Estimation of Potential Water Levels in the Peconic River near Brookhaven National Laboratory Based on a Review of Hydrologic Data

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Glossary

Bankfull	Condition when the water elevation in the river fills the banks. Further increases in water level causes flooding of adjacent land.
BNL	Brookhaven National Laboratory.
EA	Flow station located at the outfall of the Sewage Treatment Plant.
HmN	Flow station located approximately ½ mile downstream from the Sewage Treatment Plant.
HQ	Flow station located at the eastern boundary of the BNL site.
MSL	mean sea level.
SER	Site Environmental Report. Annual report that summarizes environmental conditions at Brookhaven National Laboratory.
Start of flow	Location where water flow begins in the river due to the intersection of the groundwater level and the streambed level.
STP	Sewage Treatment Plant.
USGS	United States Geological Survey.

Estimation of Potential Water Levels in the Peconic River near Brookhaven National Laboratory based on a review of hydrologic data

1.0) Background

Brookhaven National Laboratory (BNL) is a multi-disciplinary research facility that has been in operation since 1948. The facility is owned by the U.S. Department of Energy and operated by Brookhaven Science Associates. BNL is located in Suffolk County, New York on Long Island. Operations at the facility generate wastewater which is sent to the sewage treatment plant (STP) that has historically discharged approximately 260 million gallons/yr (700,000 gallons per day) to the Peconic River, Figure 1.

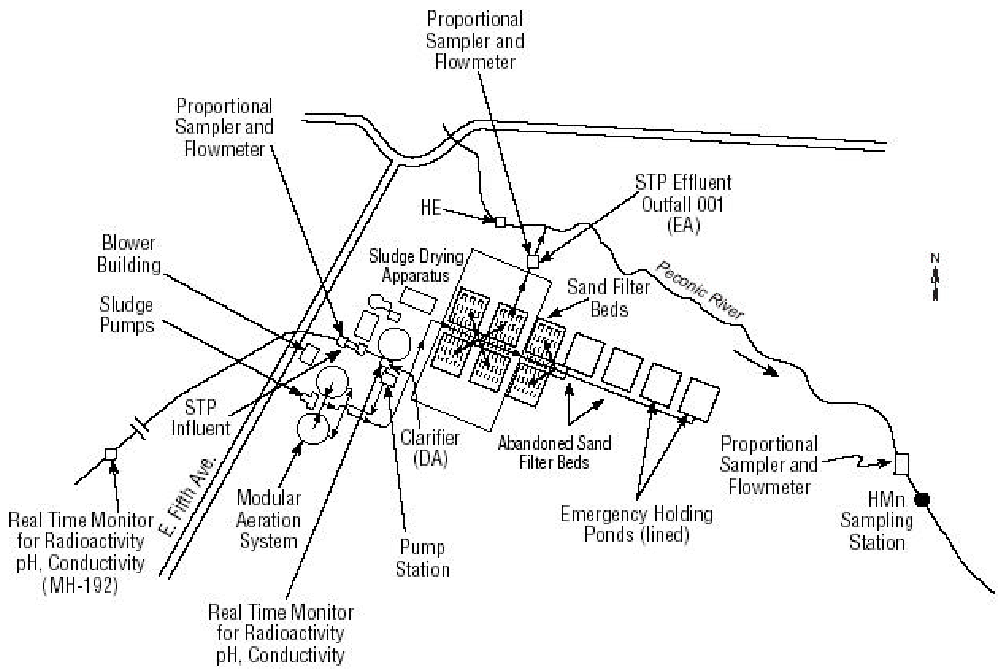

Figure 1 BNL Sewage Treatment Plant and Sampling Stations

The western branch of the Peconic River originates west of the site across the William Floyd Parkway and runs through BNL, Figure 2. The flow in the river is controlled by three major factors: groundwater elevation, run-off from precipitation events, and anthropogenic influences such as the discharge from the STP. Other potential secondary anthropogenic influences could include public water supply or private wells that could lower the water table and the return flow of water through cesspools, septic tanks, and leakage from the water distribution system. However, information supplied by the Suffolk County Water Authority indicates that

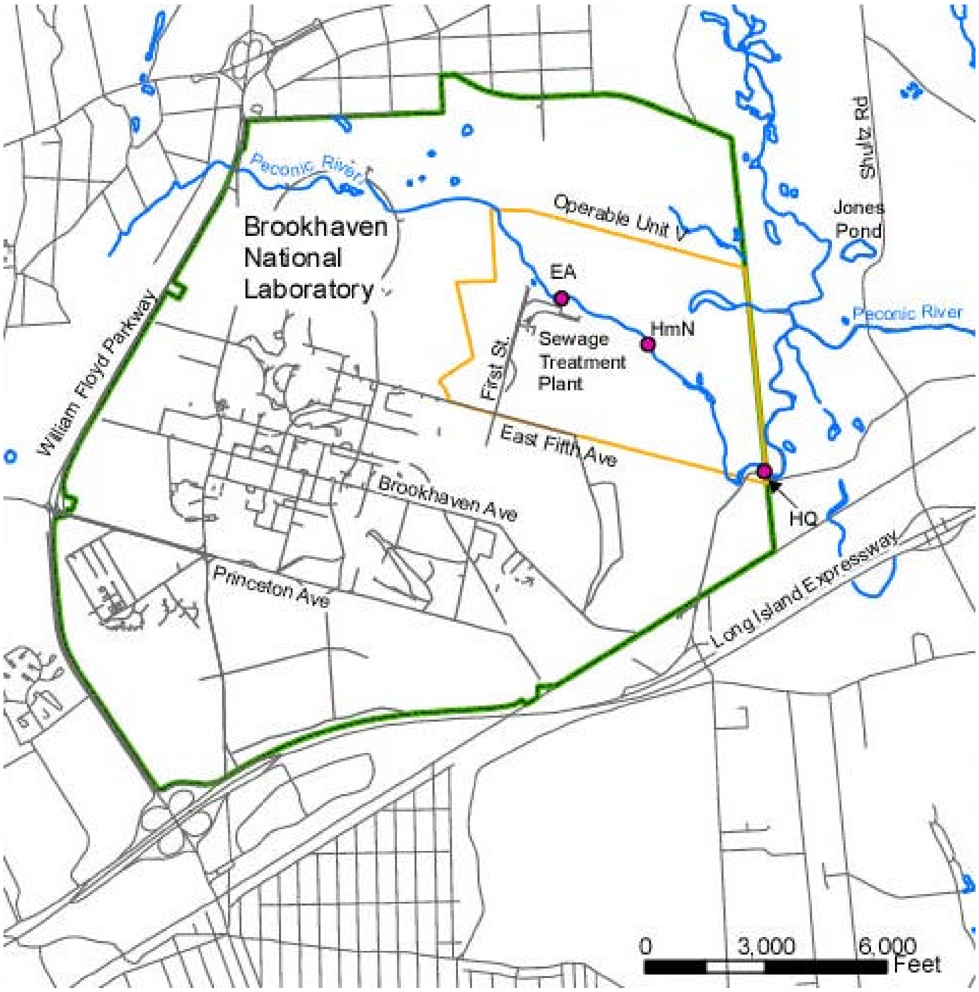

Figure 2 The Peconic River in the vicinity of BNL and location of flow stations within the BNL site.

there are no public wells that would impact hydraulic head along the western branch of the Peconic River and there are not many private wells that would impact flow in this section of the Peconic River. Other secondary sources are also believed to have minimal impact along this stretch of the river. Water may leave the riverbed providing infiltration to the groundwater, which occurs if the groundwater level is less than the elevation of the riverbed, or the discharge of the river water to a larger body of water (Flanders Bay).

In natural systems, the water table elevation is controlled by recharge, which is influenced by sources (precipitation) and sinks (evaporation, transpiration, and run-off). A complete review of the hydrologic conditions at BNL was performed by the United States Geological Survey (USGS, 1999). The water table elevation varies from year to year and seasonally due to changes in recharge. Precipitation at BNL is relatively constant throughout the year with average monthly rates ranging from 3.3 inches in July to 4.9 inches in March. Recharge is generally lower during the growing season due to increased water demands by evaporation and transpiration. The typical water table cycle near BNL shows an increase in water levels in late fall through late spring (December to June) and then a decrease during the growing season and fall (July – November). Water table elevations typically change a few feet per year at most wells on the BNL site. Currently the Peconic River derives more than 90% of its flow from ground water and less than 10% from run-off (USGS, 1999). This implies that flow in the Peconic River near BNL will be strongly dependent on water table elevations

In the vicinity of BNL, the Peconic River is an intermittent stream. The flowing reach of a stream begins where the water table intersects the stream channel (USGS, 1999). The point of intersection is defined as the start of flow. The start of flow moves upstream or downstream as the water table elevation changes and therefore occurs at different locations throughout the year. The start of flow for the western branch of the Peconic River is in the vicinity of BNL. In years of high water table elevation, the start of flow is west of BNL across the William Floyd Parkway. In years of low water table elevation, the start of flow has been located in Manorville, approximately 2.1 river miles east of the eastern site boundary.

2.0) Problem

A risk assessment based on measured contamination of the Peconic River sediments downstream of the STP has identified consumption of fish contaminated with mercury and PCBs as having the largest potential impacts on human health. The risk assessment also identified uncertainties in the risk estimates that could be reduced through more detailed studies of the Peconic River system. Two important areas that were selected for further investigation are a) the availability of sufficient fish biomass in the 2.8 mile reach of the river from the STP to Schultz Road and b) the process of transforming inorganic mercury found in the sediments to an organic form (methyl mercury) that is bioavailable and enters the food chain.

Both of these studies require knowledge about the water levels and potential flow rates in the Peconic River. The area of potential fish habitat and therefore biomass is strongly correlated with the water level in the Peconic River (Meixler, 2002). In periods of low precipitation, significant sections of the 2.8 mile reach of river are dry. In addition, at different water levels, different habitats become available for fish. Therefore, both the number and types of fish change with water table elevation. The rate of methyl mercury formation depends on the chemical and biological conditions found in the stream. For example, the dissolved oxygen content, pH, and the presence of sulfate reducing bacteria impact the formation of methyl mercury. These parameters are also impacted by the flow conditions of the river.

Therefore, estimates of the flow conditions in the reach of the Peconic River from the STP to Schultz Road are needed, in conjunction with information from other studies, to reduce uncertainties identified in the risk assessment. This information will help support future risk management decisions about cleanup of the Peconic River sediment

3.0) Objective

Develop an understanding of the flow characteristics of the Peconic River and a quantitative estimate of the fraction of time that the river flow can be characterized as low in which large sections of the streambed are dry and there is no flow at the eastern BNL boundary (such as experienced between September and January since 1996 and all of 2002), high (river banks are full of water and water covers adjacent wetlands) and mid (an intermediate water level).

4.0) Approach

The historical record of hydrologic measurements was reviewed to provide insight on flow in the 2.8 mile reach of the Peconic from the STP to Schultz Road. Three types of data sets were evaluated to determine the potential for continual flow:

1) Flow records to provide a baseline for flow through the BNL site. The review included inputs to the Peconic River at the STP as well as flow off-site. The stream monitoring station designated as HQ is located at the site boundary and was used to determine flow leaving the site.
2) Water level measurements with the intent of correlating flow in the river with water table elevation.
3) Precipitation records with the intent of determining if there is a correlation between river flow and precipitation.

Using the above information, the type of flow is defined as follows:

- Low – Similar to conditions in 2002. Large stretches of the western branch of the Peconic River are dry. As a functional definition, this will be defined when no flow occurs at the eastern site boundary (station HQ).
- High – The river is full to its banks and water has started to fill nearby low-lying areas (marshes) and exposing increased habitat for fish. A field study performed by Cornell University (Meixler, 2002) measured bankfull depth at 93 locations in the 2.8 mile reach of the river from the STP to Schultz Road. This study showed that the stream channel is shallow with an average bankfull depth of 2 feet. Data collected upgradient, and near station HQ, showed bankfull depths between 1.5 and 2 feet. For the purposes of this report, high river conditions will be defined as occurring when the hydraulic head near station HQ exceeds 40 feet mean sea level (MSL), 1.5 feet above the minimum elevation for flow (e.g. low river conditions). Using the lower value for average bankfull depth will tend to predict higher fractions of time for high river conditions.
- Mid - Defined as constant flow through the entire upper reach of the river but contained within the banks. Therefore, at station HQ, this occurs when the hydraulic head is between 38.5 and 40 feet MSL.

These definitions are consistent with those used in the field study (Meixler, 2002) that based estimates of the area of fish habitats and fish biomass on river flow conditions in the reach of the Peconic River between the STP and Schultz Road.

The primary use of this analysis will be to support estimates of the amount of fish biomass that could potentially exist in the river. The amount of fish biomass depends on the amount of available habitat, which relates to low, mid, and high river conditions (Meixler, 2002). Recolonization of expanded habitat is expected to occur over a time frame of a few weeks to a month (Meixler, 2002). Therefore, monthly average values of hydrologic variables will be used to assess river conditions. Short-term transient effects due to precipitation events that alter the river level for a few days are not important for this assessment because they will not permit recolonization of expanded habitat. For this reason, this analysis attempts to define average flow conditions in the river based on the following specific hydrologic records:

Station Records

Water flow is measured at four stations along the western branch of the Peconic River at BNL. Figure 2 shows a section of the Peconic River that includes the region between the STP and Schultz Road. Figure 2 also shows the North branch of the Peconic River and the joining of the two branches just west of Schultz Road. Measurements at BNL began in 1962 at the outfall of the STP, station EA, and at station HmN. An additional station, HQ, was added in 1967. From 1962 – 1995, flow measurements were made with continuous recording of flow rates at the V-notch weirs. This data was summarized as monthly or annual flow rates and reported in annual Site Environmental Reports. The locations of these three stations are marked in Figure 2. During the period between 1980 and 1995, flow measurements at station HmN and HQ were hampered by low flow and equipment problems. This is discussed in more detail later in the report. In 1995, HE, HmN and HQ were equipped with Parshall flumes that also allow continual automated flow proportional sampling and volume measurements.. Therefore, 'monthly' measurements used in this assessment represent the integrated flow for the entire month.
In addition, the USGS has maintained a station in Riverhead since 1943. Figure 3 shows the location of this station. The information from these stations has been examined for correlations in flow between different stations and for correlations between flow and measured hydraulic head in wells near the river.

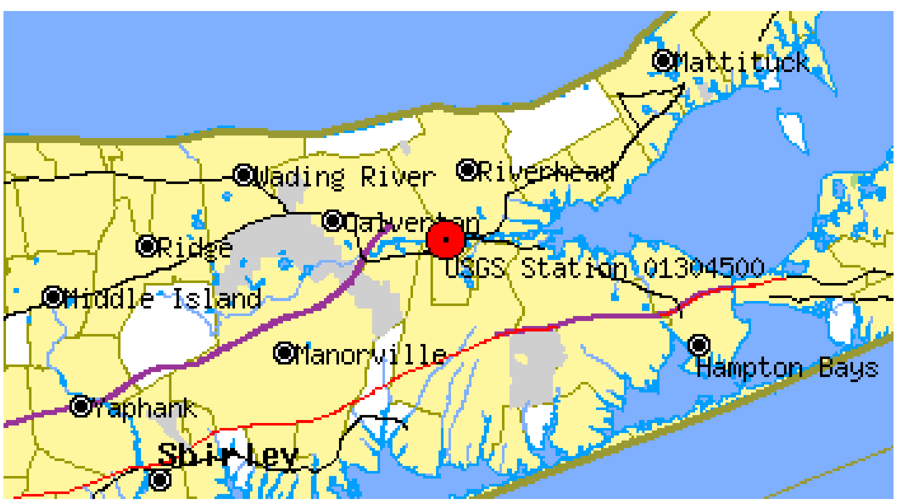

Figure 3 Location of USGS station on the Peconic River in Riverhead

Partial Flow Records

Partial flow records are measures of flow rate collected at one point in time. The USGS collected such measurements at Schultz Road intermittently from 1961 – 1998. Mr. Ron Busciolano of the USGS supplied these data from annual reports compiled by the USGS. These data have been used to correlate flows at Schultz Road with those found at station HQ.

Precipitation Records
Precipitation records have been collected continually at BNL since 1948. Precipitation is a key component of recharge and therefore, impacts water table elevations and flow in the river.

