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Geostatistical and Hydrochemical Trends in The Upper Passaic River Basin : Impact of Road Deicing Application

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Abstract

Sodium chloride deicing salts have been used to remove snow and ice from roadways in the Northern United States since the early 1900s. Road deicing reduces accident rates, road delays, and improve road accessibility. While it is known that the use of road deicers is beneficial, road salts have also been shown to affect surface water and groundwater quality. This study conducted major ion concentration analyses on groundwater samples collected by the United States Geological Survey (USGS) for the Upper Passaic River Basin (UPRB). Results show that the contribution of chloride to total dissolved solids increased significantly by 2010. Trend plots show strong correlation of increases in sodium and chloride with time that are not observed with other major ions such as calcium and magnesium. Decadal bivariate plots of sodium against chloride show strong increases in correlation from 1960 to 2010 and an overall strong correlation while those of calcium against chloride and calcium against sodium display poor correlation. Plots of piper diagrams show that the ionic composition of groundwater samples has changed through time, starting as a single $Ca(HCO_3)_2$ species and shifting towards a NaCl dominated species. In general, groundwater in the UPRB is fresh with total dissolved solids less than 500 mg/L. Against the natural evolutionary trend, chloride is found to dominate other chemical species in this freshwater system. The findings of this study show evidence that NaCl road salt application can be linked with changes in groundwater composition for the UPRB.

MONTCLAIR STATE UNIVERSITY

Geostatistical and Hydrochemical Trends in the Upper Passaic River Basin: Impact of Road Deicing Application

by

Connor E. Firor

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GEOSTATISTICAL AND HYDROCHEMICAL TRENDS IN THE UPPER PASSAIC RIVER BASIN: IMPACT OF ROAD DEICING APPLICATION

A THESIS

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1. Introduction

1.1 Problem Statement

Since the beginning of the 20th century, road salt has been used as a deicing agent on motorways throughout the Northeastern United States (Kelly et al., 2010). Primarily, sodium chloride (NaCl) has been the central deicing agent utilized, while in some cases liquid calcium chloride ($CaCl_2$) and brine have been used as a substitute (New Jersey Department of Transport, 2018). In 2017, New Jersey alone used 374,921 tons of NaCl deicing salt, with 3,143 and 4,495 tons of $CaCl_2$ and brine used respectively (NJDOT, 2018). Utilizing data from the New Jersey Department of Transportation, estimations for 2017 showed that New Jersey consumed 9.7 tons of NaCl, 21.4 gallons of $CaCl_2$ and 31 gallons of brine per lane mile (NJDOT, 2018). Road salt application actively reduces accident rates and road delays while improving road accessibility in winter months. However, deicing also has negative repercussions on human health and the environment (Kuemmel & Hanbali, 1992). Excess amounts of sodium chloride consumption is linked directly with hypertension (high blood pressure), which can lead to minor or severe heart complications in patients on sodium-strict diets (Howard & Haynes, 1993). In terms of ecological degradation, elevated levels of deicing application are linked with adverse effects on many avian and aquatic species, mainly due to misidentification of food sources and hydrochemical toxicity (Corsi et al., 2010). Therefore, the assessment of groundwater contamination in relation to deicing road salts is essential in understanding the quality of groundwater resources in the Upper Passaic River Basin.

1.2 Study Objectives

The objective of this study is to determine whether road deicing application has had a significant effect on the groundwater composition of Water Management Area 06 (WMA6), commonly referred to as the Upper Passaic River Basin. This goal was completed by the following analysis of geostatistical and hydrochemical trends of groundwater samples over a 50-year timeframe, 1960-2010:

1. Determining correlations in ion to ion relationships using simple linear regression analysis.
2. Identifying geostatistical trends in major ionic concentrations over time, specifically Na^+, Cl^-, Mg^{2+}, Ca^{2+}, and SO_4^{2-}.
3. Evaluating the hydrochemical composition of groundwater facies in decadal segments.
4. Creating a visual representation of potentiometric surface and ionic concentration averages.

1.3 Study Site

1.3.1 Location and Physical Setting

The Upper Passaic River Basin is located in northern New Jersey, falling between boundaries of latitudes 41º10” and 40º40” north and longitudes 74º40” and 74º15” west (Figure 1). The extent of the UPRB is in Morris county, an area of significant population increases, from 261,620 in 1960 to 492,276 in 2010 (U.S. Census Bureau, 2015). The UPRB is 361.5 sq. mi in extent and is a high-density region when considering urban development and roads. There are approximately 3,049 miles of roads spread relatively evenly throughout the watershed management area (Figure 2) (New Jersey Geological Survey, 2010). Using data from NJDOT and New Jersey Department of GIS an estimate of the amount of road salt used in 2017 in the UPRB is found to be roughly 29,389 tons (Table 1) (NJGIS, 2017; NJDOT, 2018). The UPRB varies significantly in terms of elevation. The northwest region is of higher elevation with a decreasing slope trend towards the southeast (Figure 3). This variation in elevation could potentially influence ionic concentrations and potentiometric surface.

