD_5$	13	1.94	0.79	0.85	3.25	40.55
NH_3-N	13	0.13	0.51	0.27	2.12	45.21
NO_3-N	13	0.26	0.16	0.02	0.48	60.99
NO_2-N	13	0.67	0.07	0.58	0.81	10.61
DO	13	2.66	1.71	1.30	6.50	64.30
Salinity*	13	8.97	0.88	7.61	10.50	9.80
Chlorophyll-a	13	4.38	5.20	1.47	20.10	118.71
TKN	13	2.09	0.86	0.98	3.65	41.17
TPO_4	13	0.69	0.15	0.48	1.00	21.28
TSS	13	65.07	55.84	21.20	210.00	85.82
MONTH OF AUGUST						
$CBOD_5$	12	3.10	0.87	1.95	4.50	27.92
NH_3-N	12	1.05	0.49	0.07	1.85	46.84
NO_3-N	12	0.79	0.15	0.58	1.08	19.42
NO_2-N	12	0.36	0.03	0.33	0.42	7.59
DO	12	4.40	2.60	1.80	11.30	59.15
Salinity*	12	11.66	1.39	8.15	13.75	11.96
Chlorophyll-a	12	16.16	10.02	7.89	36.40	62.04
TKN	12	2.10	0.64	1.23	3.24	30.53
TPO_4	12	0.67	0.22	0.40	1.19	33.27
TSS	12	73.28	28.57	38.40	116.00	38.99

* Note: Salinity in PPT

Table 3.6: Summary of Import/Export of Mass Flux in the Sawmill Creek System - Station S-3

STATION	DATE	T	CYCLE	FLOW	SALINITY	BOD5	NH3	NO3	NO2	TKN	TOTAL N	TPO4	DO	CHL-A	TSS
S-3	11/88	D	CYCLE 1	O	I **	E	E	E *	E	E	E	E	E	E	E
		N	CYCLE 2	O	I *	E	E **	E	O	E **	E	E	E *	E	E
		D	CYCLE 3	O	O	E	E	O	I *	E *	I	I	E	E	I
			NET 1+2	O	I **	E	E	E	E	E	E	E	E	E	E
			NET 1+2+3	O	I *	E	E	E	E **	E **	E **	E *	E	E	E *
S-3	07/89	D	CYCLE 1	O	E *	E	I **	O	I	E **	O	I	E	E	E
		N	CYCLE 2	E *	E **	I	E	E	I **	E	E	I **	I	O	I
			NET	O	E **	E	E **	E	I **	E **	E **	I	E	E	E
S-3	08/89	D	CYCLE 1	O	E	I *	I	O	I **	E	I	E	E	E	I **
		N	CYCLE 2	E *	I *	I	E **	I	O	I	I	I	I	I	I **
			NET	E *	E *	I	I	I **	I **	I **	I	E **	I *	E *	I **

S3 = SAWMILL CREEK AT NJ TPKE

O = CHANGE IN MASS ≤ 1.0%
* = CHANGE IN MASS ≤ 5.0%
** = CHANGE IN MASS ≤ 10.0%

D = DAYTIME
N = NIGHTTIME

chlorophyll-a, TSS and, to a limited extent, NO_3-N (1.7%) were noted. Salinity was imported.

For Cycle 2, flow showed an import of 0.2%, with the same pattern of export of all parameters except salinity. During Cycle 2, export of NO_3-N was 127.8% of the incoming mass compared to 1.7% export during Cycle 1.

Flows balanced in Cycle 3 (-0.2%). $CBOD_5$, NH_3-N, DO, chlorophyll-a, and, to a lesser extent, TKN were exported. NO_3-N and Total N showed essentially no net transport, while NO_2-N was slightly imported (3%). Sufficient data were not available for a complete analysis of Cycle 4.

Net Analysis for November - Calculation of net flow for the entire November sampling period (total flood volume over all three cycles compared to total ebb volume over those cycles) showed essentially total balance. The net analysis revealed export of $CBOD_5$ (18%), NH_3-N (20%), NO_3-N (32%), NO_2-N (6.9%), TKN (6.9%), Total N (12.7%), DO (34%), TPO_4 (2.2%), chlorophyll-a (88.3%) and TSS (3.6%); salinity was imported (3.5%).

July Data - For Cycle 1 in July, flow balanced within 0.2%. BOD_5, TKN, DO, salinity, chlorophyll-a, and TSS were exported, NH_3-N, NO_2-N, and TPO_4 were imported, and NO_3-N and Total N showed essentially no net transport.

During Cycle 2, flow balanced at -1.3%. NH_3-N, NO_3-N, TKN, Total N, and salinity were exported while $CBOD_5$, NO_2-N, DO, TPO_4 and TSS were imported. Thus, only NO_2-N, TKN, and TPO_4 showed consistent results over both cycles in July.

Net Analysis for July - The net analysis comparing the sum of the flood data over both cycles to the ebb tide data revealed that total flow essentially balanced. Net export was calculated for $CBOD_5$, NH_3-N, NO_3-N, TKN, Total N, DO, salinity, and chlorophyll-a and net import for NO_2-N, TPO_4, and TSS.

August Data - During Cycle 1 in August, flows essentially balanced (0.9%). $CBOD_5$, NH_3-N, NO_2-N, Total N, and TSS were imported and the other parameters were exported, except for NO_3-N which showed essentially no net transport.

During Cycle 2, export of flow occurred (-4.0%). $CBOD_5$, NO_3-N, TKN, Total N, DO, salinity, TPO_4, chlorophyll-a and TSS were imported. NH_3-N was exported while NO_2-N showed no net transport. Thus, consistent transport directions occurred during both cycles for $CBOD_5$, Total N, and TSS only.

Net Analysis for August - The net analysis combining data for both tidal cycles in August revealed net flow export of -1.5%. Review of total mass transport indicated net import of $CBOD_5$, NH_3-N, NO_3-N, NO_2-N, TKN, Total N, DO and TSS and export of salinity, chlorophyll-a and TPO_4.

Comparison of Sampling Periods - The net analyses for each sampling period were compared; that is the volume and mass of each constituent transported during the flood portions of each tidal cycle was summed for each sampling period and compared to the total ebb volume and mass. Review of these net analyses revealed no net flow transport, except for slight (<2%) export in August. Only chlorophyll-a showed consistent transport results (export) for all three months. Differences in the results among the sampling period would not be surprising if a consistent seasonal pattern had been found. That is, July and August data, taken only two weeks apart, would be expected to be more similar than either of those would be to the November data. However, the November and July data showed the same net transport direction for $CBOD_5$, NH_3-N, NO_3-N, TKN, Total N, DO, and chlorophyll-a. The July and August data were the same only for salinity, NO_2-N and TSS. Thus, there did not seem to be a consistent seasonal pattern to the results, although August was consistently different.