Groundwater Elevation Records

Flow in the Peconic River is closely coupled with groundwater elevations. In 1995, a series of shallow groundwater wells were installed near and inside the Peconic River streambed within the BNL property. In addition, USGS routinely collects hydraulic head data from a series of wells in the vicinity of BNL. Mr. Ron Busciolano of the USGS supplied web addresses for the data from these wells. Appendix A, lists the web links and provides an approximate location for each well and the time period over which data are available. Three wells were selected to examine for correlation between groundwater elevations and flow measurements at HQ.

Start of Flow Records
The USGS has periodically measured the location of the start of flow in the Peconic beginning in 1966. The location of the start of flow represents the point where flow begins due to either natural or man-made processes. For example, in certain years when the water table is low, flow will start at the STP, cease due to infiltration into the groundwater near the STP and then resume again further downstream. For this report, start of flow refers to the location where flow starts that is not impacted by the discharges from the STP. This working definition for start of flow provides information on whether it is likely that flow occurred at the site boundary in the western branch of the Peconic.

5.0) Results

5.1 Measured Flow Along the Peconic River

Water flow discharges from the STP have been measured since 1962. Figure 4 provides the historic discharges from this facility as obtained from annual BNL Site Environmental Reports (SERs). Average yearly flow has been 2.6 10^8 gal/yr. The figure shows that discharges were highest in the late 1960's and 1970's and have been continually below the average since 1990 and substantially below the average since 1997. Monthly discharge records indicate that flows are continuous throughout the year with the maximum and minimum monthly flows within a factor of 3. For example, in 2001, the peak monthly flow was 1.6 10^7 gal in June and the minimum was 7.4 10^6 gal in November. This corresponds with typical usage patterns at BNL which have higher water demands in summer.

Flow at station HmN, located approximately 0.5 miles downstream from the outfall of the STP, generally matched the flow from the outfall from 1962 – 1982. During years of high precipitation, flow at station HmN was as much as twice the volume as that from the STP discharge value indicating flow from upstream of the STP was contributing to the total flow. In dry years, flow was somewhat less than at station EA, indicating losses due to recharge to the groundwater and evapotranspiration. In 1983, damage to the station HmN V-notch weir combined with flows above the capacity of the weir prevented accurate measurements of flow from June – October (SER, 1984). From 1984 – 1995, vegetative growth downstream from the weir prohibited accurate measures of flow. However, no flow was reported in the SER in most years during this period.

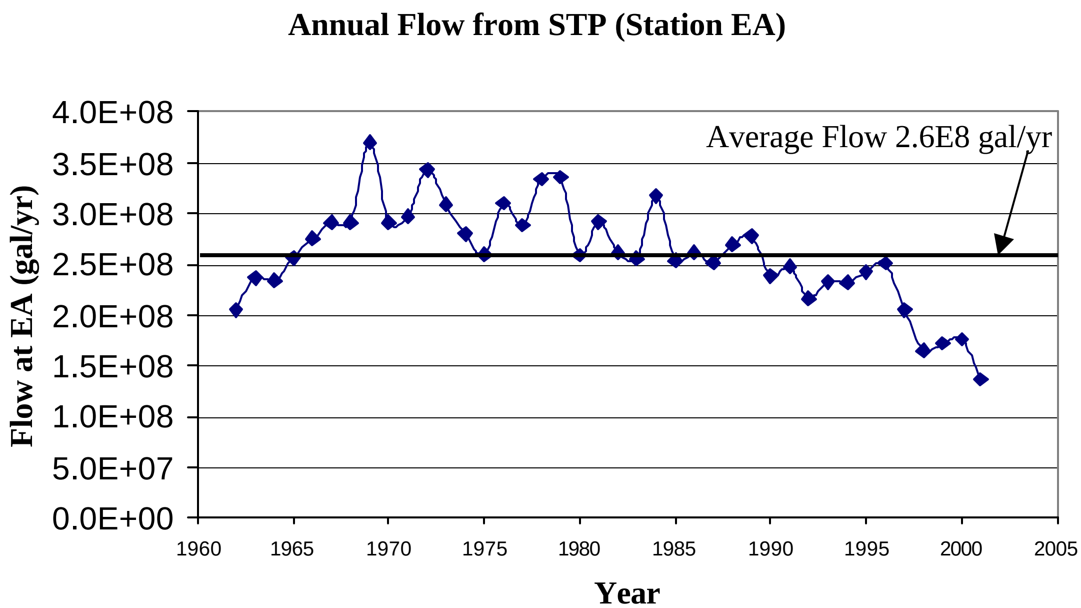

Figure 4 Annual flow (gal/yr) from the STP to the western branch of the Peconic River

The flow from station HQ is an important measure in determining flow conditions in the 2.8 mile reach of river downstream from the STP. Records for flow at this location were taken from the annual SER. An SER was not prepared from 1967 - 1969. However, a historical review of environmental data was performed in 1989 for that time period (Meinhold and Hull, 1989). This review included estimates for flow at station HQ. However, the basis for these estimates was not provided and therefore, the data quality can not be assured. Figure 4 presents the annual flow (gal/yr) at station HQ. The annual flow volumes in the 1970's were 2 to 5 times higher at this location than the input from the STP, indicating flow was being supplied by the groundwater. This correlates with above average precipitation during the period. In 1983 obstructions downstream of the weir at station HQ raised the water level prohibiting accurate measures of flow. In the SER's from 1984 – 1988 qualitative statements were made that indicated that there was little or no flow during this period. The 1989 SER (SER, 1990) stated that vegetative growth downstream from the weir at station HQ prohibited accurate measurements of flow. The SER's from 1990 – 1995 stated that the water level was below the weir and no flow was occurring. The SER for 1995 reported that the stream was completely dry near HQ which prevented the collection of routine surface water samples (SER, 1996). Flow measurements were reinstated starting in 1996 after installation of a new flow meter. The historical record between 1980 and 1995 qualitatively supports that there was little flow during this period. However, due to the absence of quantitative measurements, this information was not used to assess river flow conditions.

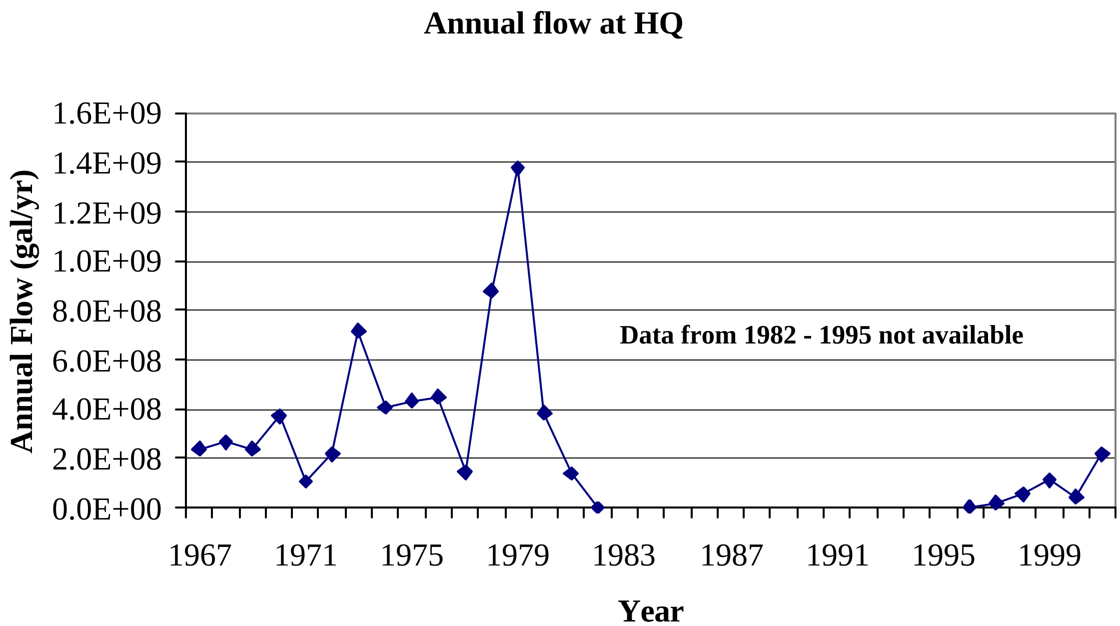

Figure 5 Annual flow measured at BNL site boundary (Station HQ)**.**

From 1972 - 1979 and from 1996 to the present, monthly flow measurements have been reported from station HQ. Examination of these measurements indicate a yearly cycle, in which flow peaks in April, declines through the summer and fall and begins to increase in December, Figure 6. The average monthly values presented may be artificially high because of the high flows during the 1970's and not including the reported zero flows for most of the 1982- 1995. There is substantial variation around the average values presented in Figure 6. For example, in 2002 the flow was zero in each month. The reported zero flows from 1982 – 1995 were not used to estimate average values because equipment problems made measurements unreliable (see discussion above). While for the most part, this was a dry period and flows were reported as zero or low in the SERS, flow most likely did occur in the 1983 – 1984 and 1989 – 1990 time periods based on high flows measured at the Riverhead station in the Peconic River and precipitation well above average. Therefore, data from 1982 – 1995 were not used to estimate average monthly flows at station HQ, due to uncertainty in the data.

Figure 7 illustrates the annual variation using station HQ monthly flow rate data from 1996 – 2001. It indicates that between the months of September and December there has been essentially no flow since 1996. During this period flow has peaked in the May to June time period and steadily decreased to zero flow by September. In 2002, flow did not occur at station HQ at any time. Data for annual flow rates at stations EA, HmN, and HQ are presented in Appendix B. Monthly flow data at station HQ is provided in Appendix C.

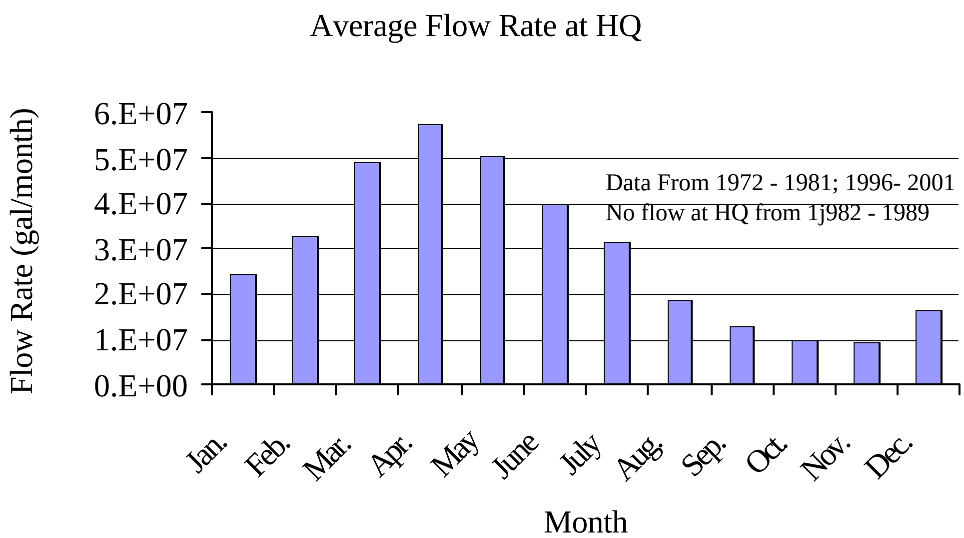

Figure 6 Average Monthly flow at station HQ, BNL site boundary

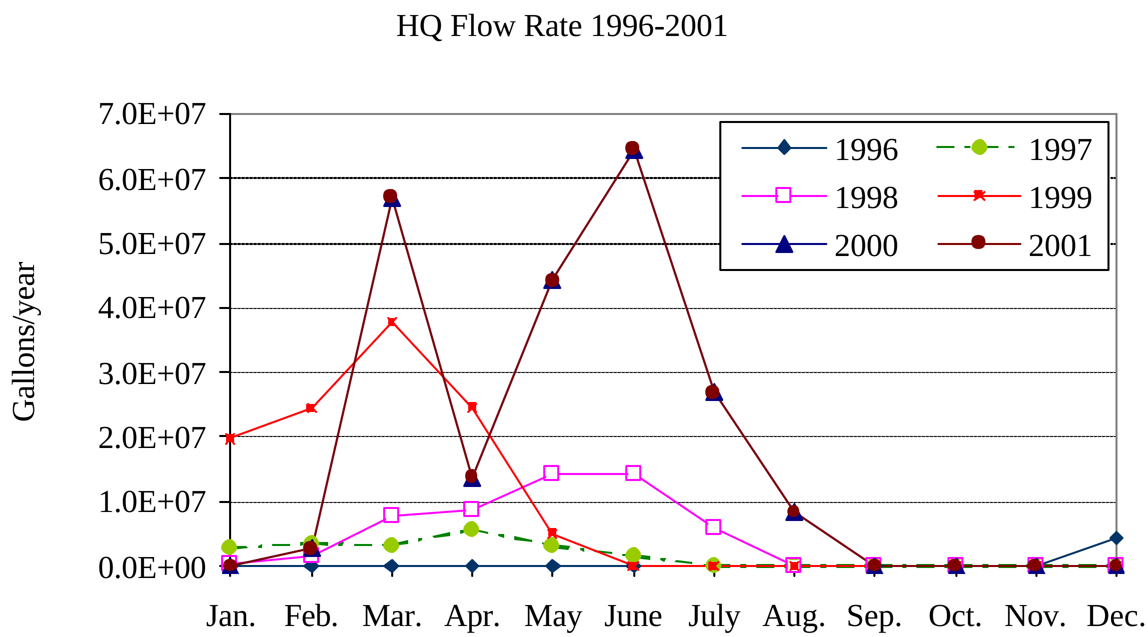

Figure 7 Monthly flow at station HQ from 1996 - 2001

The USGS maintains a station in Riverhead, (USGS 01304500) that has collected daily stream flow data for the Peconic River since 1943. Appendix D contains the measured yearly flow rate at this site for 1943 – 2000. Figure 8 shows the yearly stream flow from this site. Average stream flow at this station has been 8.7 x 10^9 gal/yr, approximately 30 times the average flow rate at station HQ. This indicates that tributaries other than the western branch of the Peconic River and groundwater recharge downstream of the eastern BNL boundary are supplying the majority of flow at this point. The stream flow ranged from a minimum value of 3.7 x 10^9 gal/yr in 1966 to a maximum flow rate of 1.6 x 10^{10} gal/yr in 1979, the same year as the peak at station HQ

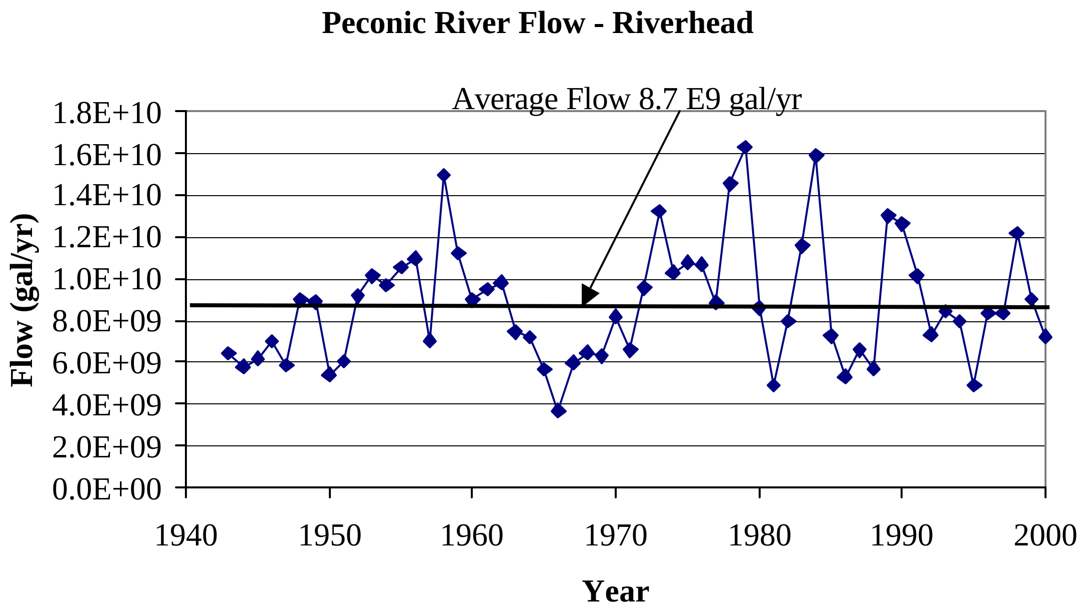

Figure 8 Flow rate at USGS station 01304500 on the Peconic River in Riverhead, NY

The monthly variation in flow was similar to that found at Station HQ, (see Figure 6), with peak flows in April that steadily decrease until November.