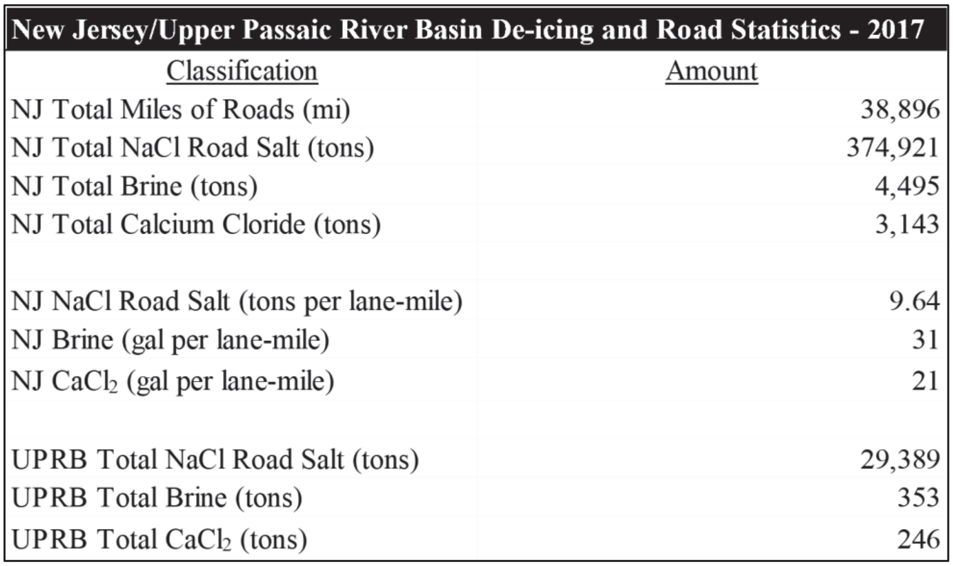
1.3.2 Geology

The UPRB has a unique bedrock geology caused by the division of the Ramapo Fault through the middle of the site (Figure 4). To the southeast is the Newark Basin, which is dominated by hard sedimentary rocks, primarily sandstone (often referred to as the Towaco Formation) (Dalton et al., 1999). The Towaco formation originates from the formation (Appalachian Orogeny) and subsequent rifting of the supercontinent Pangea between 197-198 ma ago (Olsen, 1980). The Newark Basin also comprises of igneous lava flows dominated by basalt, comprising of plagioclase, clinopyroxine, magnetite and ilmenate. In contrast, The New Jersey Highlands to the northwest is dominated by a large variety of metamorphic rocks including but not limited to gneiss, granite, quartz, and biotite feldspars (Dalton et al., 1999, Bedrock Geologic Map of New Jersey, 1996). The Highlands are remnants of an ancient mountain range, formed during the Grenville Orogeny, 1259-980 ma ago (Tollo, 2004). The differences in bedrock geology plays a key role in determining groundwater system dynamics, specifically in terms of hydraulic conductivity, storage capacity, and contact time. Consequently, geologic variations can potentially influence ionic composition in groundwater. Sedimentary basins have a higher porosity (typically between 10-30%) than igneous and metamorphic basins (typically less than 10%) (Earle, 2015). Similarly, permeability is lower in igneous and metaphoric environments (10^{-12} to 10^{-8} m/s) than in sedimentary basins (10^{-8} to 10^{-4} m/s) (Earle, 2015).

1.3.3 Climate and Hydrogeologic Environment

Figure 5 depicts major river systems in the UPRB watershed. The UPRB includes the upper branches and the headwaters of the Passaic River along with the Whippany and Rockaway rivers (NJDEP, 2012). The UPRB lies within a humid continental climatic region, varying between temperate and warm (Lundlum, 1983). The average annual temperature is roughly 54ºF with average annual highs of 62ºF and lows of 40ºF (U.S Climate Data, 2018). The region sees, on average, 50-60 inches of rain annually (NOAA, 2018). Average snowfall from 1981-2010 was calculated to be 28.6 inches annually (National Climatic Data Center, 2018). Geologically classified, the UPRB is considered a lowland piedmont physiographic region. The piedmont lowlands are classified by a rolling decrease in elevation towards the coast. From a hydrogeological perspective the UPRB groundwater system can be compared to that of groundwater systems seen in coastal plains located throughout the eastern seaboard (Dennis et al., 2002) (Figure 6).

Table 1. Annual deicing and road statistics for the Upper Passaic River Basin, New Jersey in 2017 (Calculated from NJDOT and USGS data).



New Jersey/Upper Passaic River Basin De-icing and Road Statistics - 2017	
Classification	Amount
NJ Total Miles of Roads (mi)	38,896
NJ Total NaCl Road Salt (tons)	374,921
NJ Total Brine (tons)	4,495
NJ Total Calcium Cloride (tons)	3,143
NJ NaCl Road Salt (tons per lane-mile)	9.64
NJ Brine (gal per lane-mile)	31
NJ $CaCl_2$ (gal per lane-mile)	21
UPRB Total NaCl Road Salt (tons)	29,389
UPRB Total Brine (tons)	353
UPRB Total $CaCl_2$ (tons)	246

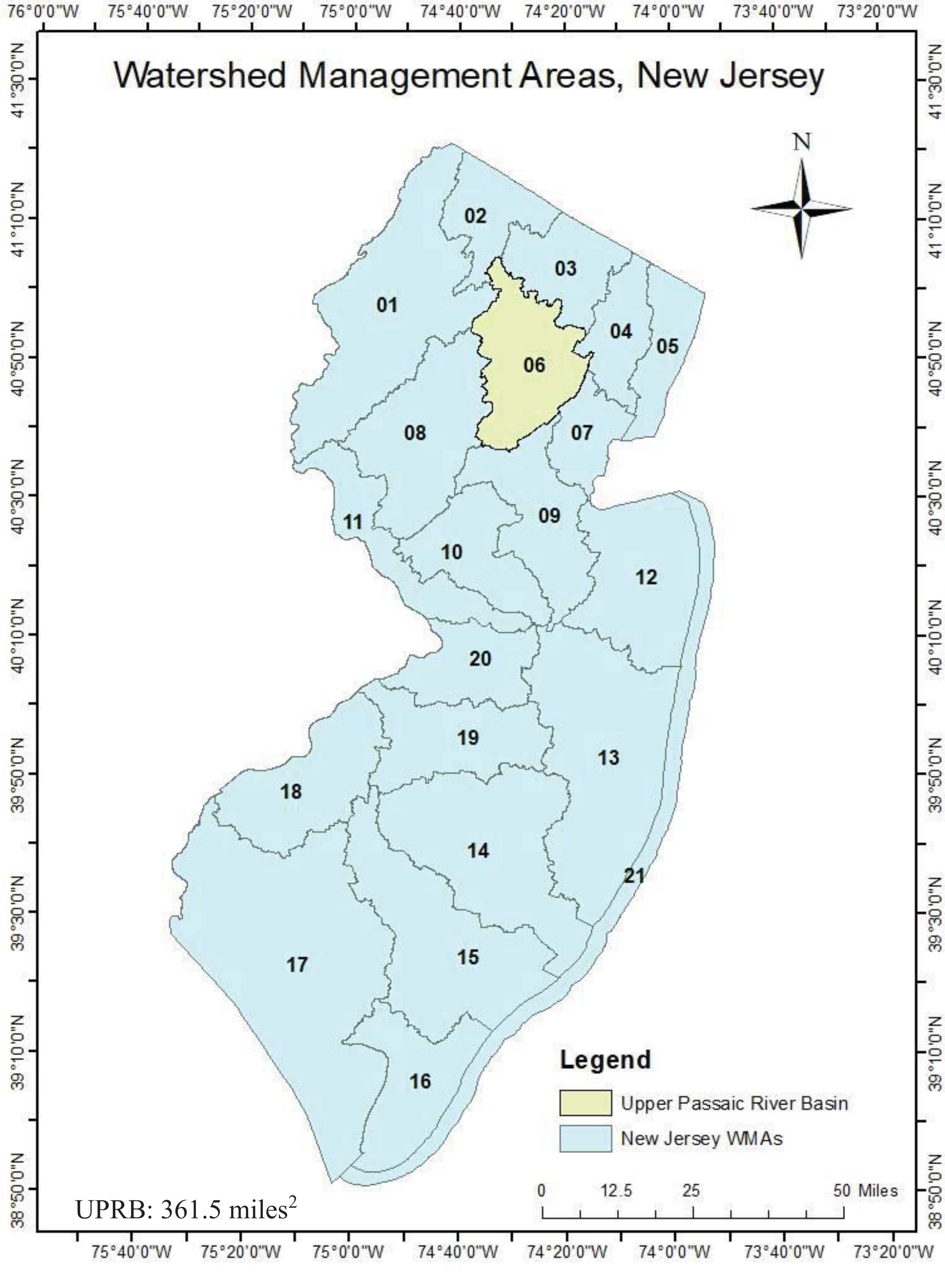


Figure 1. Location of the Upper Passaic River Basin (New Jersey Department of Environmental Protection, 2009).