Station S3 is located in a portion of Sawmill Creek in which mudflats are the predominant ecological system, although some marsh areas do exist particularly adjacent to the Creek. Thus, the results of the microscale marsh and mudflat experiments, also located in Sawmill Creek, were analyzed in relation to the results obtained at Station S3. DO was exported at Station S3 during November and July but imported in August based on the net transport analyses. The November and July data are consistent with the results of the marsh and mudflat studies. The net results from August are inconsistent with those at Stations M1 and M2, as are results from one tidal cycle in July. Station S3 showed the same change in net transport direction between the July and August sampling periods as Station M2 (the microscale marsh) for both NH_3-N and NO_3-N. No data were available at Station M1 (the microscale mudflat) in August. During November and July, the mudflat showed net import of NH_3-N, TKN and Total N and export of NO_2-N and NO_3-N. The same pattern occurred at S3 for NO_2-N, but the opposite pattern occurred at Station S3 for NH_3-N, TKN and Total N.

The lack of consistency in the nitrogen results and the DO results in August between Station S3 and Stations M1 and M2 may suggest that some other factor is affecting the transport dynamics at Station S3. Two large HMDC sanitary landfills are located on Sawmill Creek upstream of Station S3. Thus, if leachate from these landfills is entering Sawmill Creek it may be affecting the DO and nutrient exchange dynamics at Station S3. Therefore, in a digression from the experimental results, the following paragraphs summarize the data regarding water quality in the leachate from the HMDC landfills.

Landfill Data - Two sanitary landfills operated by HMDC are located at the head of Sawmill Creek. These are called the 1C and the Balefill Landfills. No data were available that measured the rate of flow or quality of any leachate that directly entered the Creek. However, several wells monitor the leachate at the perimeter of these landfills. Figure 3.1 shows the location of these wells in relation to Sawmill Creek. In order to examine the possible affect of the landfill complex on water quality of the Sawmill Creek system and consequently the Hackensack Estuary, data from these wells were examined. Tables 3.7 and 3.8 summarize the water quality from these results for the past three years.

Data were collected quarterly, however an analysis of Variance (ANOVA) statistical test on quarterly data revealed no seasonal patterns in the data for BOD_5, NH_4, pH, COD, TDS, lead, TOC, or zinc at Well 1C-1. Significantly higher NO_3 concentrations were noted in April at Well 1C-1 for the two measurements taken at that time. At Well 1C-2, NH_4, and NO_3 concentrations were higher during April (based on two measurements in each season) at the 5% and 1% test levels, respectively. No other constituents showed seasonal patterns. At Well 1C-3, NO_3 concentrations again were significantly greater in April than in the other four seasons but no seasonal patterns were noted for the other parameters. Review of all the data revealed that NO_3 concentrations from April at all wells was consistently an order of magnitude greater than that measured in other months. It must be noted, however, that the April data generally was taken only two times during the 1987 to 1989 study period, while data were taken three times in the other seasons.

Review of Table 3.7 reveals that ammonia concentrations varied from a minimum of 24.5 mg/l at Well 1C-1 to a maximum of 2,616.6 mg/l at Well 1C-3 and averaged 530.4 mg/l, 636.9 mg/l and 1064.2 mg/l at Wells 1C-1, 1C-2 and 1C-3, respectively. These concentrations contrast dramatically with concentrations in the range of 0.4 mg/l to 10.1 mg/l in Sawmill Creek at Station S4 at the head of Creek adjacent to the landfills and 0.07 to 4.49 mg/l at Station S3 in Sawmill Creek at the crossing of the New Jersey Turnpike. The instream concentrations seem to suggest that NH_3-N levels were higher at Station S4. Because of difficulties in calculating flow at Station

Table 3.7: Summary of Water Quality Data from HMDC/MSLA 1C Sanitary Landfill 1987-1989

Well No.	STAT	BOD_5 mg/L	COD mgN/L	NH_4 mgN/L	NO_3 mgN/L	pH SU	TDS mg/l	TOC ppm	Pb ug/L	Zn ug/L
1C-1	MEAN	75.4	12982.2	530.4	33.4	7.5	7119.7	995.2	131.4	222.5
	STDEV	34.8	34613.4	440.9	49.7	0.4	847	579.1	150	116
	MIN	10.0	479.9	24.5	5.5	6.8	5625	8	10	128
	MAX	138.0	111458.0	1016.4	143.0	8.3	8878	2160	500	492
	N	10	10	10	10	10	10	9	10	10
1C-2	MEAN	90.0	4430.8	636.9	45.5	7.5	9397.5	1463.6	239.6	352.7
	STDEV	54.1	2736.1	497.7	60.8	0.4	713.0	1003.1	131.6	170.4
	MIN	10.0	465.4	44.8	7.9	7.0	8424.0	146.0	10.0	192.0
	MAX	168.8	8055.0	1337.8	162.9	8.2	10447.0	3360.0	460.0	644.0
	N	9	8	8	9	9	9	8	9	9
1C-3	MEAN	123.1	3693.9	1064.2	41	7.5	19997.7	1362.8	194.2	561.3
	STDEV	34.8	2272.3	766.9	57.4	0.4	32019.3	754	140.5	613.7
	MIN	10	472.6	35	6.7	7	8742	763	10	149
	MAX	138	8103	2616.6	154.4	8.4	111086	3264	430	2203
	N	10	9	10	10	10	10	9	10	10

Source: HMDC Data

TABLE 3.8: Summary of Water Quality Data from HMDC Balefill Sanitary Landfill 1987-1989

Well No.	STAT	BOD_5 mg/L	COD mgN/L	NH_4 mgN/L	NO_3 mgN/L	pH SU	TDS mg/l	TOC ppm	Pb ug/L	Zn ug/L
BF-2	MEAN	28.2	958.9	425.4	10.8	7.0	7558.7	554.9	132.0	149.0
	STDEV	8.7	625.2	138.7	9.4	0.4	12832.5	443.3	122.2	121.9
	MIN	10.0	8.5	40.3	2.1	6.5	2819.0	2.9	10.0	42.5
	MAX	37.5	2121.0	544.6	31.2	8.0	46228.0	1621.0	370.0	415.0
	N	11	11	11	11	11	11	9	11	11

Source: HMDC Data

S4, it was not possible to directly compare the loading of NH_3-N at these two stations. Differences in concentrations may be the result of actual loading differences or of different flow volumes at each station. However, salinity is a conservative substance and analysis of the data at the two stations does not reveal differences in salinity great enough to suggest that the volume of flow at one station is significantly greater than at the other. The variation in in-stream concentrations, however, preclude any statistical comparison of data between Stations S3 and S4.

Nitrate concentrations range from 5.5 to 162.9 mg/l in the leachate, compared to ranges of 0.05 to 1.19 mg/l at Station S4 and 0.02 to 10.5 mg/l at Station S3 in the Creek.