A scatter plot of annual flow rates at the BNL site boundary, station HQ, versus annual flow rates at the USGS station 01304500 in Riverhead, NY, was prepared to determine if there was a strong correlation between these two variables. The best fit correlation is:

Riverhead Flow (gal/yr) = 1.71 x HQ Flow (gal/yr) + 7.4 x 10^9

The correlation coefficient for the goodness of fit was 0.6. A correlation coefficient of 1 would indicate a perfect fit between the 2 variables. The intercept for zero flow at station HQ is 7.4 x 10^9 gal/yr flow rate in the Peconic River at the Riverhead station. In the 57 year period from 1943 – 2000, the flow rate has been less than the intercept value 19 times, most recently in 1995.

In an effort to determine if shorter-term flow rate measurements were better correlated between these two locations, a similar analysis using the monthly flow at the USGS station in Riverhead with the monthly flow at station HQ was performed for the 165 months in the periods of 1972 - 1979 and 1996 - 2002 that monthly flow data were available. In this case, the intercept for zero flow was 8.4 10^9 gal/yr and the correlation coefficient was 0.54. This indicates that shorter term impacts did not improve the correlation and that flow at HQ was likely to occur only if the flow rate at the Riverhead station exceeded 7.4 – 8.4 10^9 gal/yr.

For the remainder of the analysis, the limit of 7.4 10^9 gal/yr as the minimum required for flow will be used as this will tend to predict more time at higher flow conditions at station HQ and therefore, lead to higher estimates of available biomass.

The flow at the USGS station in Riverhead is not highly dependent on the flow at station HQ because less than 5% of the flow that reaches the USGS Riverhead station passes through station HQ. A value of 0.6 does not indicate a strong correlation.

Partial flow rate records were collected at Schultz Road on the Peconic River from 1961 – 1998, Appendix E. During this period, 96 samples were collected and the flow rate varied from 0 to 27 ft^3/s (6.4 x 10^9 gal/yr). Zero flow was measured at Schultz Road on five occasions (August and November 1966, September 1968, October 1987, and October 1994). The peak flow was measured in May 1979. For months in which monthly flow data were available for station HQ, the measured flow rates at Schultz Road were converted from cubic feet per second to gallons per year and compared to the monthly average flow rates measured at station HQ (gal/yr). Figure 9 shows the correlation that was obtained.

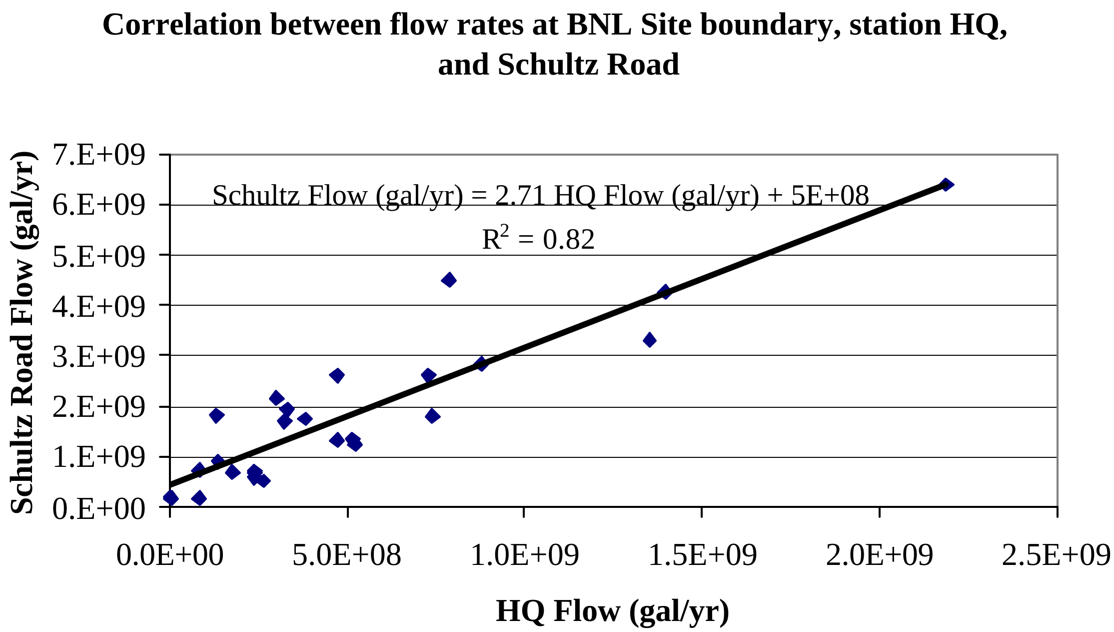

Figure 9 Correlation between flow at Schultz Road and BNL site boundary, station HQ.

The best fit linear correlation between flow at HQ and Schultz Road is:

Schultz Flow (gal/yr) = 2.71 x HQ Flow (gal/yr) + 5E+08

The goodness of fit in the correlation between Schultz Road and station HQ, is 0.82, which is substantially better than the correlation between HQ and Riverhead. This correlation indicates that there will be little or no flow at station HQ if the measured flow rate at Schultz

Road is less than 5.0 x 10^8 gal/yr. The flow rate has been less than this value in 14 of the 96 measurement points and this typically occurs between late summer and fall (August through November).

Ideally, the preceding correlation would be made between the flow rate at station HQ on the day of the partial flow measurement. However, these data were not readily available. Using the average monthly flow rate may impact the correlation. This impact is not felt to be of major significance for the purpose of this analysis, determining the fraction of time the river is at high, mid, or low flow conditions. The reason for this is that flow in this stretch of the river is groundwater controlled. Changes in groundwater occur on a longer time-scale than transitory events due to precipitation and run-off. Since field measurements are generally taken during fair weather, they are likely to be more representative of average conditions than peak conditions. Using the monthly average flow rate, should be accurate enough representation of average conditions for this correlation.

5.2 Precipitation

Precipitation data has been continuously collected at Brookhaven National Laboratory since 1948. Annual precipitation data are presented in Appendix F. Figure 10 presents the annual precipitation record from 1948 to 2001. The average precipitation rate during this period is 48.4 inches/yr and total precipitation is usually between 40 and 60 inches/yr. The maximum rainfall occurred in 1989 and was 68.8 inches. The minimum rainfall occurred in 1965 and was 34.4 inches. From Figure 10, it appears that there was a drought in the early to mid 1960's, precipitation was above average in the 1970's, the 1980's were characterized by the two highest annual rainfalls measured and six years of substantially below average rainfall, and the 1990's were characterized by a drought in the early part of the decade.

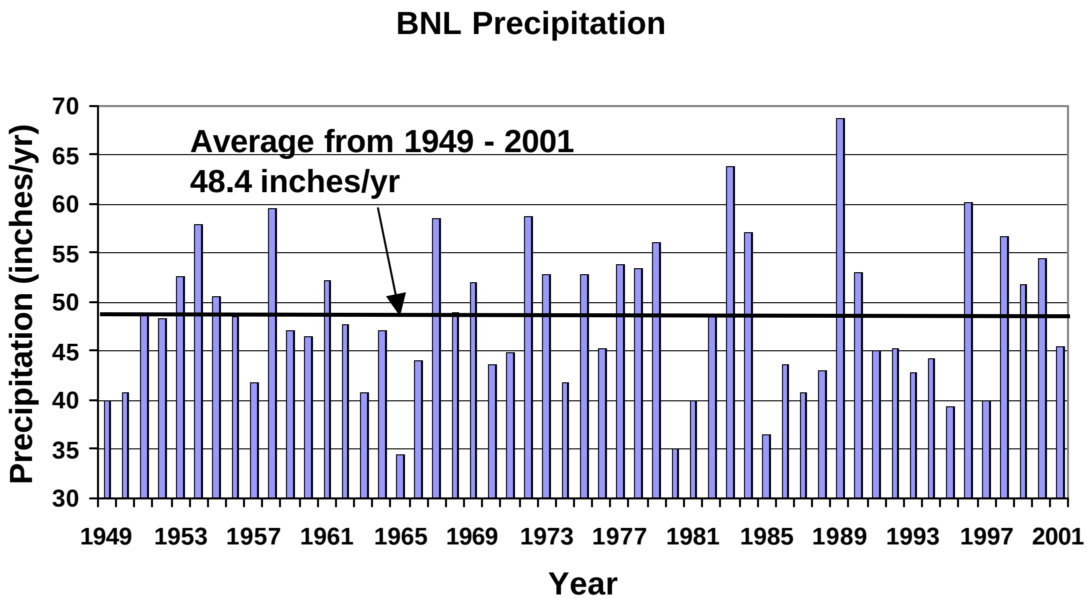

Figure 10 Annual precipitation (inches) measured at Brookhaven National Laboratory

Attempts to correlate annual flow rates with precipitation were not successful. The correlation coefficient for a linear best fit line was only 0.01, indicating substantial scatter. Although a general trend occurs in which higher precipitation leads to higher flows, this was not always the case and large fluctuations around this trend were common. High flow rates could occur during years of low precipitation if the preceding years had above average rainfall. The converse was also true. This supports the concept that the river flow is correlated with the groundwater elevation and not necessarily precipitation.

Attempts to correlate daily precipitation values with flow are believed to be inappropriate for this analysis. Flow in the river is groundwater controlled, which depends on precipitation. However, it does not depend on any single precipitation event. For example, there was no flow at station HQ during 2002, yet there was 52 inches of precipitation, 3.5 inches above the average and tens of precipitation events. During 2001, flow was 3 inches below normal for the year and the last six months of 2001 were 7.6 inches below average. This deficit led to a lowering of the water table that did not recover to levels necessary for flow at station HQ during all of 2002.

5.3 *Correlation of groundwater elevation and flow at the BNL site boundary, Station HQ*

Data from water table wells near the Peconic River are presented in Figure 11. The figure shows the STP, Peconic River, and hydrographs for wells in the vicinity of the river during the period of June 1990 – June 2002. Exact well locations are marked by a line from the hydrograph and the well number written on the map. Wells designated 39-05, 39-11, 39-12, 40-01, 40-08, 60-01, 60-02, 61-03, and 61-07 are on the map. Most of these wells were installed around 1995, therefore, the much of the data is from this period forward. Well 61-

07 is located within a few hundred feet of station HQ. Well 61-03 is slightly further upstream. As a method of correlating flow with hydraulic head, the flow data from station HQ was compared to the data from Well 61-07 and 61-03. Figure 12 presents this information for Well 61-07. The data used to generate this figure is in Appendix G.

From Figure 12, it is clear that flow does not begin at station HQ until the hydraulic head becomes greater than approximately 38.5 feet MSL. This is consistent with the known elevation, 38.45 ft, at the base of the station. Similar plots of hydraulic head versus flow rate for well 61-03, and 61-07 showed similar results, with no flow until a certain hydraulic head was attained. The hydraulic head required for the onset of recharge to the stream bed becomes larger as one moves further upstream.

The data from wells are limited to the time period after 1995. However, the USGS has had monitoring well S6441.1 near the intersection of North Street and Schultz Road in operation from 1949 - 1990. This well was replaced by an adjacent well, S6441.2, in 1991. The wells are so close that the location of these two wells appears at the same point on the map on Figure 13. The well is within ½ mile of the point at which the Peconic River intersects Schultz Road. Plotting the monthly flow rate at station HQ against the hydraulic head measured in these wells yields Figure 14. The data indicates that flow will not start at station HQ unless the hydraulic head at wells S6441.1 or S6441.2 is above 36.8 ft MSL. The well near Schultz Road is approximately 1.6 miles downstream from station HQ and therefore, flow starts at a lower hydraulic head than the value at well 61-07 on the BNL site. This correlation compares station HQ flow to Well S 6441.1 and S6441.2 head at 41 data points due to the lack of data prior to 1972 and between 1980 and 1995. However, the complete data set for well S6441.1 and S6441.2 includes 275 measurements of head. The hydraulic head is less than 36.78 feet 46% of the time. The lowest measured head with flow at station HQ was 36.2 ft MSL. Measurements of hydraulic head are less than this value 30% of the time. The best fit line does not have a particularly high correlation coefficient (0.55). This is due primarily to a few data points with high flow that are poorly represented in the hydraulic head data set for the wells S6441.1 and S6441.2. The correlation of hydraulic head measurements with the flow rate on the day the measurement was taken would probably show a better match. This was not attempted due to difficulties in obtaining the daily flow data and more importantly, the objective of the analysis was to determine the available fish habitat based on hydrologic variables. Thus, the key component of this analysis is the determination of the onset of flow, not the correlation of flow rate with hydraulic head once flow begins.