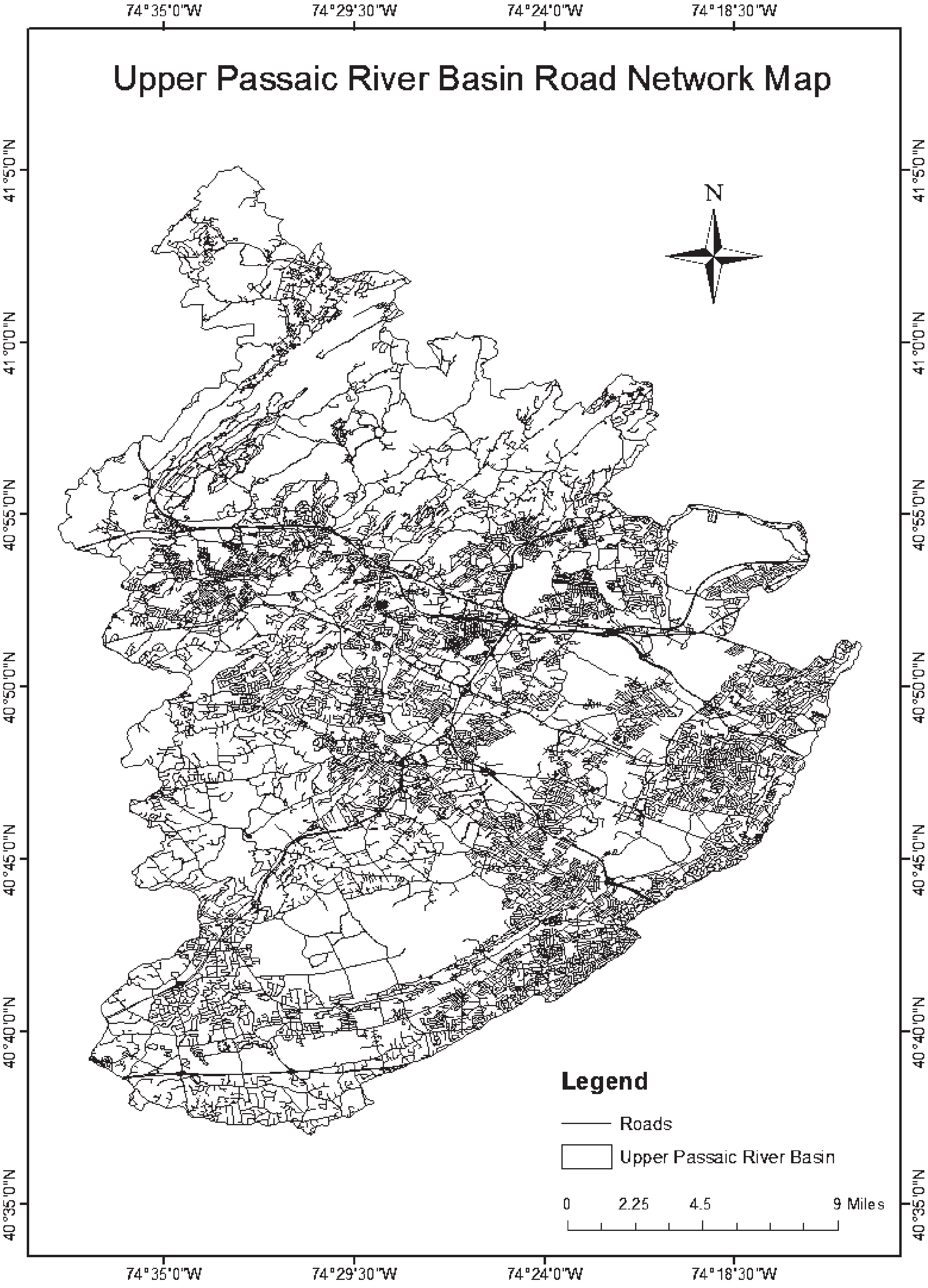


Figure 2. Spatial distribution of roads in the Upper Passaic River Basin, New Jersey (New Jersey Geographic Information Network, 2017).