The high concentrations of these constituents in the leachate reveal the potential for a significant source of these constituentsto Sawmill Creek and thus, the main stem of the Hackensack River. However, lack of knowledge of the hydraulics of the ground water - surface water interaction at the landfills precludes a analysis of specific loading rates. The possible impact of the landfills on Sawmill Creek is discussed in further detail, below.

Overall Analysis of the Sawmill Creek System - As noted above, the Sawmill Creek system results were not entirely consistent. In November, 1988 and July, 1989, the net analyses for each sampling period revealed consistent export of the nitrogen series parameters (except NO_2-N which was imported in July), as well as $CBOD_5$. During August, all nitrogen series parameters were imported. The data are not sufficient to explain the transport reversal in August. Do was imported during the summer sampling periods.

Considering the July and November data for NH_3-N, net export occurred at Station S3. As noted above, the portion of the Sawmill Creek tidal system above Station S3, which would affect its water quality on the ebbing tide, consists of mudflat with some marsh along the banks of the Creek. During July and November, Station M1, the microscale mudflat station, showed net import of $CBOD_5$, NH_3-N, TKN, and Total N while S3 showed export of these constituents. Station M1 also showed export of DO in both months while Station S3 showed export in November, but import in July. At the microscale marsh station (M2), $CBOD_5$ was imported in July and not transported in November, DO was imported in November, and the transport pattern for the other parameters was as described for Station M1. Therefore, based on data for marsh and mudflat alone, import of NH_3-N and $CBOD_5$, and export of DO would be expected at Station S3. This is not the pattern found.

Constituent Transport as Station S3 - The inconsistencies in parameter transport between Station S3 and Stations M1 and M2 suggest that instream processes or other sources and sinks are contributing to the nutrient dynamics at Station S3. Likely sources and sinks would be sediments within the channel or the landfills. The high concentrations of ammonia noted in the landfill leachate support the landfills as a likely source of this nutrient. Results of the sediment exchange experiments are inconclusive with both uptake and release of nutrients occurring (see Appendix A-2-3).

The available data are not sufficient to explain these findings. The consistent export of DO from the wetlands appears to masked by processes in the channel during certain cycles in the summer, resulting in net import of DO at Station S3. Welsh (1980) noted a similar pattern with import in the marsh and mudflat and export in the channel. Her system was quite different, however, with a large channel originating upstream. She attributed the export from the channel to upstream sources or other intervening marsh-mudflat systems with different dynamics. In this system, DO may be being consumed during the oxidation of NH_3-N and BOD_5 contributed by the landfill leachate or other sources.

The August reversal in transport direction for many parameters can not be explained. If the landfills are indeed sources of NH_3-N and BOD_5 for Sawmill Creek, perhaps the leachate discharge during that period is less than in the other months, possibly the result of lower water tables. This would not explain the import of DO found during August, however.

Clearly, further data is needed to define the nutrient dynamics of the Sawmill Creek system. Data is needed to determine if the July and November data are truely representative and August is unusual, or if the system is highly variable.

To provide some notion of the magnitude of the exports of the system, loading estimates for BOD_5, NH_3-N and DO are provided even though these cannot be considered conclusive. Approximately 4,053 pounds of BOD_5 and 5,725 pounds of NH_3-N were exported at Station S3 over three tidal cycles in November or roughly 2,702 and 3,820 pounds per day of BOD_5 and NH_3-N, respectively. During July, approvimately 2,345 of BOD_5 and 536 pounds of NH_3-N were exported over two tidal cycles which is equivalent to one day. In August, however, approximately 4,135 pounds of BOD_5 and 2,678 pounds of NH_3-N were imported over two tidal cycles, or approximately one day.

For DO, about 171 pounds per day were exported in November, about 4,997 pounds were exported in July, and roughly 1,178 pounds per day were imported in August.

3.3.2 Mill Creek

3.3.2.1 Station S9

Table 3.9 summarizes the concentration data for Station S9 and Table 3.10 summarizes the import/export of mass for various constituents. Appendices A-2-1 and A-2-2 provide further detail regarding mass transport in the system.

TABLE 3.9: Concentration Data Summary - Station S9 (in mg/l)

Variable	Number of Samples	Mean	Standard Deviation	Minimum Value	Maximum Value	Coefficient of Variation
			MONTH OF NOVEMBER			
$CBOD_5$	23	3.47	1.27	2.10	7.80	36.64
NH_3-N	23	5.13	0.91	4.12	7.01	17.77
NO_3-N	23	0.68	0.11	0.41	0.96	16.15
NO_2-N	23	0.27	0.10	0.05	0.40	35.37
DO	23	3.09	1.23	0.60	5.15	39.76
Salinity*	23	7.18	1.32	4.33	9.51	18.39
Chlorophyll-a	23	17.26	7.83	2.18	29.37	45.35
TKN	23	7.57	3.35	5.06	21.68	44.24
TPO_4	23	0.57	0.39	0.20	1.80	69.88
TSS	23	27.70	9.16	12.00	53.20	33.07
			MONTH OF JULY			
$CBOD_5$	12	5.02	0.85	3.85	6.70	17.01
NH_3-N	12	1.79	0.39	0.94	2.42	21.61
NO_3-N	12	0.85	0.79	0.25	2.93	93.37
NO_2-N	12	1.05	0.27	0.44	1.34	25.30
DO	12	3.38	1.41	1.10	5.70	41.69
Salinity*	12	4.03	0.97	2.56	5.63	24.11
Chlorophyll-a	10	40.56	14.61	8.87	55.70	36.03
TKN	12	3.21	0.75	1.85	4.31	23.45
TPO_4	12	0.80	0.41	0.52	2.03	50.51
TSS	12	36.67	8.38	21.80	47.00	22.85
			MONTH OF AUGUST			
$CBOD_5$	11	3.63	1.57	2.40	8.20	43.19
NH_3-N	11	2.91	0.58	1.60	3.62	20.05
NO_3-N	11	1.17	0.62	0.68	2.31	52.93
NO_2-N	11	0.70	0.06	0.58	0.79	9.10
DO	11	2.60	1.01	0.40	4.00	38.84
Salinity*	10	5.86	1.19	3.64	7.79	20.29
Chlorophyll-a	11	10.78	6.50	3.12	24.70	60.35
TKN	11	4.90	2.13	3.56	10.90	43.42
TPO_4	11	0.98	0.19	0.70	1.37	19.23
TSS	11	33.74	5.57	24.40	40.20	16.50

* Note: Salinity in PPT

TABLE 3.10: Summary of Import/Export of Mass in the Mill Creek System - Station S-9