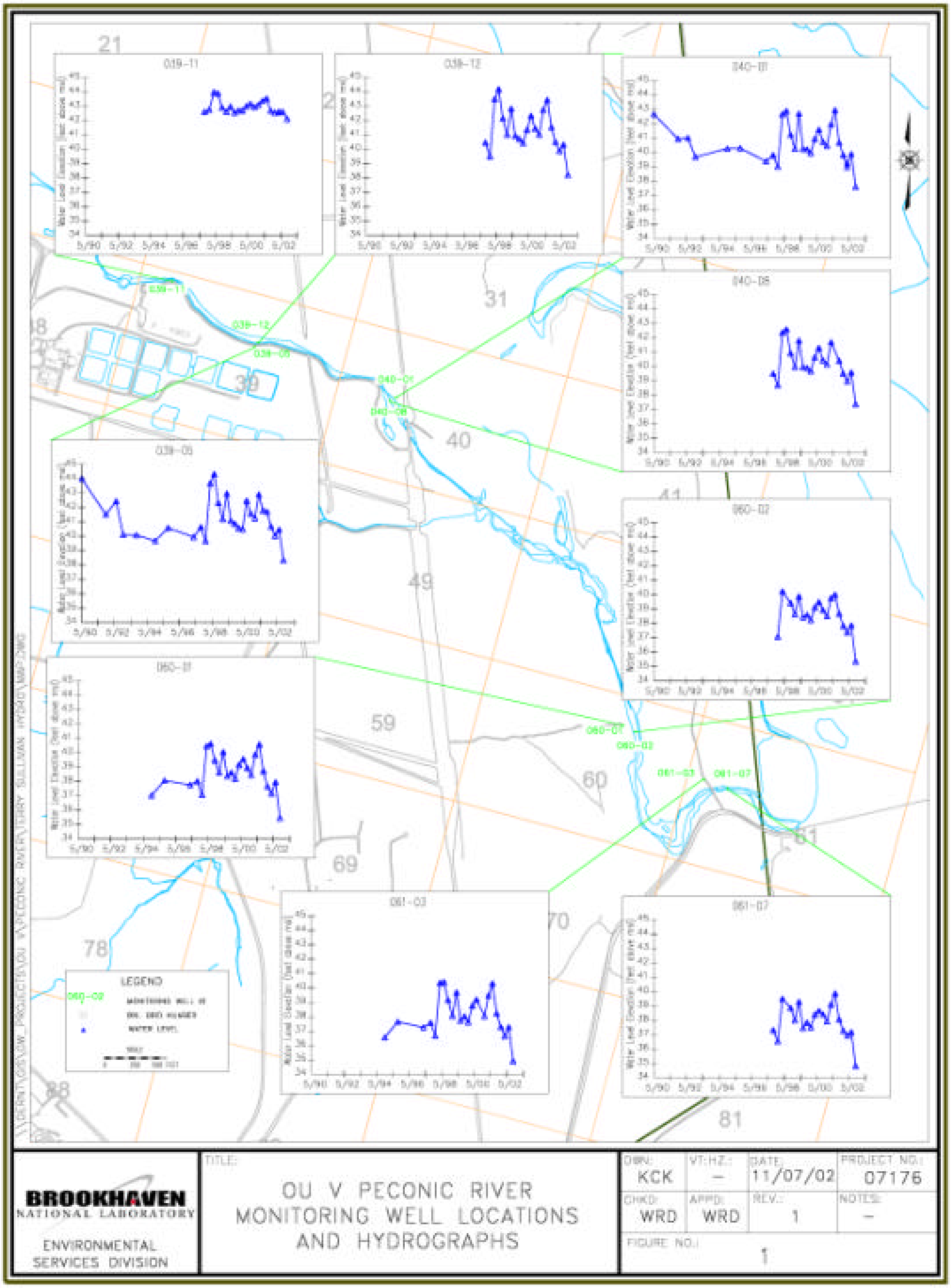

Figure 11 Map of wells on the BNL site near the Peconic River

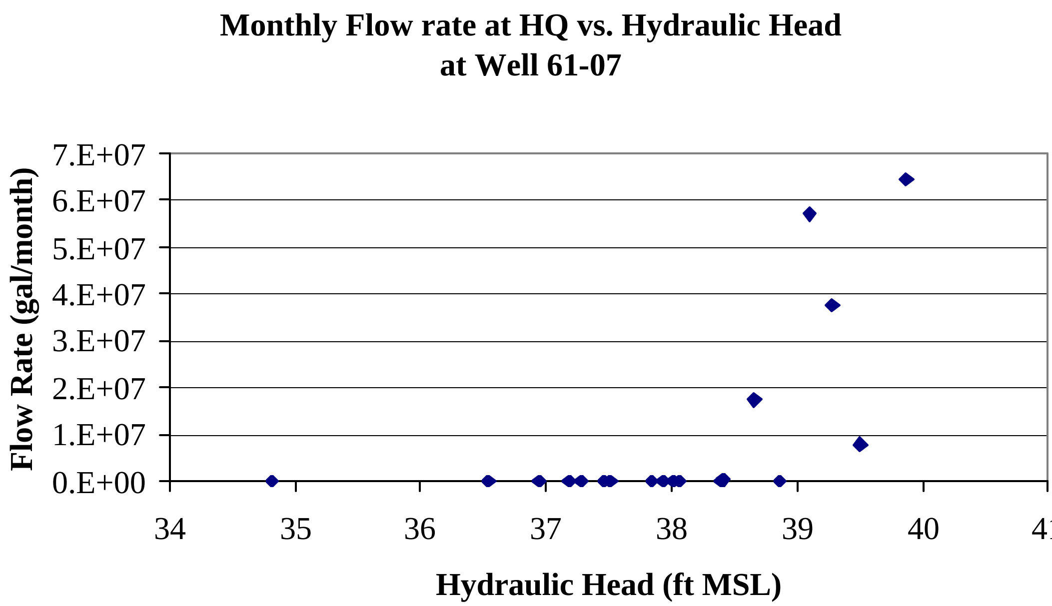

Figure 12 Comparison of flow at station HQ with hydraulic head at well 61-07

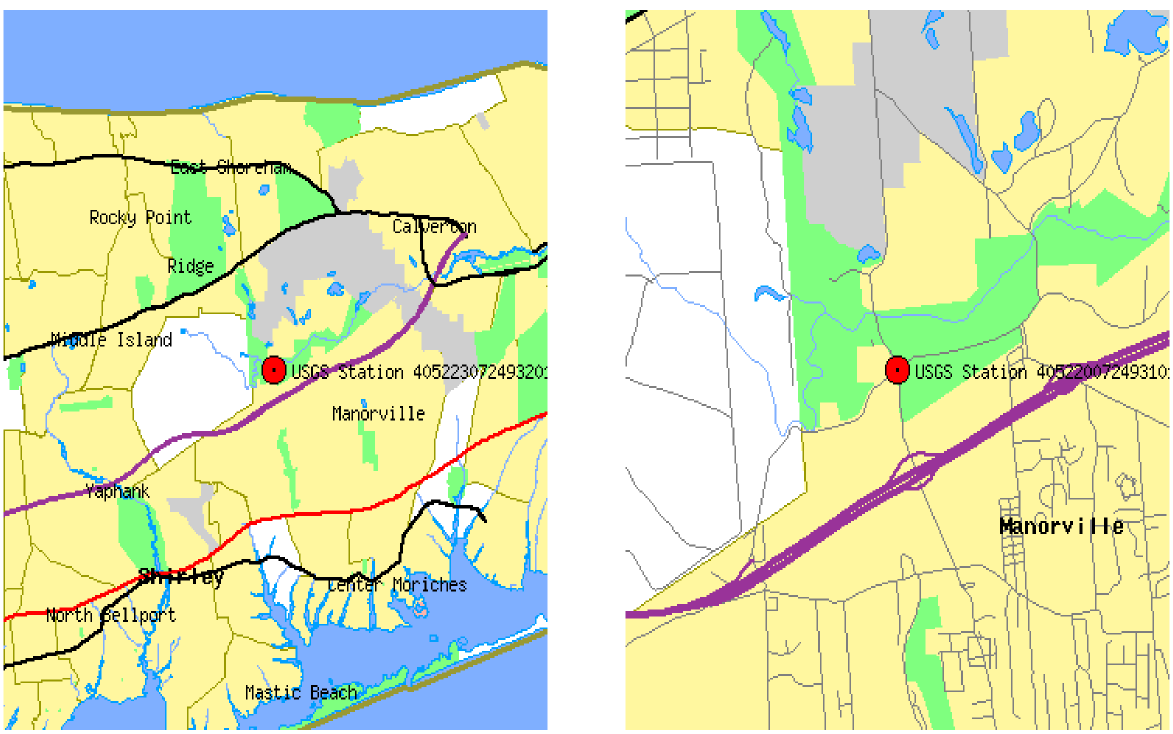

Figure 13 Location of collocated USGS wells 6441.1 (1949 1990) and 6441.2 (1994-). The Map on the left provides an overview of the location in relation to BNL and the Peconic River. The map on the right provides higher resolution of the location.

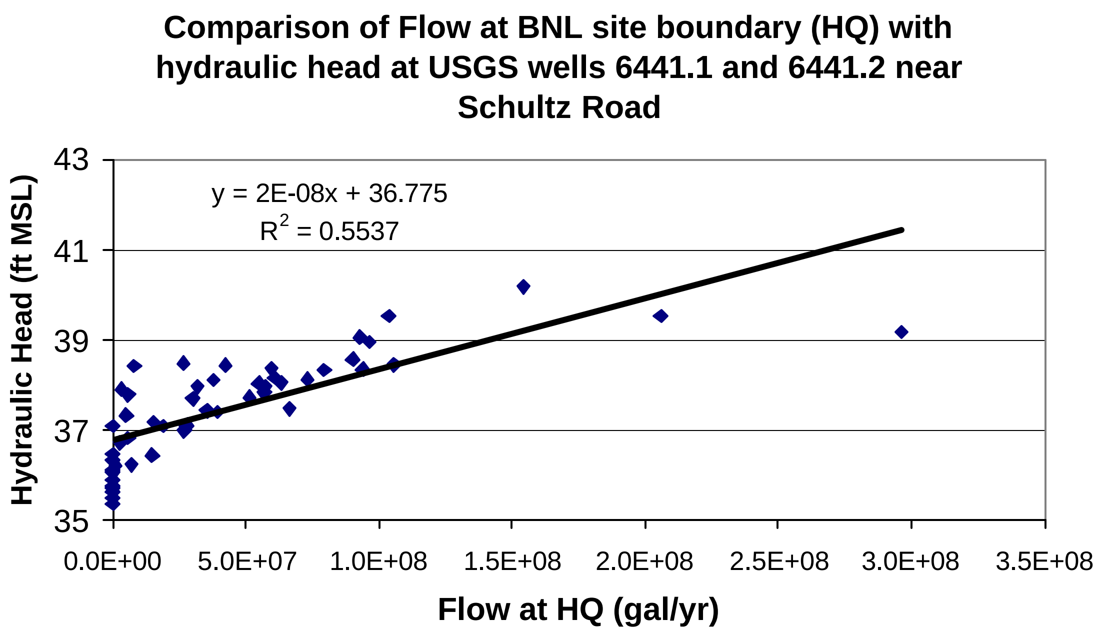

Figure 14 Comparison of flow rate at the BNL site boundary (HQ) with hydraulic head at USGS well near Schultz Road.

Although flow measurements were not made at station HQ from 1990 – 1994, a limited number of water table maps were generated during this period. Water table maps are prepared using existing measured hydraulic head data and generate contours that represent lines of constant head. Appendix I contains all of the water table maps from 1990 – 1994. Figure 16 presents the water table map generated for May, 1990. The predicted water table at station HQ during this time is 41 ft MSL. The estimated hydraulic head from these maps is probably accurate to within "0.5 feet. In addition, archived records had a water table map from January, 1973. The predicted head at station HQ from this map was 40 ft MSL. The measured flow rate at station HQ in January 1973 was 3.7 10^8 gal/yr.

From the water table maps, an estimate of the hydraulic head at station HQ was obtained for each time period and therefore, estimates of the potential for flow were obtained. Flow is likely if the hydraulic head is above the bottom of the station, 38.45 feet MSL. Table 1 summarizes the estimated hydraulic head at station HQ and the likelihood for flow.

Table 1: Estimates of the potential for flow at station HQ from hydraulic head values obtained from water table maps.

Date	Estimated Hydraulic Head At HQ (ft MSL)	Flow likely at HQ? (Head > 38.45 ft)
January, 1973	40	Yes (measured)
May, 1990	41	Yes
October, 1991	38	Maybe
June, 1992	38	Maybe
November, 1992	37	No
September, 1993	37	No
November, 1994	36	No

From table 1, one would expect that flow occurred in May of 1990. The high water table is consistent with high precipitation in 1989 and the early part of 1990. Flows were above average at the Peconic River station and at Schultz Road were recorded during this time. The water table elevation data from October, 1991 through November, 1994 support the notion that little or no flow occurred during this period at the times of measurement. Low flows may have occurred in October of 1991 and June of 1992 as the estimated hydraulic head is close to the threshold for flow. Although the data indicates little or no flow at station HQ between 1991 and 1994, most of the maps were generated in the fall when flow is expected to be low. Flow could have occurred during other times of the year.

The USGS has intermittently determined the location of the start of flow in the Peconic River between 1966 and 1997. and a survey in October, 2002 (Meixler, 2002) measured start of flow at that time. Start of flow information provides the location at which the water table intersects the stream channel and is presented on a map of the Peconic river in the vicinity of BNL, Figure 16. Of the 14 start of flow measures taken, four times the start of flow occurred to the west of the BNL, three times it occurred near the western border of BNL, six times it occurred to the east of the BNL, and once (March, 1992) it occurred near HQ at the site boundary. In October, 1966, the start of flow was approximately 2.1 miles from the site boundary and east of Schultz Road. Table 2 presents the times at which the start of flow occurred east or west of the site boundary. Table 2 also includes the distance in river miles from the site boundary to the start of flow. Negative distances in this table imply that the start of flow occurred within the BNL site. For example, on April, 1981, the start of flow is -0.2 river miles from the point at which the Peconic River crosses the western boundary of the site.

Table 2: Location of start of flow on the Peconic River.

Start of Flow East of BNL Site	Distance River Miles East of Site Boundary	Start of Flow West of BNL site	Distance River Miles West of Site Boundary
October, 1966	2.1	April, 1981	-0.2
August, 1995	1.6	March, 1997	-0.1
March, 1995	1.0	March, 1983	-0.1
April, 1968	0.8	March, 1983	0.1
June, 1967	0.7	October, 1989	1.0
October, 2002	0.5	March, 1990	1.0
March, 1992	-0.1	March, 1991	1.1

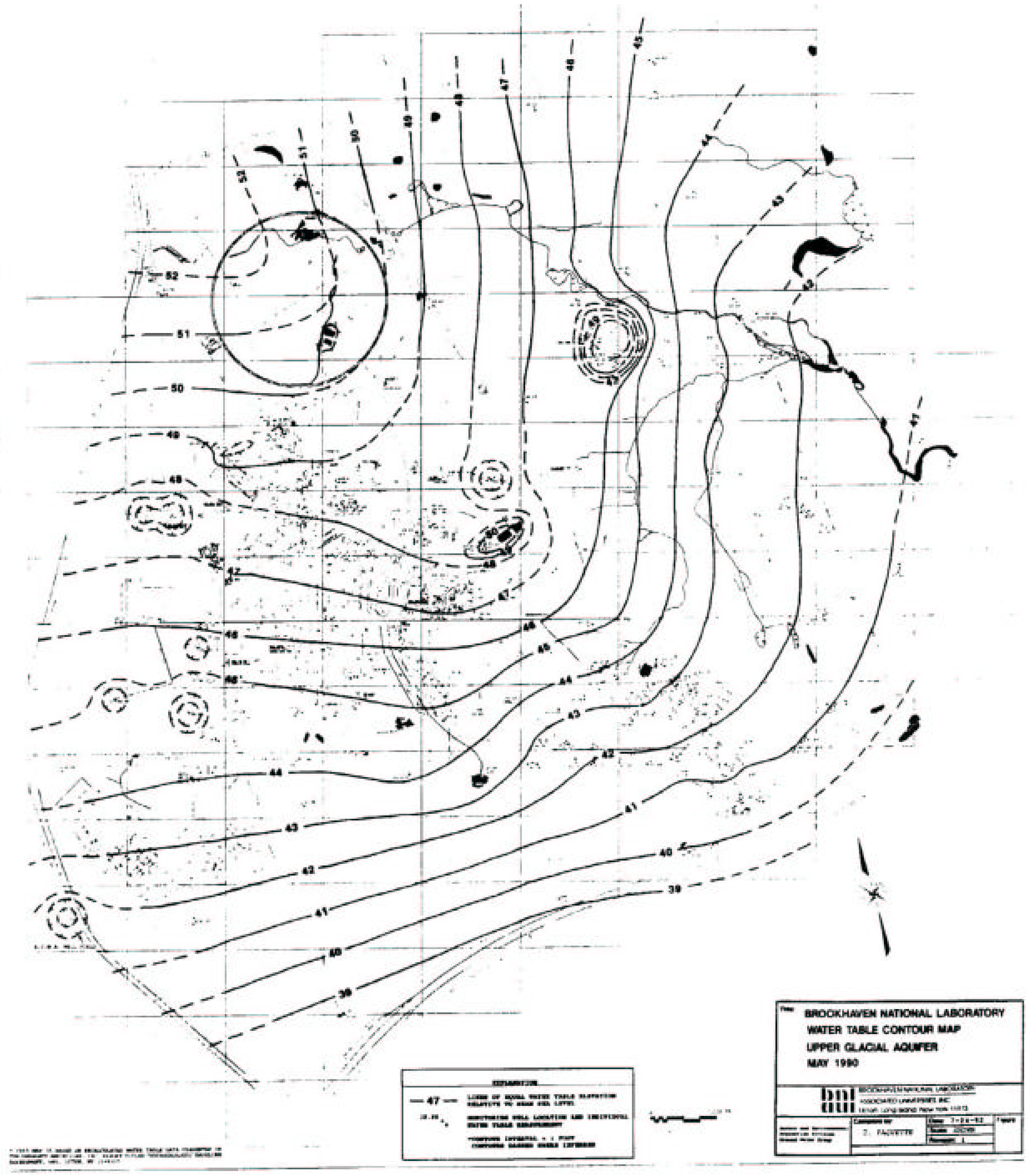

Figure 15 Water Table map for May, 1990.