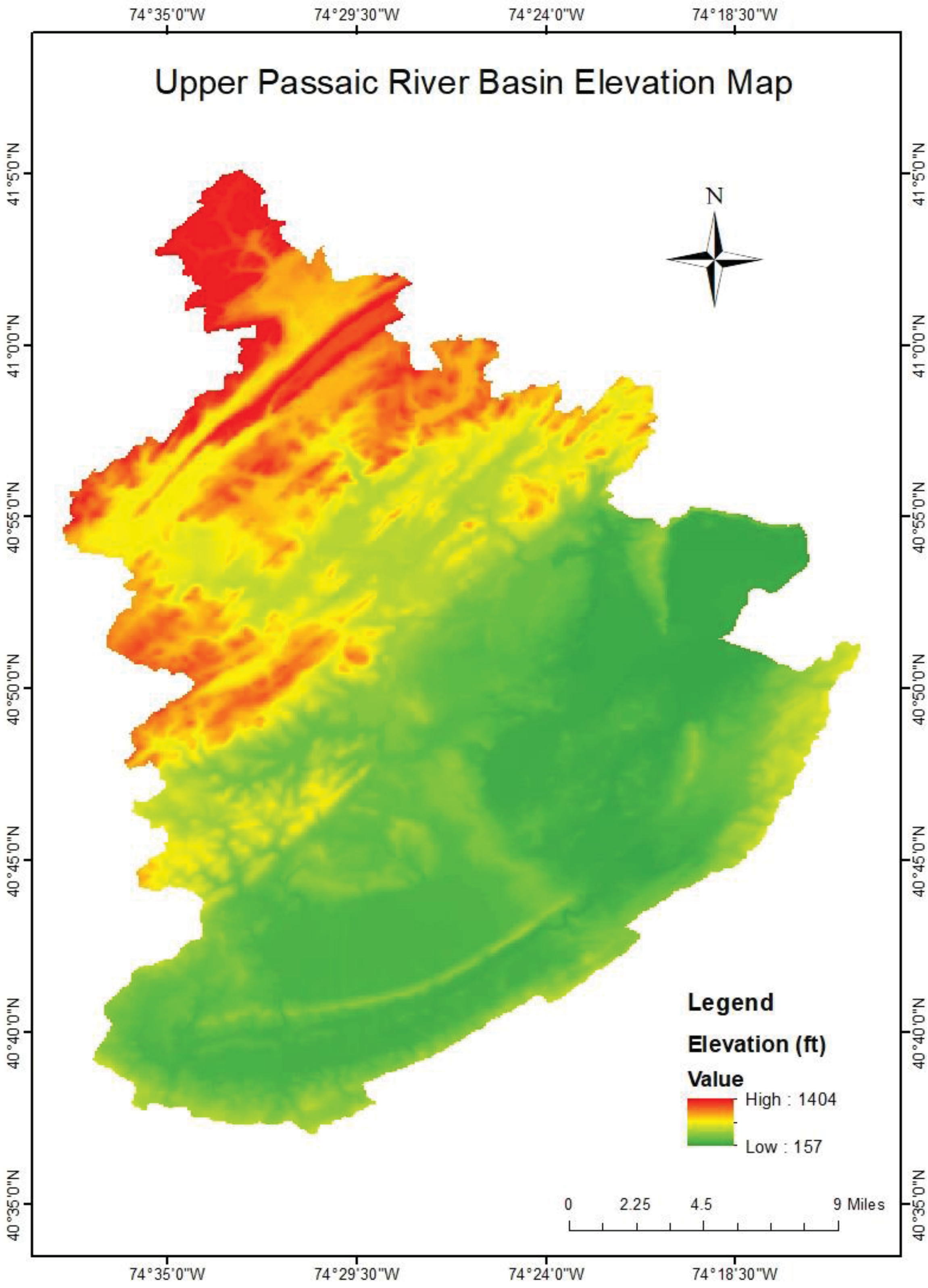


Figure 3. Elevation of the Upper Passaic River Basin, New Jersey (NJ Bureau of GIS, 2002).

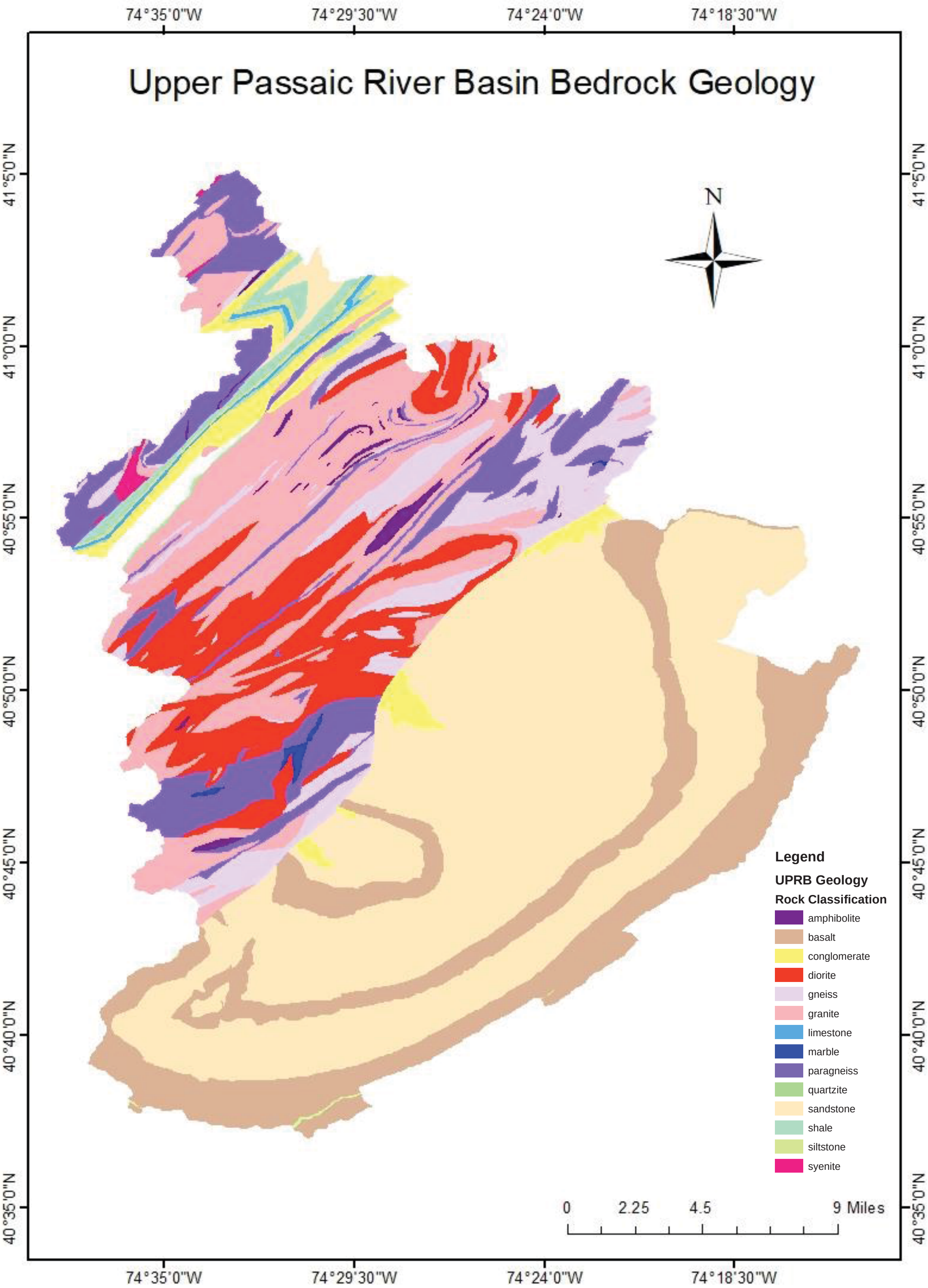


Figure 4. Bedrock geology for the Upper Passaic River Basin, New Jersey (New Jersey Department of Environmental Protection, 2007).