STATION	DATE	T	CYCLE	FLOW	SALINITY	BOD5	NH3	NO3	NO2	TKN	TOTAL N	TPO4	DO	CHL-A	TSS
S9	11/88	N	CYCLE 2	I *	I **	E	E *	O	I	E	E	E	E	I *	I
		D	CYCLE 3	E *	E *	I *	E *	E **	E **	I	I	I	E	I	I
		N	CYCLE 4	I *	I *	E	I *	I **	I *	I *	E *	I	E	I	I
			NET 2+3+4	O	O	E *	E *	O	I *	O	O	I **	E	I	I
			NET 3+4	O	O	O	O	O	E *	I	I	I	E	I	I
S-9	07/89	D	CYCLE 1	E *	E	I *	E *	I	E *	I	I	I	E *	E	I
		N	CYCLE 2	O	I *	O	I *	O	I **	E	E	E **	I	I	I
			NET	O	E	I *	O	I	O	O	I *	I *	I *	E	I
S-9	08/89	D	CYCLE 1	O	E	I **	I **	E *	I *	I	I	I **	I	I **	I
		N	CYCLE 2	E	E	I	E **	E	E	E *	E **	E **	I	I	I **
			NET	E *	E	I	I *	E **	E *	I	I	I *	I	I	I

Station S9 is located downstream of a sewage treatment plant (STP). Therefore, the quantity and quality of flows in Mill Creek are affected by the discharge from the STP during the ebb portion of the tide. Calculations of flow and mass loading at Station S9 were done both with and without consideration of the STP.

That is, the raw data were analyzed to determine the overall nutrient transport at Station S9. Then, treatment plant effluent volume and quality were reviewed to explain the overall findings and to determine how the system might function without the STP effluent. For example, if Station S9 showed a net export of flow during one cycle, the exported volume would be compared to the STP flow to determine if the export could be attributed to the STP alone. Similar analyses would be done for the export of water quality constituents. If import occurs for the system, consideration of STP inputs would reveal even greater import by the wetlands. Flows from the STP were prorated for each ebb and flood tide from the daily average flow for that day provided by the treatment plant authority. As a part of this study, the quality of the STP effluent was sampled (Station S10).

November Data - Three complete tidal cycles were sampled during November; Cycle 1 was not completely sampled. Comparison of flood flow volume to ebb flow volume at Station S9 indicated that flood volume was 1.3% greater than ebb volume during Cycle 2. When the STP flow was removed, the difference in volume based on tidal flow alone was greater: about 2.4% import. Net export of all constituents occurred except for salinity, chlorophyll-a, and total suspended solids which were imported. The largest percentage transport was TKN for which the ebbing mass was about 68% greater than the flooding mass; about 6% of this could be attributed to STP loading. In genral, the STP loadings accounted for between 0.1% and 7.5% of the net transport of water quality parameters to or from Mill Creek.

For Cycle 3, flow export of 1.9% occurred; with consideration of the STP flows this dropped to 1.2% export of tidal flow alone. $CBOD_5$, TKN, TPO_4, chlorophyll-a, and

TSS were imported while NH_3-N, NO_3-N, DO and salinity were exported. For Cycle 4, the flow balance was 4.8% (import); with the STP flows considered the balance was 5.7% import. Import occurred for all parameters except $CBOD_5$ and DO, which were exported. Thus, over the three tidal cycles analyzed, DO showed a consistent pattern of export, chlorophyll-a of import, and the other parameters showed no consistent transport pattern.

Net Analysis for November - A net analysis was done which compared total flood volume and mass over the three tidal cycles to the total ebb volume and mass over those cycles for the raw data at Station S9. Analysis over three tidal cycles in November revealed no net transport of flow, salinity, NO_3-N, TKN, or Total N. Export of 5% or less occurred for $CBOD_5$ and NH_3-N along with import of less than 5% of NO_2-N. Additionally, TPO_4, chlorophyll-a and TSS were imported while DO was exported at more than 5% of the incoming mass. Analysis of the STP loadings revealed that the export of these parameters could be explained by STP inputs with the exception of DO. That is, the marsh appears to uptake these constituents, including at least a portion of the STP loadings. For parameters that were imported, such as TPO_4, the marsh appears to uptake more of the nutrient that the STP supplies.

July Data - The net comparison of flow volume between the ebb and flood portions of the tide revealed 1.3% export during the first tidal cycle. $CBOD_5$, NO_3-N, TKN, Total N, TPO_4 and TSS were imported. The largest percentage import was of NO_3-N, of which about 153 pounds were imported over the tidal cycle, or about 30.3% of the incoming mass.

During the second cycle the flow showed 0.8% import. Comparison of net mass transported revealed import of NH_3-N, NO_2-N, DO, chlorophyll-a, and TSS and no net transport of $CBOD_5$ and NO_3-N. The percentage imports of NH_3-N and NO_2-N were about 4% and 6% of the flooding mass, respectively, and were over 20% of the flooding mass for the other imported parameters. TKN, Total N, and TPO_4 were exported, with about 31% more TPO_4 exiting the system than entered it.

Net Analysis for July - Import of TSS was the only consistent trend in transport over both tidal cycles during the July sampling period. A net analysis was conducted which compared the sum of the flooding volume and mass for each constituent for both tidal cycles to the sum of the ebbing volume and mass for those cycles. This analysis revealed no net transport of flow, NH_3-N, NO_2-N, and TKN; export of salinity and chlorophyll-a; and import of the other parameters although the percentage import of $CBOD_5$, Total N, TPO_4, and DO amounted to less than 5% of the incoming mass. With consideration of the loading from the STP, flow and all water quality parameters except salinity and chlorophyll-a were imported.

August Data - During the first tidal cycle, flow balanced at 1.3% export. $CBOD_5$, NH_3-N, TKN, Total N, TPO_4, chlorophyll-a, TSS, and to a slight degree NO_2-N (1.3%) were imported. NO_3-N, DO, and salinity were exported. Transport direction was the same after consideration of STP flows for all parameters except NO_3-N.

During the second tidal cycle, the percentage difference in flow between the flood and ebb tide was -11.9%, indicating export. With consideration of the STP flows, the percentage of flow exported drops to 6.5%. $CBOD_5$ (40%), DO (8%), chlorophyll-a (56%) and TSS (6.5%) were imported. NH_3-N (5.7%), NO_3-N (20.5%), NO_2-N (15.2%), TKN (2.3%), Total N (6.2%), salinity (11.6%) and TPO_4 (8.7%) were exported. With consideration of the STP flows and loadings, all parameters except salinity were actually imported. Thus, except for salinity, the exported parameters during Cycle 2 may all be attributed to STP loadings to the system.

Net Analysis for August - Combining all flood and all ebb data for both tidal cycles in August revealed net export of flow of less than 5%; import of $CBOD_5$, NH_3-N (<5%), TKN, Total N, TPO_4 (<5%), chlorophyll-a and TSS; and export of NO_3-N,

NO_2-N (<5%), and DO. With consideration of the STP flows, the net export percentage for flow dropped to 1.1% and all parameters except salinity were imported.