5.4 Start of Flow Data

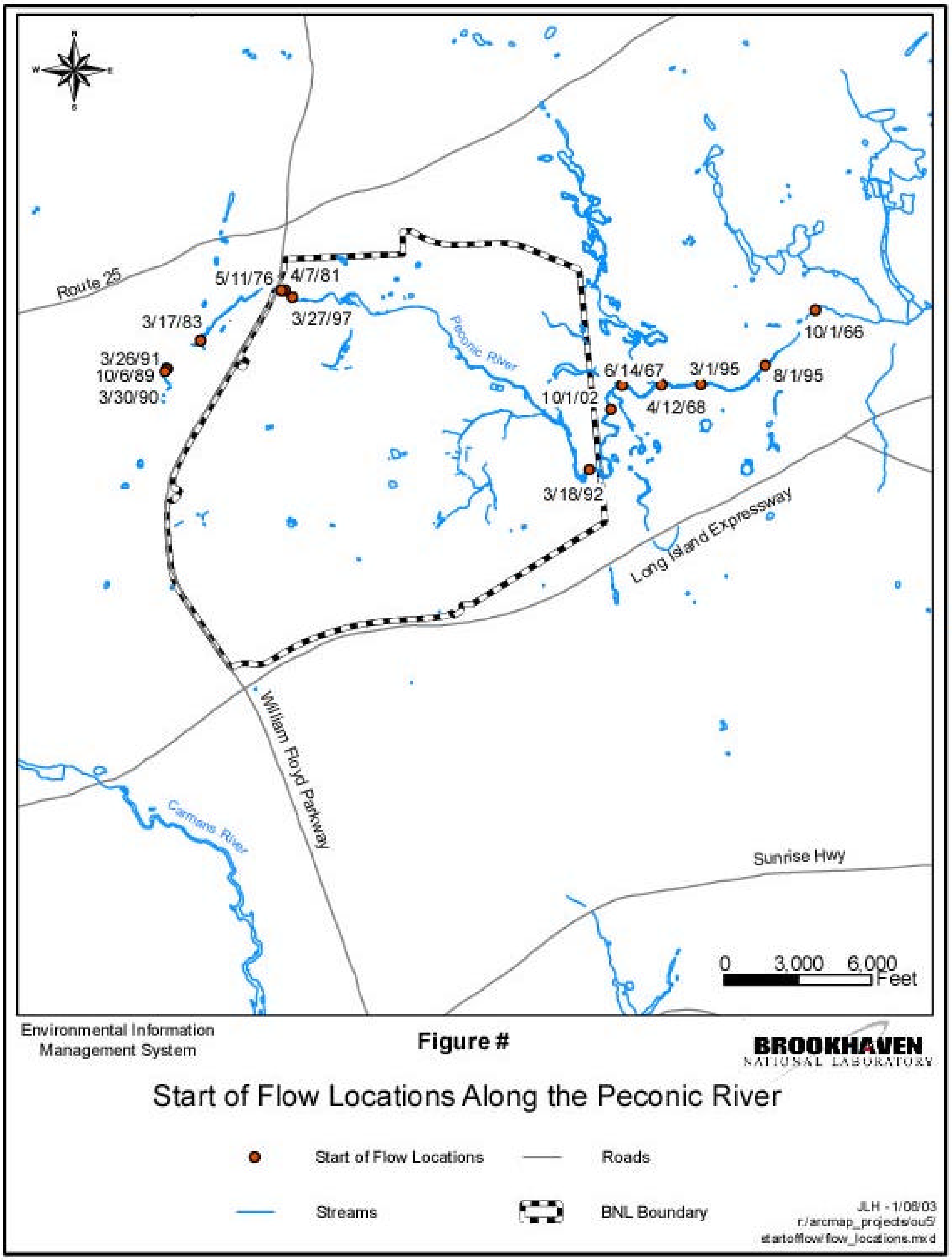

Figure 16 Measured Start of Flow Along the Peconic River (new map being generated by EIMS)

During October, 2002, Cornell University performed a survey of the Peconic River from the STP to Schultz Road (Meixler, 2002). During the survey they noted the point where flow from the STP stopped due to infiltration into the streambed and the point where it started flowing further downstream due to groundwater recharge into the streambed. At this time, the start of flow due to groundwater recharge is approximately 0.5 miles downstream from station HQ at the BNL site boundary. This information is displayed in Figure 17. It would be useful to collect data on where flow ends after the STP and begins due to natural processes during routine groundwater sampling performed along this reach of the Peconic.

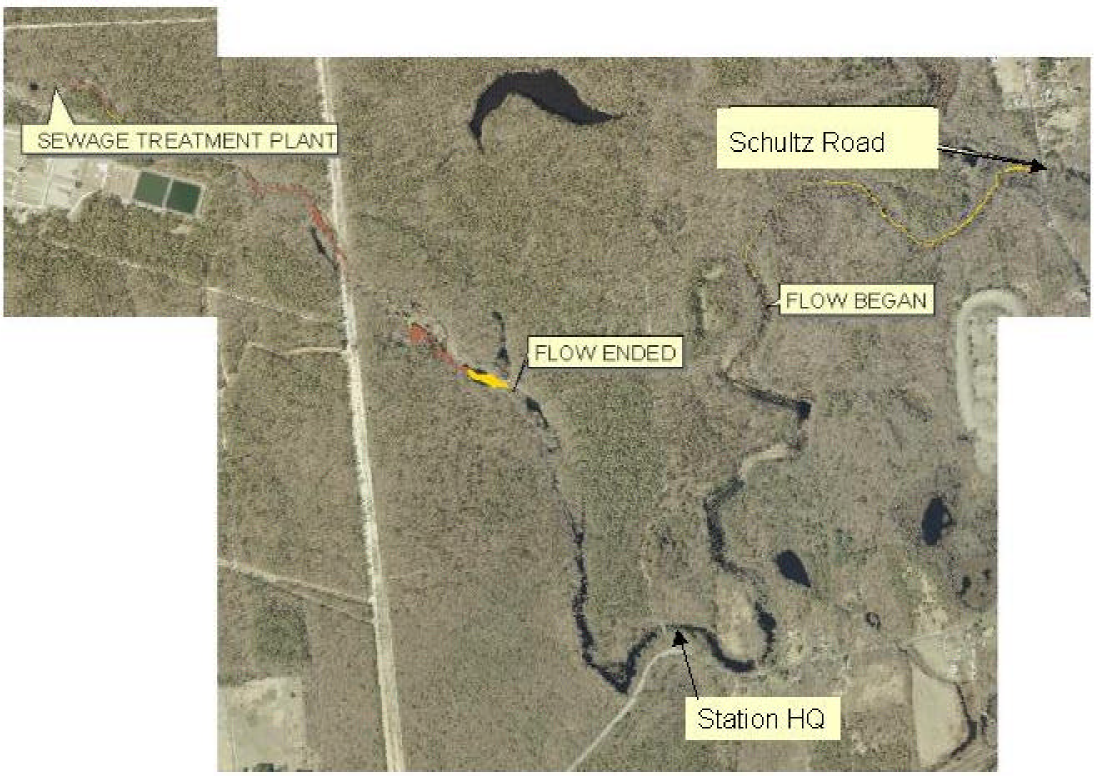

Figure 17 Start and stop of flow measured during October, 2002 survey.

6.0 Discussion

The preceding section provided the data necessary to evaluate river flow conditions. The objective of this study was to determine the fraction of time the river is expected to have flow characterized as:

- Low – Similar to conditions in 2002. During these conditions, large stretches of the western branch of the Peconic River are dry. As a functional definition, this is defined when no flow occurs at station HQ and therefore off of the BNL property.

- High – The banks of the river are full and water has started to fill nearby low-lying areas (marshes) and expanding the habitat for fish. Bank elevations in the section of the Peconic between the STP and Schultz Road averaged 2 feet. Near station HQ, bank elevations were between 1.5 and 2 feet. For the purposes of this report, high river conditions will be defined as occurring when the hydraulic head is 1.5 feet above the minimum elevation for flow (e.g. elevation of the stream bed). Using the lower value for average bankfull depth will tend to predict higher fractions of time for high river conditions.

- Mid - Defined as flow through the entire reach of the river but contained within the banks. Therefore, at station HQ, this occurs when the hydraulic head is between 38.5 and 40 feet MSL.

In each case, multiple data sets have been evaluated to determine the range of the expected flow conditions.

6.1 Low River conditions

Low river conditions (i.e., no flow off of the BNL site) are predicted to occur between 15 and 70% of the time based on the historical record. This range was determined from the following data:

- Monthly flow records at station HQ, from 1972 – 1979 and 1995 – the present, show that no flow conditions occurred in 55 of the 180 measurements (31%). The 1970's were characterized by high flows and only 1 out of the 96 measurements showed no flow. The data starting in 1996 are characteristic of a low flow period as 54 of the 84 measurements indicated no flow .
- The analysis of the partial flow records at Schultz Road indicated that there will be no flow at station HQ if the flow rate at Schultz Road is less than $5.3\ 10^8$ gal/yr. This occurred at 14 of the 96 measurements (15%).
- The correlation of flow between station HQ and the USGS station in Riverhead indicated flow would not be expected at station HQ if the flow at Riverhead was less than $7.1\ 10^9$ gal/yr. This occurred in 19 of the 57 years (33%).
- Start of flow records from the USGS indicate that 6 of the 13 measurements show flow due to natural processes beginning east of the site boundary (46%). This may be biased towards a larger estimate of low flow due to the sampling times which were often in fall.
- Hydraulic head records at Well 61-07, which is located within a few hundred feet of station HQ, indicate flow will occur only if the water table elevation exceeds the bottom of the flow gage at HQ, 38.5 ft MSL. The hydraulic head was less than 38.5 feet in 17 out of 24 measurements, (70%), between 1997 and the present. This period has been drier than average as no flow has occurred at station HQ 60% of the time during this period. The difference in predicted frequency of no flow most likely arises from the more frequent sampling of flow as compared to hydraulic head.
- Hydraulic head records at USGS wells 6411.1 and 6411.2 from 1949 – 1998 indicate flow will not occur at station HQ if the measured head in these wells is less than 36.2 feet (minimum level with observed flow) which has occurred 30% of the time. A best fit linear correlation between flow at station HQ and the hydraulic head in these wells

indicates that flow should start when the hydraulic head reaches 36.78 feet. The measured head is less than this value 46% of the time.

- Discussions in the SERs from the period of 1983 – 1995 stated that there was little or no flow at station HQ during this period. However, vegetative growth downstream of the weir prevented accurate measurement of flow. Grab sampling for radiological and chemical analysis was performed near station HQ during this period, so water was present. In 1995, there was not sufficient water to even collect grab samples. This qualitatively indicates that this period was more similar to recent times (1996 – 2002) in which flow is sporadic and typically occurs in the winter and spring months as compared to the period 1972 - 1979 in which flow was continual except for one month.

Estimates for the fraction of time that low river conditions will exist in the river have been obtained. The most reliable are the flow measurements from station HQ and hydraulic head data at nearby wells BNL well 61-07 and USGS wells S6411.1 and S6441.2. Therefore, it is likely that low river conditions will exist between 30 and 46% of the time.

6.2 High River Conditions

Data support high river conditions for periods of one month or more no more than 16 – 33% of the time. High river conditions may occur in response to precipitation events for short periods of time (a few days). However, this is not long enough for repopulation of fish habitat exposed by the high river conditions. High river conditions occur when the banks overflow and adjacent low-lying areas become flooded. In this case, flow rate may not be a good indicator of high river conditions because the flow in the low-lying areas may be slow and the primary flow will still be through the main river channel. Therefore, for the purposes of estimating the fraction of time that the river is in high river condition for an extended time period, the water table elevation is a better measure for high river conditions. The most relevant hydraulic head data comes from BNL Well 61-07 and USGS Wells 6441.1 and 6441.2.

Well 61-07 has been sampled quarterly since August, 1997. During this time, flow has occurred in 7 out of 20 measurements. The hydraulic head, never exceeded 40 ft MSL, which is the elevation defined as the minimum for high flow conditions. Therefore, flow should have been contained in the banks during this period and high river conditions did not occur.

USGS wells S6441.1 and S6441.2 have been collecting hydraulic head data since 1949. A total of 274 measurements have been made. The correlations discussed in Section 5.3 indicated that flow does not occur at station HQ if the hydraulic head in this well is less than 36.2 feet MSL and the best fit correlation indicated flow should not occur if the hydraulic head is less than 36.78 feet MSL. From the 274 measurements, head exceeded 1.5 feet above the minimum level for detected flow (37.7 feet) on 75 occasions (33%). However, it should be noted that during the period from March 1996 to the present, the water table elevation exceeded 37.7 feet 4 out of 13 measurements. This contradicts the data from Well 61-07, which is much closer to station HQ which did not have any occurrences of high river conditions. Therefore, this estimate of high river conditions is most likely too large. Using the best fit water table elevation for start of flow, 36.78 feet, suggests that high river conditions would exist if the water table level at this well exceeded 38.28 feet. This occurred on 44 measurements (16%). During the period from August 1997 on, only 1 measurement exceeded 38.28 feet, which is more consistent with the data from Well 61-07 than the previous estimate.

6.3 Mid River Conditions

Mid river conditions are expected to occur between 35 and 41% of the time. Mid river conditions occur when the river is continually flowing, but it is contained within the stream channel banks. Again, the hydraulic head data from BNL well 61-07 and USGS wells S 6411.1 and S 6411.2 provide the most relevant data for the assessment.

BNL well 61-07 has had groundwater elevations between 38.5 MSL (minimum necessary for flow) and 40 feet MSL (average bank height of 1.5 feet) on 7 of 20 (35%) occasions since measurements began in August 1997.

USGS well S6411.1 and S6411.2 have been in service since 1949 and provide a longer term framework for the analysis. Mid river conditions are defined as the time when the hydraulic head is between the minimum elevation for flow (36.2 feet observed, 36.78 feet best fit prediction of the data) and the bankfull height, which is taken as 1.5 feet in this analysis. The data indicates that the hydraulic head lies between 36.2 and 37.7 feet MSL 41% of the time and between 36.78 and 38.28 feet MSL 38% of the time. Figure 18 presents the hydraulic head data at USGS wells S6411.1 and S6441.2. from 1949 to 2000. The graph has been color coded (red – low flow, yellow – mid flow, and green – high flow) based on water table elevation in these wells and illustrates the fraction of time in each river condition.

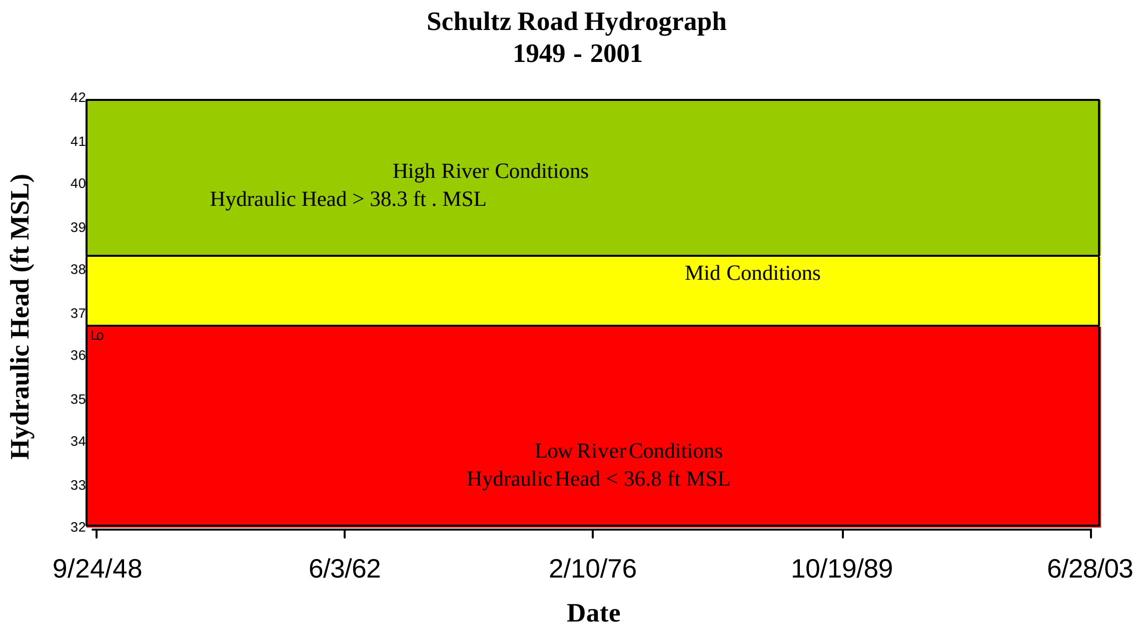

Figure 18 Schultz Road Hydrograph depicting periods of low, mid, and high river conditions

7.0 Conclusions

Multiple lines of reasoning have been used to assess river conditions along the reach of the Peconic River from the BNL Sewage Treatment Plant to Schultz Road. The objective of this study was to estimate the fraction of time the river will be in:

- Low river conditions – large stretches of the riverbed are dry, similar to conditions in 2002. No flow at station HQ or offsite at the eastern BNL boundary.
- Mid river conditions- river is flowing but contained within its banks
- High river conditions – river overflows its banks causing increased fish habitat

Data used in the assessment included:

- Flow records from various stations along the river,
- Hydraulic head data from several wells near the river,
- Partial Flow records collected at Schultz Road by the USGS
- Start of flow records collected by the USGS.
- Precipitation records.

The data indicate that the fraction of time for the three river conditions will be:

Low	30 – 46%
Mid	35 – 41%
High	16 – 33%

Due to the seasonal variations in water table elevation, high flow conditions are more likely to occur in spring and low flow conditions are more likely to occur in late summer and fall. Monthly data collected at station HQ since 1996 indicates low flow (no flow off the BNL site) from September through December and mid flow conditions in Spring. Flow in summer is variable and can be categorized as low or mid.