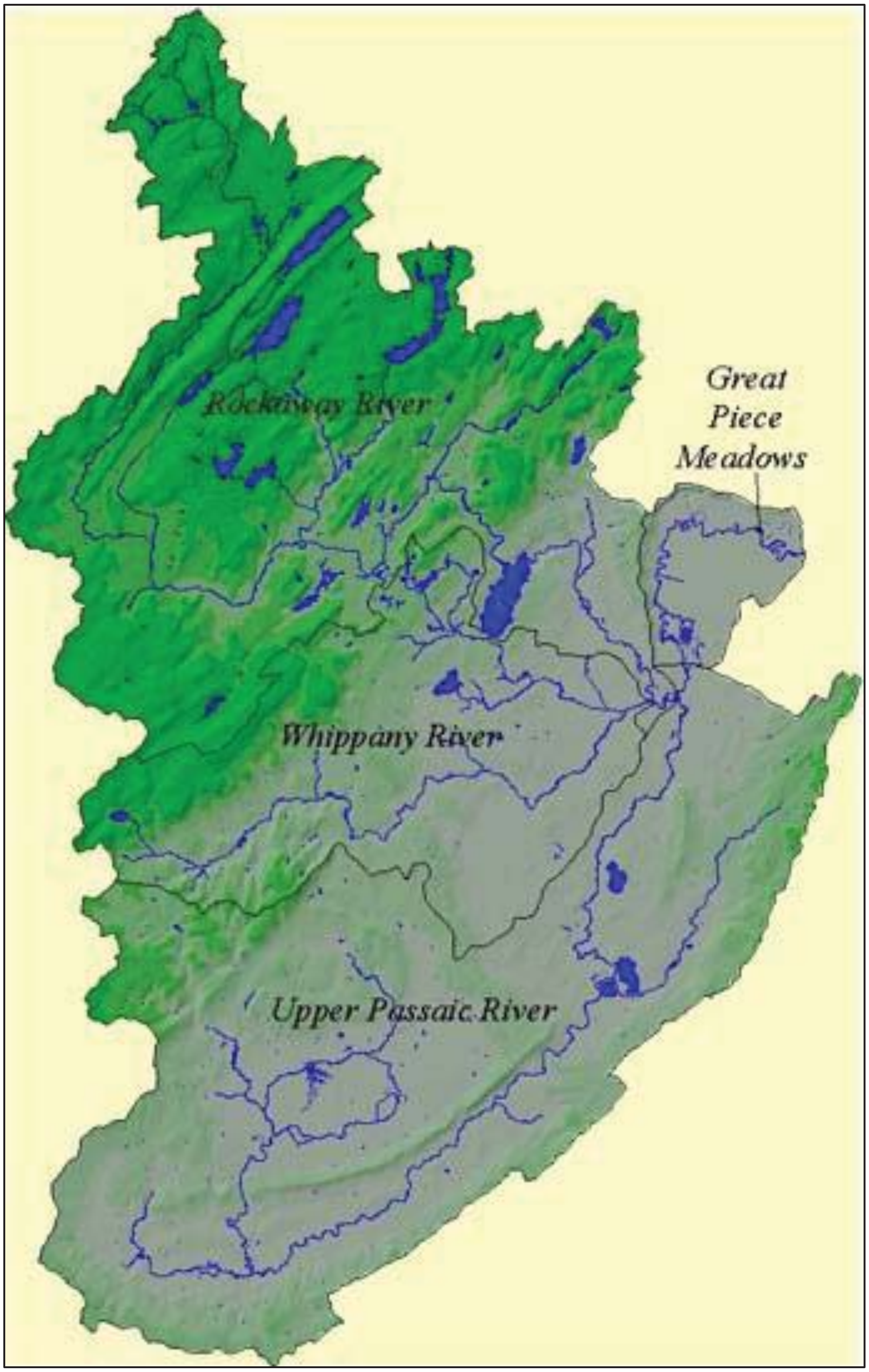


Figure 5. Illustration of the Upper Passaic River Basin watershed, including major river systems (Reprinted from New Jersey Department of Environmental Protection, 2012).

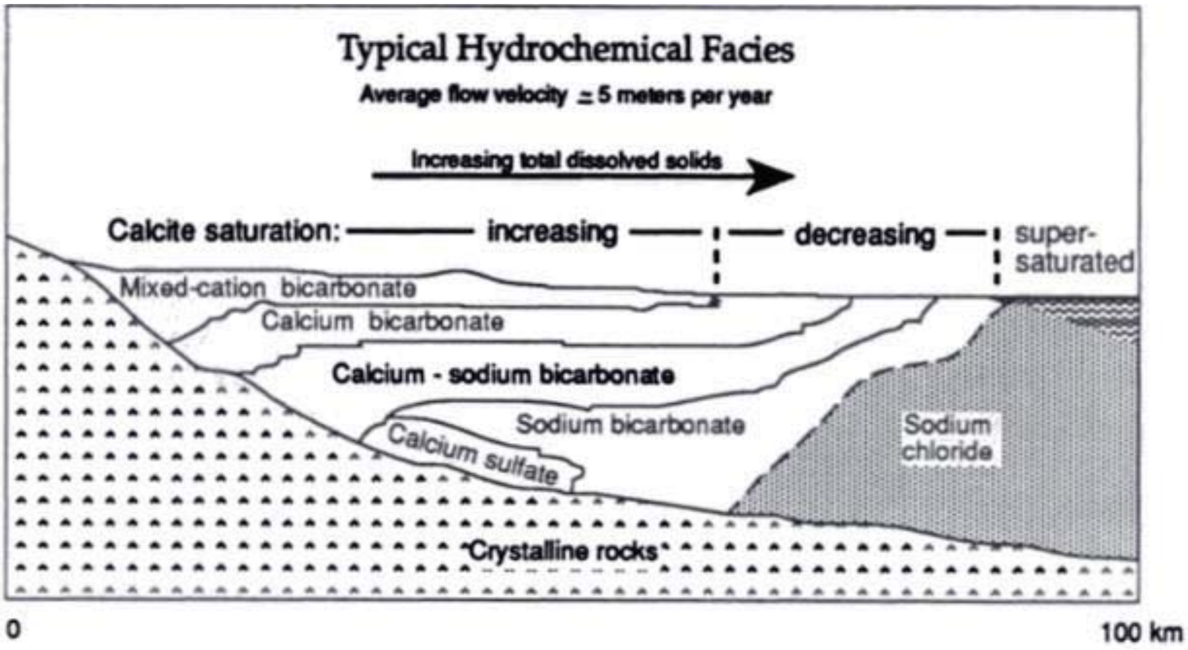


Figure 6. A representation of groundwater composition as age increases (Reprinted from Alley, 1993).

2. Background

2.1 General Overview

In the 1960s, approximately 32,030,000 metric tons of deicing material was used on roadways throughout the United States (Kelly & Mathos, 2014). This rate increased by 67% to 53,490,000 metric tons of deicing material application in the 2000s. The relationship between increased rates of deicing salt application and groundwater composition have been researched through numerous groundwater composition studies. Peters & Turk (1981) researched groundwater composition trends in the Mohawk River, New York from the 1950s to 1970s in relation to deicing application. Results of the study show that there was a 72% increase in Na^+ concentrations [2,880 to 4,950 $(kg/km^2)/y$] and a 145% increase in Cl^- concentrations [3,040 to 7,450 $(kg/km^2)/y$] over a 20-year span. Bivariate and prediction interval analysis attributed the Na^+ and Cl^- increases to be a direct result of NaCl road salt application (Peters & Turk, 1981).