Comparison of Sampling Periods - The only parameter to display consistent transport results over all seven sampling periods was TSS (import). Comparing the net analysis for the three sampling periods, Total N, TPO_4 and TSS were imported. The other parameters revealed mixed results. The comparison of July data to August data showed consistent export of salinity, and import of $CBOD_5$, with mixed results for other parameters. No clear seasonal pattern to the data was revealed.

3.3.2.2 Station S9A

Station S9A is located upstream of S9 and is designed to measure the loads in Mill Creek from the Secaucus STP and other upstream sources. The combined analysis of S9 and S9A should allow determination of how much loading is attributable to the STP and other sources and how much is attributable to the surrounding marshes. Data for S9A was only collected during July and August, 1989. Table 3.11 summarizes the concentration data for that station, while Table 3.12 provides a summary of the mass transport results. See Appendices A-2-1 and A-2-2 for detailed tables and figures regarding the mass transport results.

July Data - During July, for Cycle 1, the net flow balance was 8.2% export. However, essentially all of the imbalance was attributable to the Seacaucus STP so that export of 0.8%, or no net transport, was achieved when the STP flow was taken into account. $CBOD_5$, NH_3-N, TKN, and Total N were imported. Since the STP was adding these constituents to the Mill Creek system under ebbing tide, the net import due to processes other than the STP was even larger than indicated simply by comparing the flow and ebb masses. If the STP is taken into account, import of NO_3-N, NO_2-N, TPO_4, DO and TSS occurred in addition to import of $CBOD_5$, NH_3-N, TKN and Total N.

TABLE 3.11: Concentration Data Summary - Station S9A (in mg/l)

Variable	Number of Samples	Mean	Standard Deviation	Minimum Value	Maximum Value	Coefficient of Variation
			MONTH OF JULY			
$CBOD_5$	12	6.05	2.33	3.80	13.00	38.54
NH_3-N	12	1.99	0.39	1.57	2.56	19.39
NO_3-N	12	1.32	0.98	0.21	3.13	74.43
NO_2-N	12	0.91	0.33	0.51	1.33	36.39
DO	12	3.62	1.83	1.20	7.20	50.60
Salinity*	12	3.47	1.05	2.20	5.40	30.16
Chlorophyll-a	10	56.40	24.62	2.93	87.20	43.65
TKN	12	3.56	1.66	2.30	8.29	46.62
TPO_4	12	1.08	0.52	0.55	1.95	47.88
TSS	12	27.28	5.84	16.80	35.20	21.40
			MONTH OF AUGUST			
$CBOD_5$	11	4.22	0.55	3.25	5.10	13.06
NH_3-N	11	2.16	0.86	1.35	4.02	39.60
NO_3-N	11	2.22	0.81	0.84	3.40	36.46
NO_2-N	11	0.66	0.07	0.59	0.84	10.63
DO	11	2.38	1.60	0.00	4.50	67.30
Salinity*	11	3.92	1.07	2.74	6.17	27.18
Chlorophyll-a	10	7.48	3.99	2.86	16.40	53.38
TKN	11	4.32	0.71	3.54	5.67	16.41
TPO_4	11	2.00	0.71	0.92	3.02	35.51
TSS	11	29.18	7.33	18.40	38.80	25.13

* Note: Salinity in PPT

TABLE 3.12: Summary of Import/Export of Mass in the Mill Creek System - Station S-9A

STATION	DATE	T	CYCLE	FLOW	SALINITY	BOD5	NH3	NO3	NO2	TKN	TOTAL N	TPO4	DO	CHL-A	TSS
S-9A	07/89	D	CYCLE 1	E **	E	I **	I **	E	E	I	I	E	E *	E	O
		N	CYCLE 2	E	E	E	E	I	E	E	E	E	I	E	E **
			NET	E	E	I *	E **	I *	E	I	I	E	I *	E	E *
S-9A	08/89	D	CYCLE 1	E	E	E	E	E	E	E **	E	I	E	E	E
		N	CYCLE 2	E	E	E	E	E	E	E	E	E	E	E	E
			NET	E	E	E	E	E	E	E	E	E **	E	E	E

S9 = MILL CREEK BOUNDARY STATION
S9A = MILL CREEK MIDDLE BELOW STP

O = CHANGE IN MASS ≤ 1.0%
* = CHANGE IN MASS ≤ 5.0%
** = CHANGE IN MASS ≤ 10.0%

D = DAYTIME
N = NIGHTTIME

For Cycle 2, the flood and ebb flows showed a net export of 26.6% without consideration of the STP flow and a 12.8% export with consideration of that flow. During this Cycle, BOD_5, NH_3-N, NO_2-N, TKN, Total N, salinity, TPO_4, chlorophyll-a and TSS were exported. With the STP loadings accounted for, BOD_5, NO_3-N, TKN, Total N, DO, TPO_4, and chlorophyll-a were imported, while the other parameters were exported.

Net Analysis for July - A net analysis was conducted which combined the two tidal cycles. Over the two tidal cycles in July, net flow export was 14.5%. With the STP flow considered, the export percentage dropped to 4.8%. Over this period there was net import of BOD_5 (1.5%), NO_3-N (2.6%), TKN, Total N, and DO (4.6%) and net export of the other parameters. In addition, there was net import of BOD_5, NH_3-N, NO_3-N, TKN, Total N, DO, TPO_4, and TSS after consideration of STP loadings on the ebb tide. Analysis of the flow-weighted concentrations indicated net export of NO_2-N, salinity and chlorophyll-a and net import of other constituents.

August Data - During August, for Cycle 1, net export of flow of 19.9% occurred; consideration of STP flows adjusted this value to 6.6% export. Without the consideration ofSTP input, net export of all constituents except TPO_4 occurred. With consideration of STP input on the ebb tide, net import of $CBOD_5$, NH_3-N, NO_3-N, NO_2-N, TKN, Total N, and TPO_4 was observed. Analysis of the flow-weighted concentrations showed net export of $CBOD_5$, NO_3-N, NO_2-N, DO, salinity, and chlorophyll-a.

During Cycle 2, flow export of 35.2% was observed without consideration of STP flow and export of 8.9% occurred with consideration of STP flow. Net export was observed for all parameters. However, consideration of the STP loadings reversed this trend for BOD_5, NH_3-N, NO_3-N, NO_2-N, TKN, and Total N. The flow-weighted concentrations, without consideration of the STP loadings, showed export of NH_3-N, NO_3-N, NO_2-N, TKN, Total N, DO, and TPO_4 and import of the other parameters.

Net Analysis for August - Analysis of net transport combining the two tidal cycles in August revealed export of flow (24.7%), and of all water quality parameter, without consideration of STP flows. With the STP flows considered on the ebb tide, the results were net export of flow (7.3%) and of DO, salinity, chlorophyll-a, and TSS. The other parameters were imported. The net flow-weighted concentrations revealed export of NO_3-N, NO_2-N, Total N, DO, and salinity.