The information on the flow conditions in the river as defined by the fraction of time for the three conditions will be used to support additional ongoing studies that address uncertainties in the risk assessment. In particular, the flow conditions will be essential in estimating the amount of fish biomass available for potential consumption.

7.1 Recommendation

Collect data on the location where flow ends downstream of the STP and the location where flow resumes due to natural conditions as part of quarterly groundwater monitoring performed along this section of the Peconic River.

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Appendix A
USGS Monitoring Wells in the Vicinity of BNL

Ron Busciolano, a USGS hydrologist, supplied these web links for wells in the vicinity of BNL. A brief annotation of their location is supplied after the link. At these web links, the data, graphs of the data, and maps containing the sample location can be accessed and downloaded.

Recorder Wells

S 5517. 1 -
http://waterdata.usgs.gov/ny/nwis/gwsi/?site_no=405149072532201
Well near BNL Center Club. Data from 1948.

Monthly Wells

S 6413. 1 -
http://waterdata.usgs.gov/ny/nwis/gwsi/?site_no=405308072553101
Well in Middle Island. West of Rocky Point Yaphank Road. Data from 1954.

S 6331. 1 -
http://waterdata.usgs.gov/ny/nwis/gwsi/?site_no=405222072523301
Well between AGS (bldg 911) and BGRR (bldg 701). Data from 1953.

S 74292. 1 -
http://waterdata.usgs.gov/ny/nwis/gwsi/?site_no=405322072454101
Well in Manorville within 1 mile of the Peconic River. Data from 1983.

Annual Wells

S 65855. 1 -
http://waterdata.usgs.gov/ny/nwis/gwsi/?site_no=405351072535101
Northwest of BNL in Middle Island. Near William Floyd and Route 25. Data from 1978.

S 76834. 1 -
http://waterdata.usgs.gov/ny/nwis/gwsi/?site_no=405446072524801
North of BNL on State Property north of route 25. Data from 1984.

S 74289. 1 -
http://waterdata.usgs.gov/ny/nwis/gwsi/?site_no=405418072511201
North of BNL on Route 25. Data from 1983.

S 74291. 1 -
http://waterdata.usgs.gov/ny/nwis/gwsi/?site_no=405421072474501
Calverton/Manorville area north of Forge Pond. Data from 1983.

S 36013. 1 -
http://waterdata.usgs.gov/ny/nwis/gwsi/?site_no=405505072432201
Near Peconic River in Calverton/Riverhead area. South of Tanger Mall. Data from 1983.

S 74302. 1 -
http://waterdata.usgs.gov/ny/nwis/gwsi/?site_no=405434072421401
Riverhead. Near Peconic River, north of Route 25. Data from 1983.

S 47754. 1 -
http://waterdata.usgs.gov/ny/nwis/gwsi/?site_no=405412072441402
Riverhead. Near intersection of Route 25 and LIE. Data from 1973, however only 2 measurements between 1984 and 1994.

S 36147. 1 -
http://waterdata.usgs.gov/ny/nwis/gwsi/?site_no=405259072465601
Manorville near Peconic River west of Forge Pond. Data from 1970.

S 6441. 1 -
http://waterdata.usgs.gov/ny/nwis/gwsi/?site_no=405223072493201
Near Schultz Road and Peconic River. Data from 1949. Data sporadic after 1990.

S 6441. 2 -
http://waterdata.usgs.gov/ny/nwis/gwsi/?site_no=405220072493101
Near Schultz Road and the Peconic. Data from 1991.

S 36150. 1 -
http://waterdata.usgs.gov/ny/nwis/gwsi/?site_no=405117072490301
Approximately 1 mile from the Southeast corner of BNL. South of the LIE. Data from 1951.

S 2485. 1 -
http://waterdata.usgs.gov/ny/nwis/gwsi/?site_no=405109072513001
South side of the BNL site near Long Island Expressway. Data collected since 1950.

S 54883. 1 -
http://waterdata.usgs.gov/ny/nwis/gwsi/?site_no=405123072533701
Southwest corner of BNL site. Data collected since 1975.

Wells No Longer Measured

S 74287. 1 -
http://waterdata.usgs.gov/ny/nwis/gwsi/?site_no=405201072544301
1 mile west of the main entrance to BNL on Smith Road. Water levels measured from 1983 – 1998.

S 54884. 1 -
http://waterdata.usgs.gov/ny/nwis/gwsi/?site_no=405418072494401
Approximately 1 mile from the Northeast corner of the BNL site and south of Route 25. Near ponds south of Lake Panamoka.
Data measured from 1975 – 1999.

S 74294. 1 -
http://waterdata.usgs.gov/ny/nwis/gwsi/?site_no=405213072481101
Manorville near LIE. Within 1 mile of the Peconic River. Data from 1983 – 1998.

S 74297. 1 -
http://waterdata.usgs.gov/ny/nwis/gwsi/?site_no=405338072430501
Approximately 1.5 mi south of the Peconic River in the Manorville/Riverhead area. Data collected form 1083 - 1995

Peconic River Data

http://waterdata.usgs.gov/ny/nwis/discharge?search_site_no=01304500&search_site_no_match_type=exact&format=station_list&sort_key=site_no&group_key=NONE&sitefile_output_format=html_table&column_name=agency_cd&column_name=site_no&column_name=station_nm&column_name=lat_va&column_name=long_va&column_name=state_cd&column_name=county_cd&column_name=alt_va&column_name=huc_cd&list_of_search_criteria=search_site_no

Peconic River flow data from the station in Riverhead. Data collected monthly since 1943.

Appendix B:
Annual Flow Records from BNL flow measurement stations EA, HmN, and HQ.

Year	EA	HmN	HQ
	-----	million gallons	
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1962	205	92	ns
1963	2353	255	ns
1964	234	280	ns
1965	257	289	ns
1966	277	293	ns
1967	291	317	238
1968	291	344	265
1969	370	291	238
1970	291	423	370
1971	297	320	106
1972	343	358	215
1973	308	631	715
1974	280	440	404
1975	260	392	432
1976	310	386	450
1977	288	272	144
1978	334	542	882
1979	336	1326	1374
1980	259	335	388
1981	281	238	138
1982	261	183	0.4
1983	256	364	nr
1984	279	nr	nr
1985	253	nr	nr
1986	263	nr	nr
1987	212	nr	nf
1988	206	nr	nr
1989	278	nr	nr
1990	238	nr	nr
1991	248	nr	nr
1992	216	nr	nr
1993	233	nr	nr
1994	232	nr	nr
1995	243	nr	nr
1996	251	nr	5
1997	205	nr	20
1998	165	nr	56
1999	172	nr	112

2000	176	nr	43
2001	137	nr	218

nr = not reported in the Site Environmental Report
nf = no flow measurements possible. Between 1984 and 1995, the water leaving the BNL site each year was reported as being small or none at all.

Appendix C
Monthly Flow Records at Station HQ from 1972 – 1979 and 1996 – 2001.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total (million gallons/yr)
1972	29	26	20	45	37	37	32	26	16	87	9	13	378
1973	0	0	0	0	0	0	0	0	0	0	0	0	106
1974	2	1	10	22	28	30	42	12	4	7	16	42	215
1975	31	50	65	107	116	94	110	56	39	10	11	26	715
1976	39	48	55	73	71	51	25	11	15	1	0	15	404
1977	28	33	49	59	61	56	48	20	9	6	27	37	432
1978	61	77	75	63	39	28	22	33	19	15	11	7	450
1979	5	8	15	32	21	8	3	1	0	6	11	36	144
1996	0	0	0	0	0	0	0	0	0	0	0	4	4
1997	3	4	3	6	3	2	0	0	0	0	0	0	20
1998	0	1	8	9	14	14	6	0	0	0	0	0	56
1999	20	24	38	25	5	0	0	0	0	0	0	0	112
2000	0	0	0	9	9	17	4	2	0	0	0	0	43
2001	0	3	57	14	44	65	27	8	0	0	0	0	218
2002	0	0	0	0	0	0	0	0	0	0	0	0	0

Flow is reported in millions of gallons per month.

Appendix D:
Annual Peconic River Flow Records at USGS flow station in Riverhead, NY

Flow at USGS Station in Riverhead (USGS 01304500)
Note this data is provided in units of ft^3/s, which has been translated to gal/yr for consistency with other data in this report.

Year	Flow (gal/yr)
1943	6.43E+09
1944	5.79E+09
1945	6.17E+09
1946	7.00E+09
1947	5.84E+09
1948	8.98E+09
1949	8.87E+09
1950	5.39E+09
1951	6.05E+09
1952	9.17E+09
1953	1.01E+10
1954	9.67E+09
1955	1.05E+10
1956	1.09E+10
1957	7.02E+09
1958	1.49E+10
1959	1.12E+10
1960	8.96E+09
1961	9.48E+09
1962	9.79E+09
1963	7.45E+09
1964	7.19E+09
1965	5.65E+09
1966	3.69E+09
1967	5.96E+09
1968	6.45E+09
1969	6.29E+09
1970	8.18E+09
1971	6.57E+09
1972	9.55E+09
1973	1.32E+10
1974	1.03E+10
1975	1.08E+10
1976	1.07E+10
1977	8.84E+09
1978	1.45E+10
1979	1.63E+10
1980	8.58E+09
1981	4.89E+09
1982	7.94E+09
1983	1.16E+10

Year	Flow (gal/yr)
1984	1.59E+10
1985	7.26E+09
1986	5.30E+09
1987	6.57E+09
1988	5.70E+09
1989	1.30E+10
1990	1.26E+10
1991	1.01E+10
1992	7.31E+09
1993	8.44E+09
1994	7.94E+09
1995	4.89E+09
1996	8.35E+09
1997	8.35E+09
1998	1.22E+10
1999	9.01E+09
2000	7.21E+09

Average = 8.7 10^9 gal/yr
Minimum = 4.2 10^9 gal/yr in 1966
Maximum = 1.6 10^{10} gal/yr in 1979.

Appendix E
Partial Flow Records at Schultz Road

The following data was taken from USGS records of partial flow measurements at Schultz Road on the Peconic River.

Date	Flow (ft^3/s)	Flow (gal/yr)
4/28/61	10.9	2.58E+09
8/25/61	4.41	1.04E+09
10/12/61	4.09	9.67E+08
1/11/62	10.2	2.41E+09
3/27/63	9.6	2.27E+09
5/29/63	3.53	8.35E+08
7/11/63	1.03	2.44E+08
9/25/63	0.19	4.49E+07
10/29/63	0.21	4.97E+07
1/23/64	3.34	7.90E+08
5/26/64	4.54	1.07E+09
12/16/64	1.84	4.35E+08
5/12/65	2.6	6.15E+08
9/27/65	0.08	1.89E+07
10/13/65	0.12	2.84E+07
6/7/66	0.26	6.15E+07
8/2/66	0	0.00E+00
11/16/66	0	0.00E+00
1/5/67	0.04	9.46E+06
5/4/67	0.96	2.27E+08
7/6/67	2.31	5.46E+08
10/27/67	0.12	2.84E+07
2/1/68	1.97	4.66E+08
9/4/68	0	0.00E+00
11/5/68	0.02	4.73E+06
5/26/69	1.26	2.98E+08
11/25/69	1.3	3.07E+08
1/11/70	4.4	1.04E+09
12/2/70	1.4	3.31E+08
3/29/71	4.4	1.04E+09
4/29/71	4.7	1.11E+09
6/21/71	1.8	4.26E+08
8/9/71	0.28	6.62E+07
10/4/72	0.72	1.70E+08
10/31/72	3.1	7.33E+08
2/7/73	19	4.49E+09
5/14/73	18	4.26E+09
9/5/73	5.6	1.32E+09
1/17/74	11	2.60E+09
4/3/74	12	2.84E+09
7/2/74	9.1	2.15E+09
9/11/74	2.9	6.86E+08

Date	Flow (ft^3/s)	Flow (gal/yr)
11/18/74	0.76	1.80E+08
1/15/75	8.2	1.94E+09
5/14/75	11	2.60E+09
8/6/75	3	7.10E+08
8/12/75	2.9	6.86E+08
8/18/75	2.5	5.91E+08
11/17/75	7.2	1.70E+09
7/22/76	2.2	5.20E+08
11/10/76	3.8	8.99E+08
4/19/77	7.4	1.75E+09
9/9/77	0.84	1.99E+08
11/1/77	7.7	1.82E+09
5/1/78	14	3.31E+09
9/6/78	5.3	1.25E+09
5/17/79	27	6.39E+09
8/8/79	7.6	1.80E+09
11/1/79	5.7	1.35E+09
7/17/80	3.6	8.51E+08
9/5/80	0.35	8.28E+07
2/10/81	0.22	5.20E+07
6/29/81	0.72	1.70E+08
12/10/81	0.59	1.40E+08
4/21/82	3	7.10E+08
7/20/82	1.8	4.26E+08
10/28/82	2.9	6.86E+08
9/1/83	2.4	5.68E+08
5/15/84	17	4.02E+09
8/17/84	26	6.15E+09
11/29/84	7.3	1.73E+09
2/5/85	5	1.18E+09
8/5/85	2.4	5.68E+08
10/16/85	0.6	1.42E+08
1/23/86	1.9	4.49E+08
4/23/86	2.7	6.39E+08
7/22/86	0.02	4.73E+06
5/12/87	4.1	9.70E+08
10/13/87	0	0.00E+00
3/9/88	2.4	5.68E+08
9/22/89	15	3.55E+09
4/23/90	16	3.78E+09
8/4/90	17	4.02E+09
9/28/90	7	1.66E+09
1/3/91	9.6	2.27E+09
5/20/91	7.9	1.87E+09
11/16/91	2.8	6.62E+08
7/22/92	0.96	2.27E+08
8/16/93	3	7.10E+08
7/7/94	0.52	1.23E+08
10/31/94	0	0.00E+00

Date	Flow (ft^3/s)	Flow (gal/yr)
3/20/95	1.2	2.84E+08
8/28/96	1.2	2.84E+08
3/24/97	6.2	1.47E+09
9/18/98	1.3	3.07E+08
12/28/98	0.98	2.32E+08

Average flow = 4.75 ft^3/s.
Minimum flow = 0, on 5 occasions
Maximum flow = 27 ft^3/s in May, 1979.

Appendix F

Annual Precipitation Measured at Brookhaven National Laboratory

Year	Annual Total (in)	Year	Annual Total (in)
1949	39.92	1976	45.16
1950	40.67	1977	53.82
1951	48.80	1978	53.45
1952	48.39	1979	56.12
1953	52.53	1980	34.99
1954	57.90	1981	40.03
1955	50.52	1982	48.42
1956	48.45	1983	63.84
1957	41.79	1984	57.16
1958	59.60	1985	36.53
1959	47.04	1986	43.73
1960	46.57	1987	40.79
1961	52.15	1988	43.05
1962	47.60	1989	68.66
1963	40.83	1990	53.01
1964	47.19	1991	45.13
1965	34.35	1992	45.16
1966	43.93	1993	42.90
1967	58.62	1994	44.16
1968	48.94	1995	39.40
1969	52.07	1996	60.22
1970	43.66	1997	40.04
1971	44.82	1998	56.61
1972	58.63	1999	51.72
1973	52.74	2000	54.37
1974	41.80	2001	45.55
1975	52.88		

Average = 48.4 inches/yr
Minimum = 34.3 inches in 1965
Maximum – 68.6 inches in 1989.