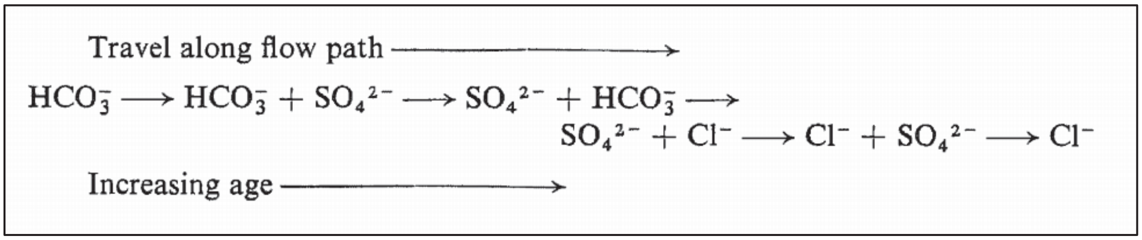
A secondary study focusing on the Mohawk River Basin (Godwin et al., 2002) was completed in 2002. The study conceptualizes Na^+ and Cl^- increases over a longer time span, 1952 to 1998. Using analytical techniques such as a Schoeller diagram and bivariate analysis, results determined that Na^+ and Cl^- levels increases by 130 and 243% respectively, while other major ions remained constant (Godwin et al., 2002). The study concluded that despite population decline and environmental regulations, Na^+ and Cl^- levels continued to rise, matching the rates of increased deicing application over the study time frame.

Foos (2003) collected 71 water samples from groundwater sources to determine spatial distribution of road salt contamination in Gorge Metro Park, Cuyahoga Galls, Ohio. Through bivariate analysis, the composition of the groundwater in the region showed a near perfect correlation between Na^+ and Cl^- ($r^2 = 0.995$) and Cl^- and TDS ($r^2 = 0.997$) (Foos, 2003). The strong correlations indicated that halite is the major dissolved solid present in the groundwater system, and Br/Cl ratios determined that the halite originated from road salts. The major ion analysis preformed on the collected samples indicated that the magnitude of road salt application is directly proportional to groundwater contamination levels (Foos, 2003).

2.2 Natural Groundwater Evolution

To better understand how Na^+ and Cl^- influence groundwater composition over time, it's important to note the natural major anion evolution sequence in groundwater. A study from Chebotarev (1955), based on 10,000 groundwater samples, shows the natural progression of dominant anion species throughout time (Sequence 1). The progression of major ion evolution is influenced by two major variables as groundwater flows from the upper zone through the intermediate zone and into the lower zone, mineral availability and solubility. The upper zone is characterized by active hydrological movement in a well-leached geologic setting, meaning TDS will generally be low. HCO_3^-, mainly derived from soil zone CO_2 and the dissolution of carbonate minerals, is generally the dominant anion present here (Freeze & Cherry, 1979). Groundwater then progresses into the sluggish intermediate zone, which has significantly less groundwater circulation. In the intermediate zone TDS increases and SO_4^{2-} is usually the dominant anion found, due to contact with highly soluble sulfate minerals. TDS continues to rise as groundwater slowly percolates into the lower zone, characterized by little to no active flushing in a geologic setting that has very soluble chloride minerals, that dissolve rapidly when in contact with water. Here the dominant anion becomes Cl^- (Freeze & Cherry, 1979). The sequence signifies there is a natural transition from HCO_3^- dominated water species to Cl^- dominated species, showing a progression from fresh water to saline water. In general, groundwater composition studies have noted that Na^+,

K^+, Ca^{2+}, Mg^{2+}, Cl^-, CO_3^{2-}, HCO_3^- and SO_4^{2-} are all major ions found in most natural aquifers (Fetter, 2014).

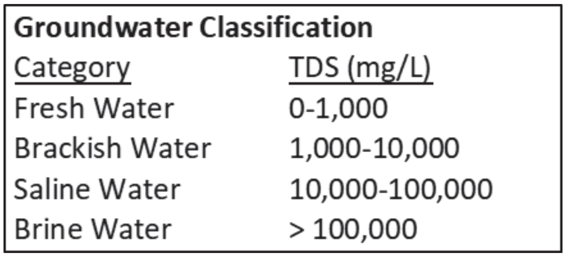


$$HCO_3^- \longrightarrow HCO_3^- + SO_4^{2-} \longrightarrow SO_4^{2-} + HCO_3^- \longrightarrow SO_4^{2-} + Cl^- \longrightarrow Cl^- + SO_4^{2-} \longrightarrow Cl^-$$

Sequence 1. Depicts the evolution of the dominant anion species as groundwater progresses through a natural flow path from freshwater to saline water (Reprinted from Freeze & Cherry, 1979).

Understanding how TDS concentrations alter the ionic composition of groundwater is relevant in identifying if external sources are influencing groundwater composition. A drastic increase of TDS concentrations in previously identified freshwater species would implicate an external source of contamination in the groundwater system (Freeze & Cherry, 1979). Freeze and Cherry classify the relationship between TDS and groundwater (Table 2).

Table 2. Classification of groundwater based on total dissolved solids (Freeze & Cherry, 1979).



Groundwater Classification

Category	TDS (mg/L)
Fresh Water	0-1,000
Brackish Water	1,000-10,000
Saline Water	10,000-100,000
Brine Water	> 100,000

Considering the natural evolution sequence of groundwater species progresses in a timescale of hundreds of thousands to millions of years, sudden alterations in ion concentrations would be indicative of external influences. Specifically, increases in Na^+ and Cl^- concentrations in low TDS settings (freshwater) implicates an anthropogenic source such as deicing application.

2.3 Passaic River Basin Groundwater Evolution

Various historical research studies have investigated groundwater composition in the Passaic River Basin through well sampling and chemical analysis. One such study conducted by Anderson and Faust (1973) focused on water quality and streamflow dynamics to characterize the Passaic River Basin by splitting the river basin into isochemical regions. The results indicate that in the northwestern section of the UPRB, a region dominated by igneous and metamorphic bedrock, TDS is generally less than 200 mg/L. The predominant cations were found to be Mg^{2+} and Ca^{2+}, ranging in total composition from 50-80%. The predominant anion was found to be HCO_3, comprising a total of 50-80% of total anions (Anderson & Faust, 1973).