Comparison of Sampling Periods - Overall, without consideration of the source, net export or no net transport occurred on all four cycles for flow, salinity, NO_2-N, chlorophyll-a, and TSS. Net export occurred over three of four cycles for BOD_5, NH_3-N, TKN, Total N, and DO. However, because of the net export of flow over three of the four cycles, much of that net export may be simply attributable to the flow imbalance and not to processes operating in the system. Much of the flow imbalance, and thus the mass loading to the system, is attributable to the STP.

Even with consideration of the flows from the Seacaucus STP, the net analyses for both sampling periods revealed flow export at Station S9A. This is the net export that would be expected in the STP were not in operation. However, it must be recalled that STP flows at this station were determined based on the average flows reported by the STP. It is possible that variations from that average occurred during some cycles. With consideration of the loadings from the STP, net import of $CBOD_5$, NH_3-N, NO_3-N, TKN, Total N, and TPO_4 and net export of DO, salinity and chlorophyll-a occurred during both sampling periods. NO_2-N and TSS were imported in one month and exported in the other. Thus, as expected, the STP plays a significant role in the nature and magnitude of pollutants flux at Station S9A.

Review of the flow-weighted concentration results, without accounting for STP effects, revealed net import of BOD_5, TKN, Total N, TPO_4, and TSS for at least three of four cycles. Net transport for the two sampling periods based on flow-weighted concentrations revealed import of $CBOD_5$, NH_3-N, TKN, and TSS in both months, and import of TPO_4 in July but no net transport of TPO_4 in August. Results for the transport of NO_3-N indicated import in July and export in August, with the opposite result for Total N. Thus, it appears that imbalance in the flow volumes influence the net transport of constituents.

3.3.2.3 Comparsion of S9 and S9A

Because of the discharge from the Seacaucus STP into Mill Creek, it is not possible to accurately assess the impact of the surrounding marsh on water quality based on the results at Stations S9 or S9A alone.

The discussion of STP loadings in the results section for Stations S9 and S9A are necessarily general. The flows from the STP were based on average daily flows reported by the plant. This flow rate was assumed to occur uniformly throughout the day which is actually highly unlikely. Thus, the loadings of each constituent attributed to the STP flow may be suspect. Therefore, another method was needed to isolate the effect of the marsh. The difference in net loadings between the two stations was calculated. Since S9A is located downstream of the STP but upstream of S9, the total loading at that station included treatment plant effects. Mill Creek includes extensive marsh area between S9 and S9A. Therefore, subtracting the mass transported at Station S9A from the mass transported at Station S9 should eliminate any effects of the STP. Table 3.13 summarizes the net transport between Station S9 and Station S9A.

For July, Cycle 1, net uptake of BOD_5, NO_3-N, TPO_4, and TSS was observed between Station S9 and S9A with net release of the other constituents. For Cycle 2, net uptake occurred for BOD_5, NO_3-N, NH_3-N, NO_2-N, DO, salinity, chlorophyll-a and TSS. Over both cycles, net uptake was observed for $CBOD_5$, NH_3-N, NO_3-N, NO_2-N, DO, TPO_4, and TSS.

TABLE 3.13: Summary of Import/Export of Mass Flux in Mill Creek - Net Transport Between Station S9 and S9A

STATION	DATE	T	CYCLE	FLOW	SALINITY	BOD5	NH3	NO3	NO2	TKN	TOTAL N	TPO4	DO	CHL-A	TSS
S-9 - S-9A	07/89	D	CYCLE 1	I	E	I	E	I	E	E	E	I	I	E	I
		N	CYCLE 2	I	E	I	I	E	I	E	E	E	I	I	I
			NET	I	E	I	I	I	I	E	E	I	I	E	I
S-9 - S-9A	08/89	D	CYCLE 1	I	E	I	I	I	I	I	I	I	E	I	I
		N	CYCLE 2	E	E	I	E	I	E	I	I	I	I	I	I
			NET	I	E	I	I	I	I	I	I	I	I	I	I

S9 = MILL CREEK BOUNDARY STATION
S9A = MILL CREEK MIDDLE BELOW STP
S9-S9A = NET DIFFERENCE (IMPACT OF MARSH)

O = CHANGE IN MASS ≤ 1.0%
* = CHANGE IN MASS ≤ 5.0%
** = CHANGE IN MASS ≤ 10.0%

D = DAYTIME
N = NIGHTTIME

For August, Cycle 1, subtracting the loadings at S9A from those at S9 revealed uptake of all parameters except DO and salinity between Station S9 and S9A. For Cycle 2, net uptake of BOD_5, NO_3-N, TKN, Total N, DO, TPO_4, chlorophyll-a and TSS was observed. Comparing the total flow and mass transport for August revealed uptake of all parameters except salinity between Station S9A and Station S9.

The analysis of marsh impacts by subtracting mass transported at Station S9A from that transported at Station S9, is based on the assumption that flows for each station essentially were balanced over each tidal cycle. Any import or export of mass at each station would then depend only on processes within the system and any differences in loading between the two stations could be attributed to effects from the intervening marsh and any instream processes. However, because flows did not balance during all of the cycles at Stations S9 and S9A noted above, some of the mass transport may be attributable to the unbalanced flows. The analysis was then repeated using the flow-weighted concentrations to eliminate effects of flow imbalance. The net transport using this method revealed release of BOD_5, NH_3-N, NO_2-N, TKN, Total N, DO, and chlorophyll-a and net uptake for NO_3-N, salinity, TPO_4 and TSS for Cycle 1 in July. This is consistent with the simple mass loading analysis for all parameters except BOD_5 which showed net uptake using mass loading. For Cycle 2 in July, net release occurred for BOD_5, NO_3-N, TKN, Total N, DO and TPO_4 and uptake for the others. These results are consistent with the net mass results for all parameters except BOD_5 and DO.

For the August data, the flow-weighted concentration results indicate uptake of all parameters except salinity and TPO_4 for Cycle 1. Again, this is consistent with the net mass results for all parameters except DO and TPO_4. For Cycle 2, net uptake is observed for all parameters except salinity using the flow-weighted concentration. These results are consistent with the simple net mass loading results for all parameters except NH_3-N, and NO_2-N. Thus, for many parameters the results are consistent using both methods.

Conclusions based on these results must be drawn with caution. As noted, even after consideration of the addition of the STP flows on the ebb tide, acceptable flow balance did not result for all tidal cycles at Station S9A. Therefore, the net transport at that station may be due to the uneven tidal patterns rather than system processes. With that caution in mind, the results indicate that the marsh in Mill Creek imported NH_3-N, NO_3-N, NO_2-N, DO, and $CBOD_5$ based on the overall net analyses for both months. When the direction of transport is determined from the flow-weighted concentration data, the results are less consistent. Using these data, NO_3-N and Total N were exported, while NO_2-N was imported. All other parameters suggested mixed transport direction. Therefore, no definitive statement regarding the impact of the marsh on nutrient flux can be made.