Appendix G
Hydraulic Head in Well 61-07 and Flow at station HQ

Date	Head (ft MSL)	Monthly Flow at HQ (l/yr)	Monthly Flow at HQ (gal/yr)
8/26/97	37.31	0	0.00E+00
8/28/97	37.31	0	0.00E+00
12/9/97	36.54	0	0.00E+00
12/10/97	36.54	0	0.00E+00
3/24/98	39.5	2.93E+07	7.75E+06
3/25/98	39.5	2.93E+07	7.75E+06
9/22/98	38.86	0	0.00E+00
9/23/98	38.86	0	0.00E+00
12/29/98	38.01	0	0.00E+00
12/30/98	38.01	0	0.00E+00
3/30/99	39.28	1.42E+08	3.76E+07
3/31/99	39.28	1.42E+08	3.76E+07
6/30/99	37.46	0	0.00E+00
9/28/99	37.84	0	0.00E+00
12/21/99	37.51	1.74E+04	4.60E+03
3/21/00	38.39	0.00E+00	0.00E+00
6/21/00	38.66	6.55E+07	1.73E+07
9/20/00	38.41	9.89E+05	2.62E+05
12/19/00	37.93	0.00E+00	0.00E+00
3/20/01	39.1	2.16E+08	5.71E+07
6/19/01	39.87	2.44E+08	6.46E+07
9/17/01	38.06	0.00E+00	0.00E+00
12/19/01	37.28	0.00E+00	0.00E+00
3/21/02	36.94	0.00E+00	0.00E+00
6/18/02	37.18	0.00E+00	0.00E+00
9/23/02	34.81	0.00E+00	0.00E+00

Appendix H
Hydraulic Head at USGS Wells S 6441.1 and 6441.2

Date	Hydraulic Head (ft MSL)	Monthly Flow at station HQ (gal/month)
1/26/49	37.77	
2/10/49	38.14	
2/21/49	38.19	
3/9/49	38.26	
3/16/49	38.46	
3/30/49	38.33	
4/13/49	38.36	
4/27/49	38.3	
5/12/49	38.23	
5/24/49	38.02	
6/8/49	37.5	
6/21/49	37.17	
6/28/49	37.01	
7/14/49	36.4	
7/26/49	36.3	
8/11/49	36.15	
8/24/49	35.96	
9/8/49	35.95	
9/23/49	35.91	
10/4/49	35.77	
10/20/49	35.6	
11/3/49	35.74	
11/15/49	35.69	
12/1/49	35.66	
12/16/49	35.8	
12/28/49	35.86	
1/12/50	35.79	
1/26/50	35.72	
2/10/50	36.04	
2/27/50	36.63	
3/29/50	36.72	
4/24/50	36.31	
5/25/50	36.48	
6/28/50	36.31	
7/27/50	35.76	
9/7/50	35.15	
10/9/50	34.73	
10/26/50	34.66	
12/24/50	34.42	
12/28/50	34.96	
1/26/51	35.39	
2/23/51	36.28	
4/2/51	36.66	
4/30/51	36.54	
5/16/51	36.33	

Date	Hydraulic Head (ft MSL)	Monthly Flow at station HQ (gal/month)
6/4/51	36.39	
6/28/51	36	
7/26/51	35.32	
8/29/51	35.23	
10/1/51	34.63	
10/29/51	34.63	
11/29/51	35.66	
12/26/51	36.59	
1/29/52	37.15	
2/27/52	37.36	
3/26/52	37.85	
4/16/52	37.41	
4/29/52	37.56	
5/1/52	37.66	
5/13/52	37.66	
6/2/52	38.15	
6/30/52	37.23	
7/29/52	36.32	
8/27/52	36.79	
10/2/52	36.13	
10/30/52	35.82	
11/25/52	36.02	
12/8/52	36.23	
12/29/52	36.34	
1/29/53	37.29	
3/2/53	37.42	
3/16/53	38.28	
4/25/53	38.88	
6/10/53	37.87	
7/13/53	36.87	
8/5/53	36.66	
8/26/53	36.48	
10/7/53	35.78	
10/27/53	35.76	
11/25/53	36.25	
12/21/53	37.53	
1/25/54	36.93	
2/24/54	36.79	
3/23/54	37.07	
4/27/54	37.52	
5/26/54	37.46	
6/30/54	36.59	
7/26/54	35.89	
8/24/54	36.16	
9/23/54	38.35	
10/22/54	37.2	
11/18/54	37.51	
12/23/54	38.6	
1/24/55	37.91	

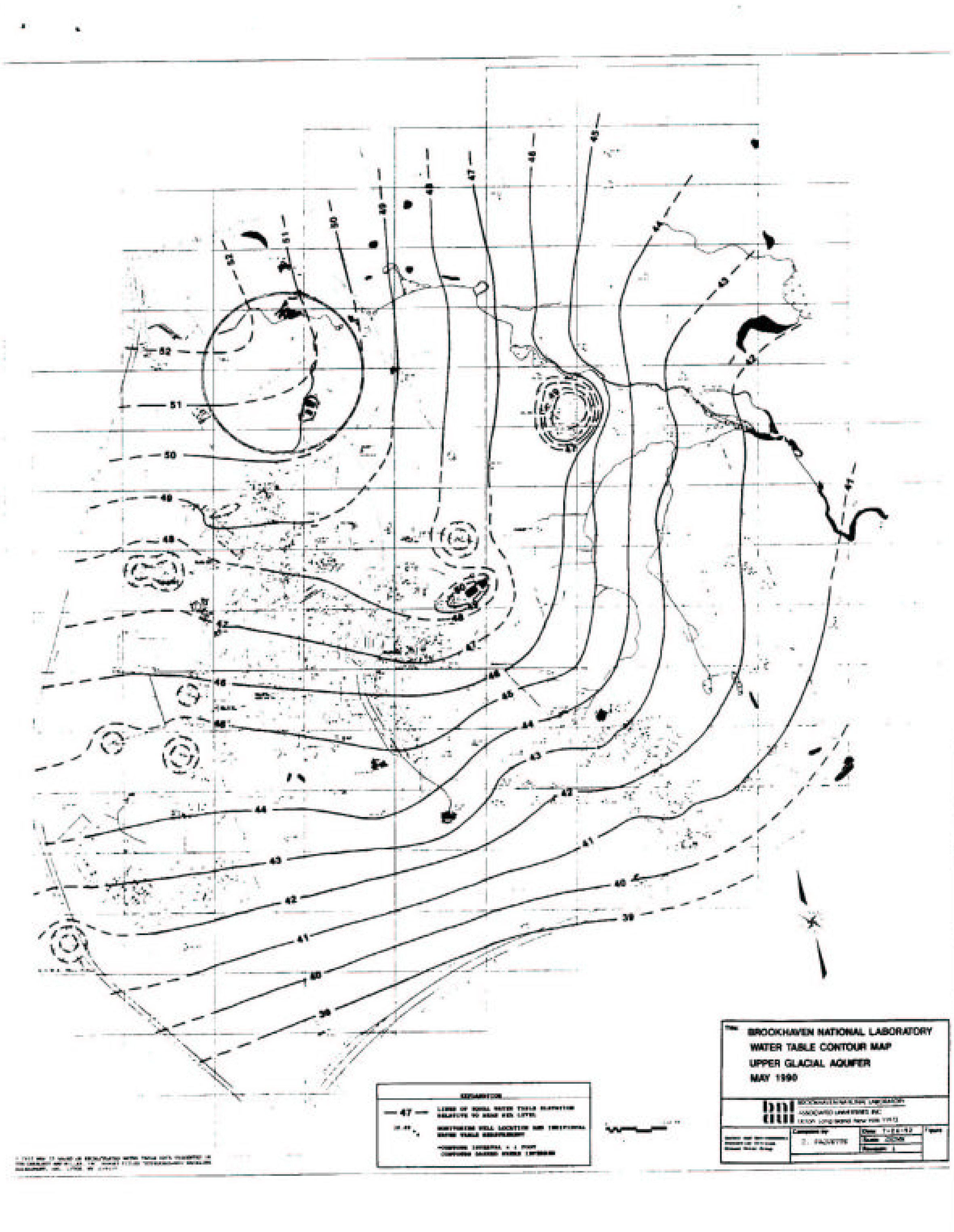
Date	Hydraulic Head (ft MSL)	Monthly Flow at station HQ (gal/month)
2/23/55	37.69	
3/23/55	37.93	
4/25/55	37.75	
5/25/55	37.48	
6/21/55	37.06	
7/25/55	36.32	
8/23/55	36.79	
10/7/55	36.16	
11/2/55	37.45	
11/29/55	38.22	
1/6/56	37.36	
1/26/56	37.41	
2/29/56	38.4	
3/30/56	38.63	
4/26/56	38.48	
5/28/56	37.93	
6/20/56	37.69	
10/4/56	36.64	
12/21/56	37.3	
7/1/57	36.11	
10/28/57	35.25	
12/17/57	36.39	
6/25/58	38.5	
12/15/58	38.41	
6/15/59	37.77	
10/28/59	36.62	
12/30/59	37.35	
7/6/60	36.85	
11/9/60	36.72	
1/6/61	36.91	
7/10/61	37.39	
11/2/61	37.05	
1/3/62	37.33	
4/30/62	38.15	
11/8/62	36.78	
4/29/63	37.22	
10/30/63	35.18	
4/30/64	37.91	
10/27/64	35.39	
4/22/65	36.73	
9/29/65	34.75	
4/28/66	33.69	
10/28/66	33.84	
4/26/67	35.98	
10/31/67	35.31	
4/26/68	36.83	
11/1/68	34.67	
4/9/69	36.78	
10/28/69	35.94	

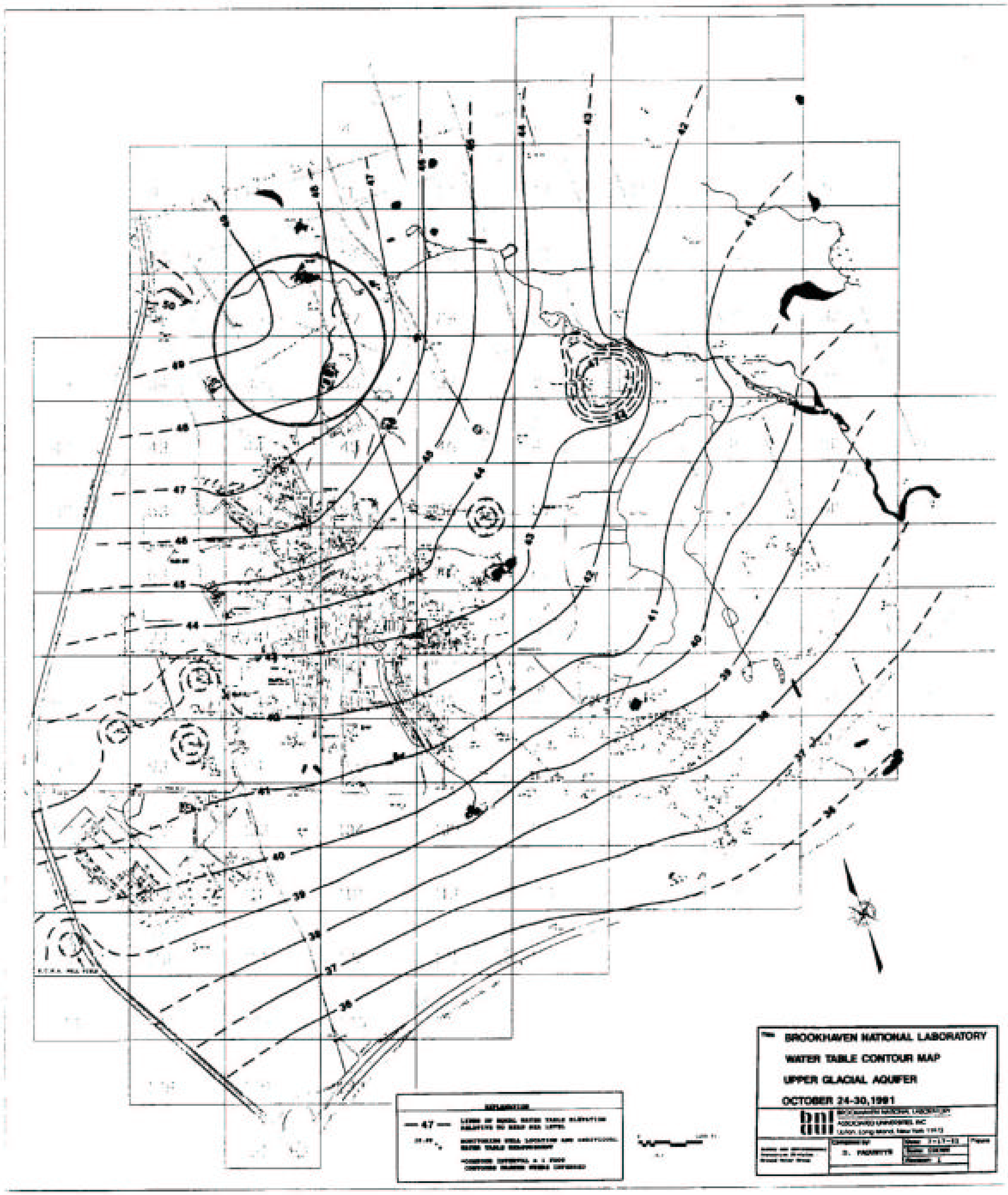
Date	Hydraulic Head (ft MSL)	Monthly Flow at station HQ (gal/month)
3/10/70	37.16	
10/22/70	35.83	
3/12/71	35.93	
9/22/71	36.76	
12/20/71	36.82	HQ (gal/month)
3/27/72	36.22	9.92E+05
7/11/72	37.7	2.99E+07
10/4/72	36.23	6.85E+06
12/27/72	38.44	4.23E+07
4/4/73	38.13	7.30E+07
6/28/73	38.35	9.39E+07
9/16/73	37.41	3.92E+07
12/26/73	38.48	2.64E+07
3/20/74	38.05	5.48E+07
6/11/74	37.73	5.13E+07
9/19/74	36.44	1.46E+07
12/30/74	37.19	1.52E+07
4/7/75	38.36	5.95E+07
6/27/75	37.84	5.66E+07
11/3/75	37	2.67E+07
1/7/76	38.15	6.08E+07
4/13/76	38.06	6.30E+07
6/29/76	37.11	2.78E+07
9/24/76	37.09	1.88E+07
1/12/77	37.33	4.81E+06
4/5/77	37.96	3.17E+07
7/1/77	36.72	2.65E+06
10/7/77	36.83	5.63E+06
10/26/77	37.79	5.63E+06
1/4/78	38.33	7.94E+07
3/28/78	39.53	1.04E+08
4/21/78	39.05	9.29E+07
6/22/78	38.46	1.06E+08
10/2/78	37.44	3.52E+07
10/18/78	37.45	3.52E+07
1/12/79	38.96	9.63E+07
2/1/79	40.19	1.54E+08
3/28/79	39.53	2.06E+08
4/12/79	39.18	2.96E+08
6/27/79	38.58	9.02E+07
10/1/79	37.49	6.64E+07
1/11/80	37.69	
3/27/80	38.42	
7/10/80	37.18	
9/30/80	36.83	
1/15/81	36.13	0
3/30/81	36.36	
6/17/81	36.17	
9/14/81	34.88	0