The southeastern region, which consists mainly of sedimentary bedrock, was found to have a higher TDS concentration, usually exceeding 100 mg/L and often 400 mg/L. Ca^{2+} and Mg^{2+} were found to make up 50% of total cations. This region measured the highest amounts of Na^+ and K^+ in the entire basin at roughly 30-60% of total cations present. The predominant anions were found to be associated with salinity, specifically Cl^-, SO_4^{2-} and F^-. The study also notes during both observation periods, 1923-1925 and 1962-1970, Na^+, K^+, HCO_3^-, and Cl^- all increased with time. Secondly, it is of relative importance to note that because the UPRB is a heavily industrialized setting, anthropogenic wastewater discharge can have a significant effect on measured TDS (Anderson & Faust, 1973).

Czarnik and Kosinski (1994) noted groundwater quality variations against time in the central region of the Passaic River Basin, which covers a significant percentage of the UPRB.

Seventy-one well samples throughout the southeastern portion of the UPRB were collected from 1959-1988 to analyze regional groundwater quality. The results indicated that the predominant ions present in sedimentary basins are Ca^{2+} and HCO_3^-, followed by Mg^{2+} and Na^+. In igneous and metamorphic basins, the predominant cation measured was Ca^{2+}, while HCO_3^- was the predominant anion. The analysis concludes that major ions such as Mg^{2+}, Ca^{2+}, Na^+ and SO_4^{2-} are generally of higher concentration in sedimentary basins compared to igneous and metamorphic (Czarnik & Kosinski, 1994).

3. Methodology

3.1 Data Collection

To achieve the goals of this research study a large amount of quantifiable data spanning over a substantial period of time is necessary. The USGS database stores a significant amount of groundwater quality data (U.S. Geological Survey, 2016). Starting in the early 20th century, the USGS began measuring and recording notable ions concentrations through mainly well sites and open water sources. These measurements included but are not limited to Na^+, Cl^-, Mg^{2+}, Ca^{2+}, SO_4^{2-}, and TDS. For the purpose of this study only these 6 measurements will be discussed. The field parameters consist of 573 different measurements spanning from 1960 to 2010 within the UPRB (Table 3). This set of data will be used as the basis for the regression analysis of the UPRB. The data set was compiled using Microsoft Excel (Version 14.4). The data were collected through various programs by the USGS – National Water Quality Assessment, USEPA, and NJDEP. Historical groundwater quality data is digitally stored in the National Water Information System web interface program. All recorded U.S. water quality data can be accessed at http://www.waterdata.usgs.gov/ by entering the locational identifiers of the study site and indicating the data parameters.

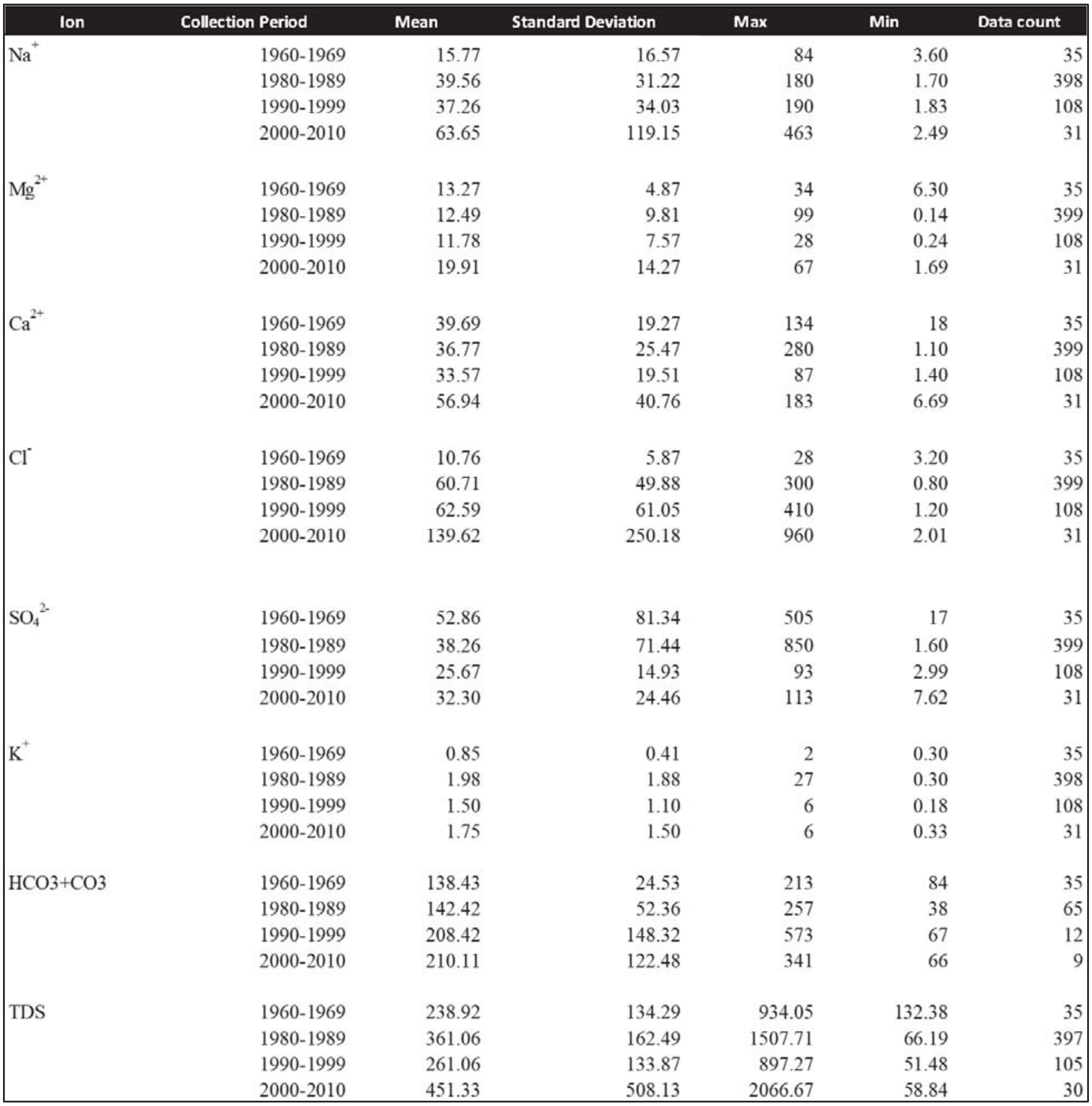
3.2 Data Analysis

3.2.1 Single Linear Regression Analysis

The regression analysis of the water quality samples in the UPRB was done using a variety of methods aimed to ascertain a clear understanding of how and why the groundwater composition has changed. The initial analysis tool was to compare the ion partnerships of Na^+ vs. Cl^-, Mg^{2+} vs. Ca^{2+}, Na^+ vs. Ca^{2+}, Cl^- vs. Ca^{2+}, and Cl^- vs. TDS using simple linear regression analysis. This was carried out using the Microsoft Excel graph feature. Na^+ vs. Cl^- and Cl^- vs. TDS were expressed as single decade plots which allowed for an observation of the change in correlation over time. The significance of Cl^- levels in relation to TDS becomes apparent after observing Cl^- vs. TDS on a decadal basis.