It is interesting to note, however, that even with the upstream treatment plant, consistent export of nutrients did not occur at Station S9. This seems to suggest that processes in the system, including the marsh, are acting to consume the excess nutrients in the system. In fact, Total N and TPO_4 are both imported into Mill Creek from the Hackensack Estuary, based on the results at Station S9 for all three sampling periods. This supports the conclusions reached above.

3.3.3 Berry's Creek

3.3.3.1 Station S-14

Summaries of concentration and mass transport data are presented in Tables 3.14 and 3.15, respectively. Appendices A-2-1 and A-2-2 provide more detailed tables and graphs of these results.

July Data - During Cycle 1 in July, the flow balance indicated export of 5.8%. Mass transport analyses indicated export of BOD_5, NH_3-N, TKN, Total N, salinity, TPO_4 and TSS and import of other parameters. During Cycle 2, flow was imported at 4.4%. Net import was observed for BOD_5, NH_3-N, NO_2-N, TKN, Total N, salinity,

TABLE 3.14: Concentration Data Summary - Station S14 (in mg/l)

Variable	Number of Samples	Mean	Standard Deviation	Minimum Value	Maximum Value	Coefficient of Variation
			MONTH OF JULY			
$CBOD_5$	12	3.34	1.73	1.60	6.90	51.83
NH_3-N	12	0.96	0.13	0.76	1.19	14.66
NO_3-N	12	0.47	0.40	0.17	1.68	86.97
NO_2-N	12	0.77	0.14	0.59	0.96	17.53
DO	12	3.10	1.15	1.90	5.40	37.14
Salinity*	12	7.34	1.24	5.81	9.42	16.83
Chlorophyll-a	12	26.94	13.71	3.52	51.40	50.89
TKN	12	2.00	0.69	1.12	3.15	34.55
TPO_4	12	0.50	0.08	0.38	0.61	15.44
TSS	12	43.83	19.62	21.60	90.00	43.94
			MONTH OF AUGUST			
$CBOD_5$	12	2.52	0.70	1.62	4.05	27.68
NH_3-N	12	0.97	0.27	0.62	1.50	28.04
NO_3-N	12	1.03	0.42	0.67	2.28	41.35
NO_2-N	12	0.44	0.06	0.37	0.56	12.89
DO	12	3.64	0.85	2.50	4.95	23.26
Salinity*	12	10.11	1.69	7.43	13.03	16.72
Chlorophyll-a	12	19.41	10.78	7.15	41.20	55.55
TKN	12	2.38	1.17	1.12	5.46	49.18
TPO_4	12	0.61	0.17	0.42	0.90	27.28
TSS	11	37.64	14.39	17.20	60.00	38.24

* Note: Salinity in PPT

TABLE 3.15: Summary of Import/Export of Mass in the Berry's Creek System - Station S14

STATION	DATE	T	CYCLE	FLOW	SALINITY	BOD5	NH3	NO3	NO2	TKN	TOTAL N	TPO4	DO	CHL-A	TSS
S-14	07/89	N	CYCLE 1	E **	E	E	E	I	I **	E	E	E **	I	I	E
		D	CYCLE 2	I *	I *	I	I **	E *	I **	I *	I *	I **	E	E	I
			NET	O	E *	I *	E *	I	I **	E	E *	O	E	I **	E
S-14	08/89	D	CYCLE 1	I **	E	I	I	E **	I	I	I	I	E	I *	E
		N	CYCLE 2	E **	E *	I *	I	E	E **	I	I **	E **	I	I	E
			NET	O	E	I	I	E	I **	I	I	I	E *	I **	E

DO, TPO_4 and TSS. Thus, flow and all water quality parameters, except NO_2-N and DO, reversed transport direction from the first to the second tidal cycle.

Net Analysis for July - Combining the two tidal cycles releaved a net difference between total tide flood and total ebb flow volume of 0.1%. Combining total mass transport during the flood tide and ebb tide for both tidal cycles revealed export of salinity, NH_3-N, TKN, Total N, and TSS and import of all other parameters except for TPO_4 which showed no net transport. The net transport of BOD_5, salinity, NH_3-N, and Total N was less than 5% of the flooding mass.

August Data - For August, Cycle 1, analysis of flow showed net import of 7.2%. Import of BOD_5, NH_3-N, NO_2-N, TKN, Total N, TPO_4, and chlorophyll-a was observed. For Cycle 2, net export of flow (9.8%) occurred along with import of BOD_5, NH_3-N, TKN, Total N, DO and chlorophyll-a. Thus, BOD_5, NH_3-N, TKN, Total N, and chlorophyll-a demonstrated net import during both cycles. Salinity, NO_3-N, and TSS were exported over both cycles. The other parameters showed mixed transport results.

Net Analysis for August - Combining the August data for both flood half-tidal cycles and both ebb half-tidal cycles revealed that flows essentially balanced (0.3% import). BOD_5, NH_3-N, NO_2-N, TKN, Total N, TPO_4, and chlorophyll-a were imported while NO_3-N, DO, salinity and TSS were exported.

Comparison of Sampling Periods - For both months, BOD_5, NO_2-N and chlorophyll-a were imported in 3 of 4 cycles and in both net analyses. DO demonstrated mixed import and export during the individual cycles, but showed net export for both July and August. The other parameters showed inconsistent transport results.

3.3.3.2 Station S15

Summaries of concentration and mass transport data are presented in Tables 3.16 and 3.17, respectively. Appendices A-2-1 and A-2-2 provide more detailed results.

July Data - During July, analysis of the total volume of ebb and flood tidal flow during Cycle 1 indicated export of 6.1%. $CBOD_5$, NH_3-N, TKN, Total N, salinity, TPO_4, chlorophyll-a and TSS were exported and NO_3-N, NO_2-N and DO were imported. During Cycle 2, flow import of 4.7% was calculated. Import of $CBOD_5$, NO_3-N, NO_2-N, TKN, Total N, TPO_4 and chlorophyll-a was observed along with export of NH_3-N, DO and TSS. Combining all flood and all ebb data in a net analysis for July revealed net flow balance, export of salinity, BOD_5, NH_3-N, TPO_4, DO, and TSS and import of the other water quality parameters.

August Data - The analysis of flows for Cycle 1 in August showed import of 6.7%. Import of over 10% of the flooding mass of BOD_5, NH_3-N, NO_3-N, salinity, and TPO_4 occurred. For Cycle 2, the flow analysis revealed 9.5% export. $CBOD_5$, NO_2-N, DO, chlorophyll-a, and TSS were imported while NH_3-N, NO_3-N, Total N, salinity and TPO_4 were exported; there was no net transport of TKN.