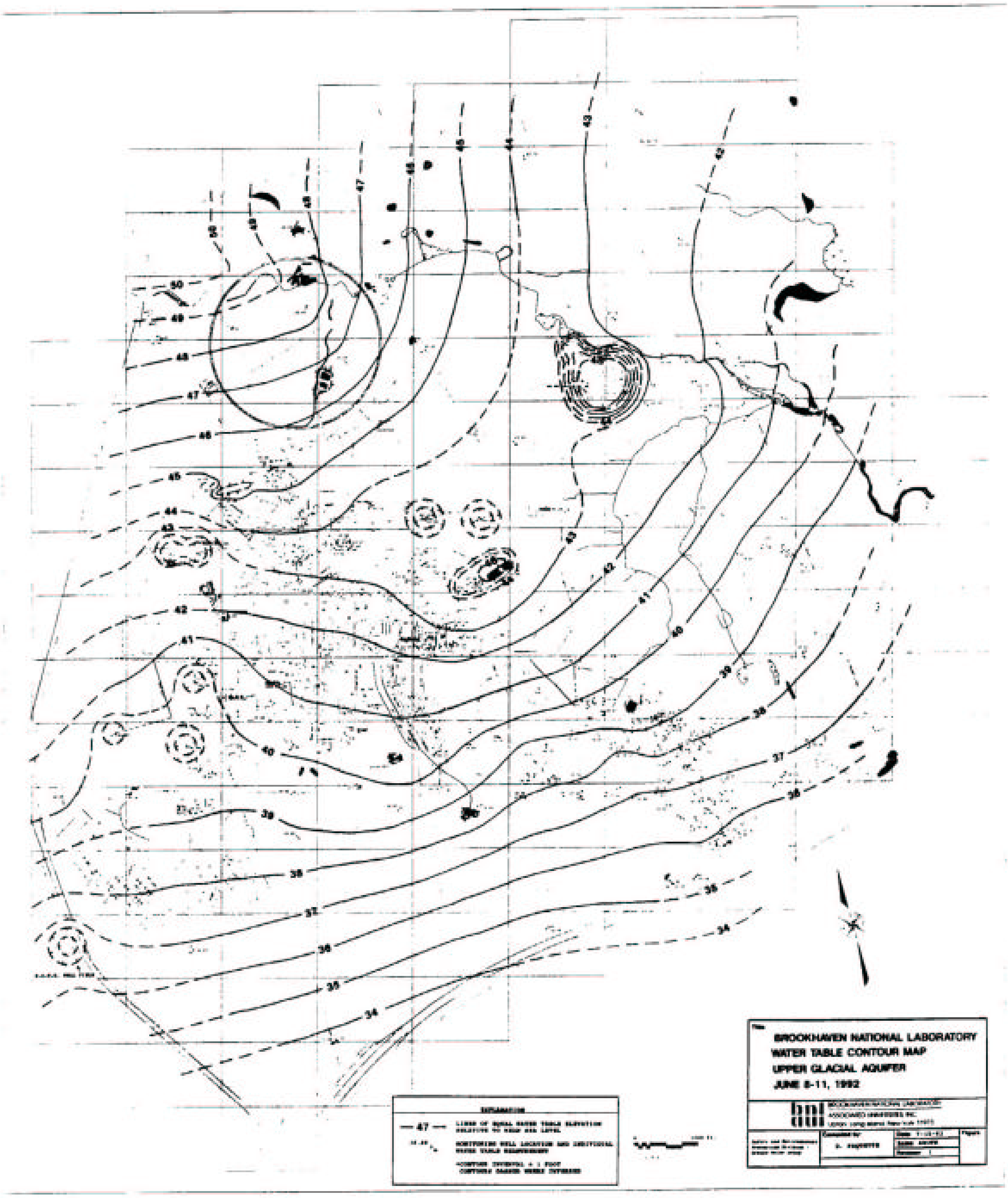
Date	Hydraulic Head (ft MSL)	Monthly Flow at station HQ (gal/month)
12/16/81	35.65	0
3/16/82	36.93	
6/17/82	39.11	
9/8/82	36.84	
9/23/82	36.62	
10/6/82	36.47	
12/8/82	36.5	
1/12/83	36.57	
3/18/83	38.49	
5/10/83	35.57	
6/15/83	38.67	
6/29/83	38.23	
9/14/83	36.99	
9/21/83	36.87	
9/22/83	36.92	
1/29/84	38.29	
2/2/84	39.68	
6/14/84	39.78	
9/27/84	38.11	
1/9/85	37.88	
3/28/85	37.81	
7/11/85	37.28	
10/4/85	36.93	
12/6/85	36.69	
6/2/86	36.12	
9/5/86	34.88	
12/4/86	35.66	
3/19/87	37.08	
6/24/87	36.8	
7/23/87	36.22	
8/26/87	35.76	
9/24/87	35.58	
10/23/87	35.41	
11/20/87	35.65	
12/28/87	35.88	
1/29/88	36.24	
2/23/88	37.32	
3/22/88	36.84	
4/27/88	36.96	
5/25/88	36.74	
6/20/88	36.24	
7/25/88	35.64	
8/26/88	34.92	
9/23/88	34.66	
10/21/88	34.45	
11/21/88	35.37	
12/29/88	36.1	
1/27/89	35.95	
2/23/89	36.14	

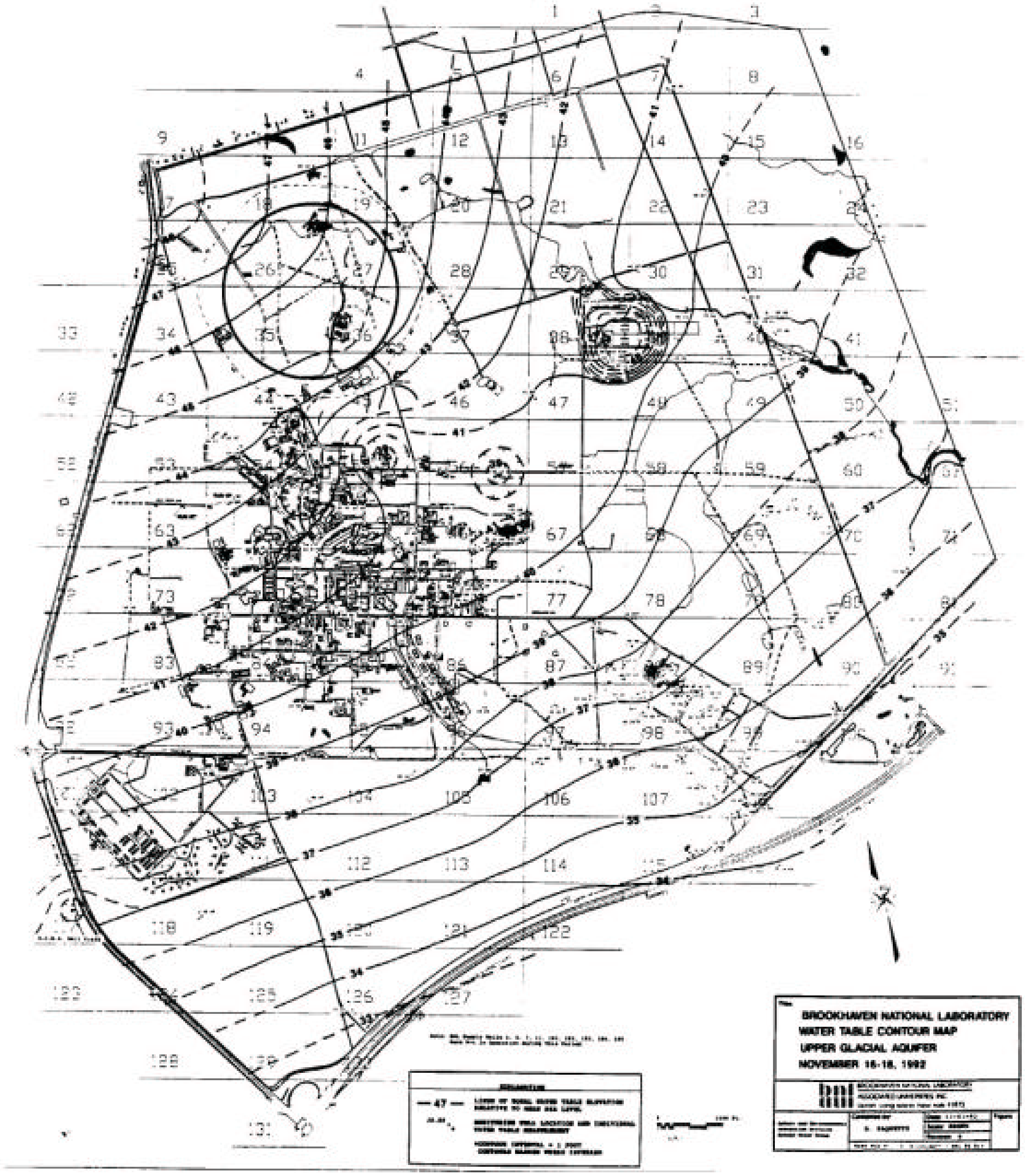
Date	Hydraulic Head (ft MSL)	Monthly Flow at station HQ (gal/month)
3/27/89	36.67	
4/18/89	37.33	
5/22/89	39.31	
6/23/89	38.9	
7/21/89	39.01	
8/22/89	39.66	
9/28/89	38.68	
10/24/89	39.47	
11/21/89	39.53	
12/27/89	38.74	
1/23/90	38.85	
2/21/90	39.26	
6/21/94	34.91	
7/28/94	33.67	
8/30/94	33.93	
9/28/94	33.67	
10/27/94	33.33	
12/21/94	34.16	
1/19/95	34.39	
5/19/95	33.82	
7/24/95	32.65	
3/12/96	36.07	0.00E+00
6/7/96	36.48	0.00E+00
6/25/96	36.33	0.00E+00
8/28/96	35.76	0.00E+00
9/16/96	35.37	0.00E+00
3/17/97	37.91	3.20E+06
8/25/97	35.9	0.00E+00
12/9/97	35.5	0.00E+00
3/17/98	38.42	7.76E+06
3/23/99	38.12	3.77E+07
3/20/00	37.1	0.00E+00
3/20/01	37.97	5.70E+07
3/25/02	35.73	0.00E+00

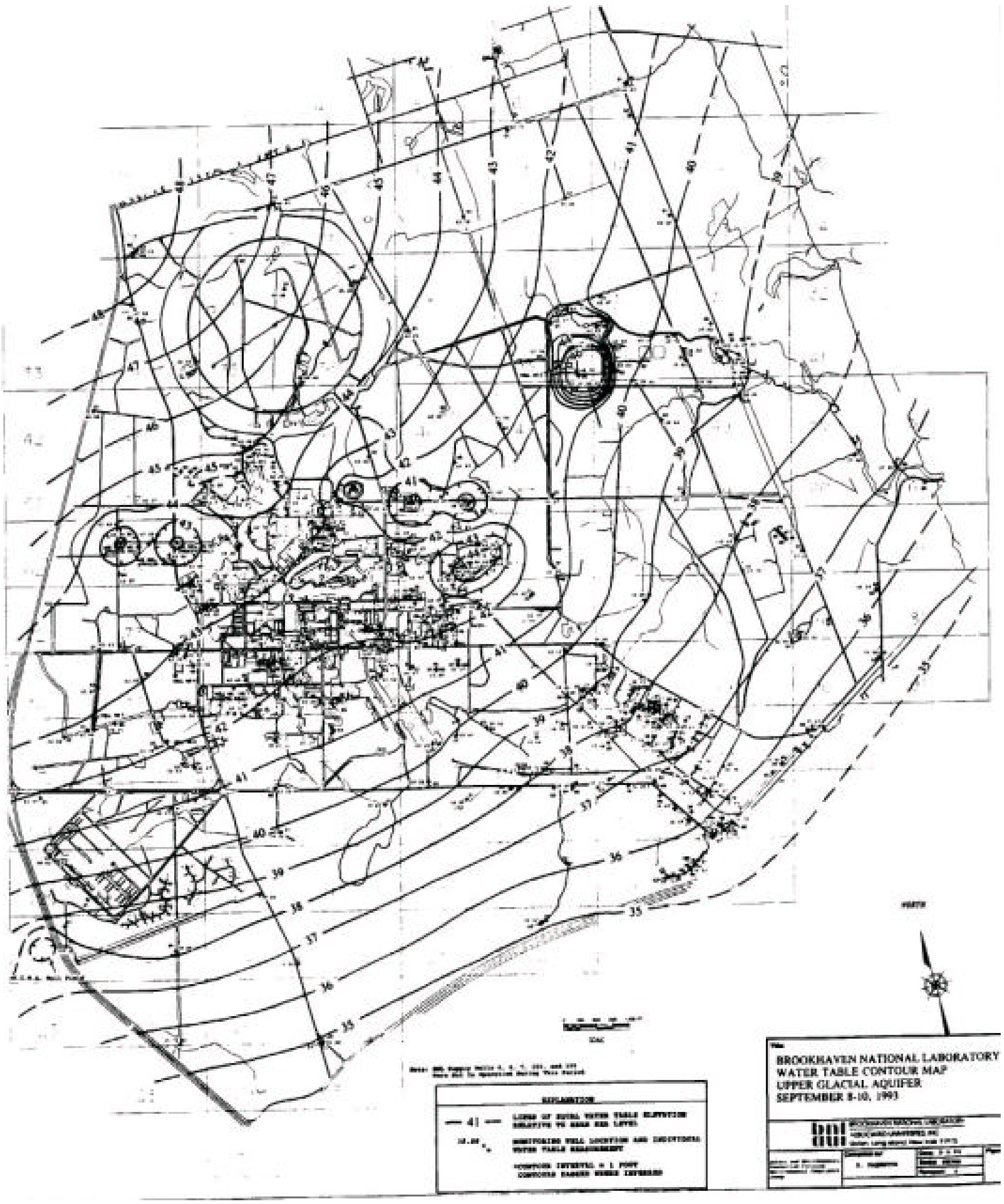
Appendix I
BNL Water Table Maps from 1990 – 1995

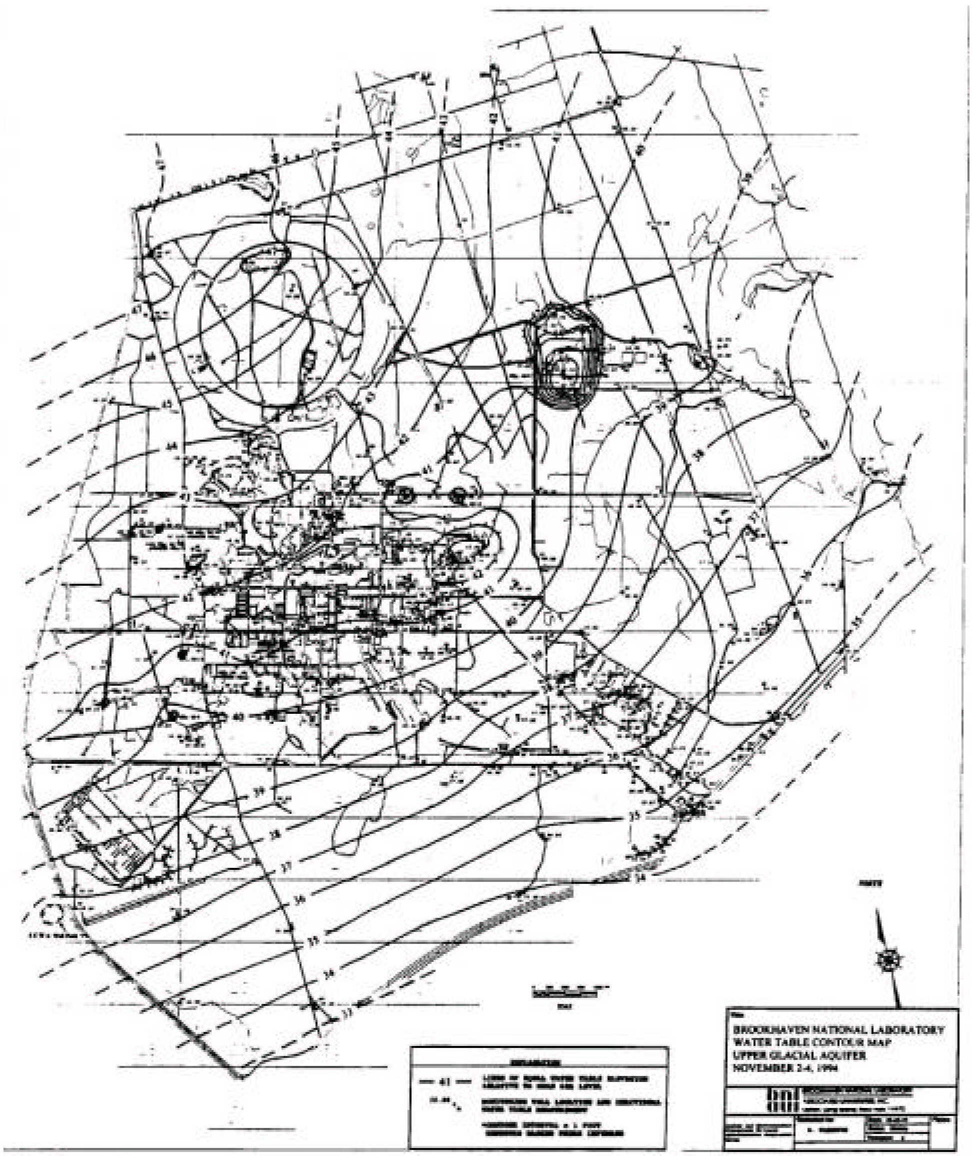



BROOKHAVEN NATIONAL LABORATORY
WATER TABLE CONTOUR MAP
UPPER GLACIAL AQUIFER
OCTOBER 24-30,1991


BROOKHAVEN NATIONAL LABORATORY
WATER TABLE CONTOUR MAP
UPPER GLACIAL AQUIFER
JUNE 8-11, 1992
EXPLANATION
ASSOCIATED UNIVERSITIES INC.


BROOKHAVEN NATIONAL LABORATORY
WATER TABLE CONTOUR MAP
UPPER GLACIAL AQUIFER
NOVEMBER 16-18, 1992


BROOKHAVEN NATIONAL LABORATORY
WATER TABLE CONTOUR MAP
UPPER GLACIAL AQUIFER
SEPTEMBER 8-10, 1993
bnl



BROOKHAVEN NATIONAL LABORATORY
WATER TABLE CONTOUR MAP
UPPER GLACIAL AQUIFER
NOVEMBER 2-4, 1994