Only $CBOD_5$ and Total N were consistent in transport direction over both tidal cycles. A net analysis was conducted for the August data which combined the flood and ebb data for both tidal cycles. That analysis showed net flow balance, import of BOD_5, NO_2-N, DO, salinity, TPO_4, and TSS and export of the other parameters.

Comparison of Sampling Periods - For both July and August, no parameter showed a consistent pattern of import or export over all four tidal cycles. When the net analyses for each month were compared, flow balanced but only NH_3-N showed a consistent pattern over the two months (net export). The other water quality parameters were exported during one month and imported during the other.

TABLE 3.16: Concentration Data Summary - Station S15 (in mg/l)

Variable	Number of Samples	Mean	Standard Deviation	Minimum Value	Maximum Value	Coefficient of Variation
			MONTH OF JULY			
$CBOD_5$	12	3.72	0.99	2.38	5.92	26.56
NH_3-N	12	1.00	0.15	0.69	1.21	14.87
NO_3-N	12	0.27	0.11	0.12	0.44	39.79
NO_2-N	12	0.75	0.18	0.49	0.97	23.42
DO	12	3.46	0.99	1.90	5.10	28.53
Salinity*	12	6.58	0.74	5.63	7.97	11.19
Chlorophyll-a	8	37.95	11.57	25.30	56.10	30.49
TKN	12	2.67	0.85	1.43	4.67	31.80
TPO_4	12	0.57	0.11	0.42	0.71	18.65
TSS	12	81.18	46.35	25.20	152.00	57.09
			MONTH OF AUGUST			
$CBOD_5$	12	2.98	0.56	2.22	3.85	18.74
NH_3-N	12	0.91	0.21	0.66	1.22	23.00
NO_3-N	12	0.80	0.24	0.37	1.18	29.52
NO_2-N	12	0.43	0.08	0.33	0.52	17.76
DO	12	3.63	1.01	2.10	5.20	27.79
Salinity*	12	8.95	1.27	7.61	12.48	14.17
Chlorophyll-a	12	34.70	11.10	17.60	57.90	31.99
TKN	12	2.46	0.77	1.27	3.83	31.10
TPO_4	12	0.66	0.16	0.48	0.99	23.79
TSS	12	51.12	24.65	19.20	98.80	48.22

* Note: Salinity in PPT

TABLE 3.17: Summary of Import/Export of Mass in the Berry's Creek System - Station S15

STATION	DATE	T	CYCLE	FLOW	SALINITY	BOD5	NH3	NO3	NO2	TKN	TOTAL N	TPO4	DO	CHL-A	TSS
S-15	07/89	N	CYCLE 1	E **	E **	E	E *	I	I **	E	E	E	I	E	E
		D	CYCLE 2	I *	E *	I **	E **	I **	I **	I	I	I **	E	I	E
			NET	O	E *	E *	E **	I	I **	I	I	E **	E **	I **	E
S-15	08/89	D	CYCLE 1	I **	I	I	I	I	E *	E	E **	I	E	E	E
		N	CYCLE 2	E **	E	I	E	E	I	O	E **	E	I	I	I
			NET	O	I *	I	E	E	I **	E **	E **	I	I *	E **	I

S-14 = BERRYS CREEK BOUNDARY STATION
S-15 = BERRYS CREEK UPPER STATION

O = CHANGE IN MASS ≤ 1.0%
* = CHANGE IN MASS ≤ 5.0%
** = CHANGE IN MASS ≤ 10.0%

D = DAYTIME
N = NIGHTTIME

3.3.3.3 Comparison of Stations S14 and S15

Station S14 is located at the mouth of Berrys Creek while Station S15 is located upstream on that Creek. In order to evaluate the effect of the wetlands in Berrys Creek on the loading of various parameters to the Hackensack River, it was necessary to eliminate the possible effects of other sources. This was accomplished by subtracting the net mass calculated at Station S15 from that calculated at Station S14. The area between the two stations is essentially all marsh. This technique would be acceptable if the flows balanced well for each cycle at each station. However, as noted above, both stations had uneven flows which did not balance well for the individual tidal cycles, but did balance when total flood flow and total ebb flow were calculated over two tidal cycles. Thus, the most relevant conclusions regarding the impact of the marsh on the water quality of Berrys Creek rests on the use of the net analyses for each month. That is, combining data from the two tidal cycles sampled in each month. Table 3.18 summarizes these results.

For July, subtracting net mass at Station S15 from net mass at Station S14 revealed import of BOD_5, NO_3-N, NH_3-N, NO_2-N, TPO_4, chlorophyll-a and TSS. NH_3-N demonstrated essentially no net transport, while export of TKN, Total N, DO, and salinity was noted. The August data showed net import of BOD_5, NH_3-N, NO_2-N, TKN, Total N, TPO_4, and chlorophyll-a and net export of NO_3-N, DO, salinity, and TSS. For both months, consistent results were obtained for BOD_5, salinity, NH_3-N, NO_2-N, TPO_4, DO, and chlorophyll-a.

To compensate for the imbalance in the transported flows, the net change in flow-weighted concentrations between Station S14 and S15 were calculated. In contrast to the Mill Creek results, noted above, the flow-weighted concentrations and mass flux analyses were in general agreement, with few exceptions.

The net transport direction results determined from the comparison of Station S14 with Station S15 also agree in most cases with the results at Station S14. Based on

TABLE 3.18: Summary of Import/Export of Mass Flux in Berry's Creek - Net Transport Between Station S14 and S15

STATION	DATE	T	CYCLE	FLOW	SALINITY	BOD5	NH3	NO3	NO2	TKN	TOTAL N	TPO4	DO	CHL-A	TSS
S-14 - S-15	07/89	D	CYCLE 1	E	E	E	E	I	I	E	E	I	I	I	I
		N	CYCLE 2	I	I	I	I	E	I	E	E	I	E	E	I
			NET	E	E	I	I	I	I	E	E	I	E	I	I
S-14 - S-15	08/89	D	CYCLE 1	I	E	I	I	E	I	I	I	I	I	I	E
		N	CYCLE 2	E	I	E	I	I	E	I	I	I	E	I	E
			NET	I	E	I	I	E	I	I	I	I	E	I	E

S-14 = BERRYS CREEK BOUNDARY STATION
S-15 = BERRYS CREEK UPPER STATION
S-14 - S-15 = NET DIFFERENCE (IMPACT OF MARSH)

O = CHANGE IN MASS ≤ 1.0%
* = CHANGE IN MASS ≤ 5.0%
** = CHANGE IN MASS ≤ 10.0%

D = DAYTIME
N = NIGHTTIME

both sets of results, the Berry's Creek marsh system appeared to import $CBOD_5$, NO_2-N, and chlorophyll-a and to export salinity and DO. The results for the other parameters were inconsistent.