The coefficient of determination (r^2) is utilized to measure the correlation between two variables in a simple linear regression model. The basis of r^2 is found by squaring Pearson's r, also known as the correlation coefficient (Seltman, 2012). Pearson's r ranges from -1 to 1, meaning the coefficient of determination can be represented from 0 to 1, with 0 indicating no correlation and 1 indicating a positive correlation (Seltman, 2012). In ion to ion analysis a value closer to 1 would indicate that the source of the ions in the groundwater system is the same. The sample size, represented by n, is relevant when considering the precision of a simple linear regression model. A larger sample size will generally lead to a more accurate statistical correlation (Handbook of Statistical Methods, 2003).

Table 3. Mean, standard deviation, and range for major ion concentration and TDS in the Upper Passaic River Basin, New Jersey (concentrations in mg/L).



Ion	Collection Period	Mean	Standard Deviation	Max	Min	Data count
Na^+	1960-1969	15.77	16.57	84	3.60	35
	1980-1989	39.56	31.22	180	1.70	398
	1990-1999	37.26	34.03	190	1.83	108
	2000-2010	63.65	119.15	463	2.49	31
Mg^{2+}	1960-1969	13.27	4.87	34	6.30	35
	1980-1989	12.49	9.81	99	0.14	399
	1990-1999	11.78	7.57	28	0.24	108
	2000-2010	19.91	14.27	67	1.69	31
Ca^{2+}	1960-1969	39.69	19.27	134	18	35
	1980-1989	36.77	25.47	280	1.10	399
	1990-1999	33.57	19.51	87	1.40	108
	2000-2010	56.94	40.76	183	6.69	31
Cl^-	1960-1969	10.76	5.87	28	3.20	35
	1980-1989	60.71	49.88	300	0.80	399
	1990-1999	62.59	61.05	410	1.20	108
	2000-2010	139.62	250.18	960	2.01	31
SO_4^{2-}	1960-1969	52.86	81.34	505	17	35
	1980-1989	38.26	71.44	850	1.60	399
	1990-1999	25.67	14.93	93	2.99	108
	2000-2010	32.30	24.46	113	7.62	31
K^+	1960-1969	0.85	0.41	2	0.30	35
	1980-1989	1.98	1.88	27	0.30	398
	1990-1999	1.50	1.10	6	0.18	108
	2000-2010	1.75	1.50	6	0.33	31
HCO3+CO3	1960-1969	138.43	24.53	213	84	35
	1980-1989	142.42	52.36	257	38	65
	1990-1999	208.42	148.32	573	67	12
	2000-2010	210.11	122.48	341	66	9
TDS	1960-1969	238.92	134.29	934.05	132.38	35
	1980-1989	361.06	162.49	1507.71	66.19	397
	1990-1999	261.06	133.87	897.27	51.48	105
	2000-2010	451.33	508.13	2066.67	58.84	30

3.2.2 Decade-averaged Statistical Analysis

Complementary to the bivariate plots, decade average plots were created with TDS, Na^+, Cl^-, Ca^{2+}, Mg^{2+} and SO_4^{2-} as the independent variable (Y-axis) and time as the dependent variable (X- axis). The purpose of the graphs was to observe how the average concentration over the entirety of the study site has varied throughout the study period. This can give valuable insight on how the composition of the groundwater has changed based on a single ion or TDS. Finally, a Schoeller diagram was developed to observe the magnitude of change on a logarithmic basis. All observations can be seen in Table 3, which includes data statistics such as standard deviation, maximum and minimum values, and data count.

3.2.3 Groundwater Species

While the bivariate plots and decade average plots allow for the analysis of a single ion or single ion relationships, piper diagrams are used to evaluate the ionic composition of the groundwater as a whole. The piper diagram combines two ternary plots, one focusing on the cations (Mg^{2+}, Ca^{2+} and $Na^+ + K^+$) and one on the anions (SO_4^{2-}, $HCO_3^- + CO_3^{2-}$ and $Cl^- + F$). The ion percentages are then projected onto a diamond graph to show the complete ionic composition of the sample site. The average TDS of the samples used in each piper diagram is displayed along with the average cation and anion concentrations. A piper diagram was created to represent each decade within the study timeframe, resulting in four plots total (1970 was not available due to lack of data). Piper diagrams allow for the evaluation of the changing iconic composition of the study site, specifically which ions dominate the groundwater of the site.

3.2.4 95% Prediction Interval Analysis

By using a 95% prediction interval plot, a statistically predicted increase was juxtaposed by the actual recorded increase. Prediction interval plots were done for Mg^{2+}, Na^{+}, Cl^{-}, Ca^{2+} and SO_4^{2-} based upon Equation 1.

$$\hat{y}_h \pm t_{(\alpha/2,n-2)} \times \sqrt{MSE\left(1+\frac{1}{n}+\frac{(x_h-\bar{x})^2}{\sum(x_i-\bar{x})^2}\right)}$$

…………………………...(1)

Where:

$\hat{y}_h$ = Sample Estimate

$t_{(\alpha/2,n-2)}$ = multiplier

$\sqrt{MSE \times \left(1+\frac{1}{n}+\frac{(x_h-\bar{x})^2}{\sum(x_i-\bar{x})^2}\right)}$ = Standard error of the prediction

Equation 1. Ninety-five percent prediction interval equation (Kutner et al., 2005)

For each interval the sample period 1960-1969 along with the corresponding upper and lower prediction intervals work as a baseline for comparison. The actual measurements of the sample period of 2000-2010 were used as a comparison to the baseline intervals. This was done to evaluate the significance of the ions variation. The sample measurements represented the dependent variable while specific conductance is the independent variable.

3.2.5 Potentiometric and Ion Concentration Maps

The UPRB data set is visualized by importing the latitude and longitude coordinates for both hydraulic head and ion concentration into ArcGIS (Version 10.5). The watershed base map, Bedrock geology, and elevation base maps were downloaded from the New Jersey Department Environmental Protection Agency (www.state.nj.us/dep/njgs/geodata/index.html).

Three types of maps were made to visualize the study site: the well location map, the potentiometric maps and ion concentration maps. To create the well location map, the extent base map was paired with well sites to better understand the spatial reference of the data set. Secondly, the potentiometric maps were created using the contour tool in ArcGIS, these maps were broken up into decades for comparison with ionic concentration maps. The same process was used to create ionic concentration maps for the ions Na^+, Cl^-, Mg^{2+}, Ca^{2+}, and SO_4^{2-}.

4. Results

4.1 Simple Linear Regression Analysis

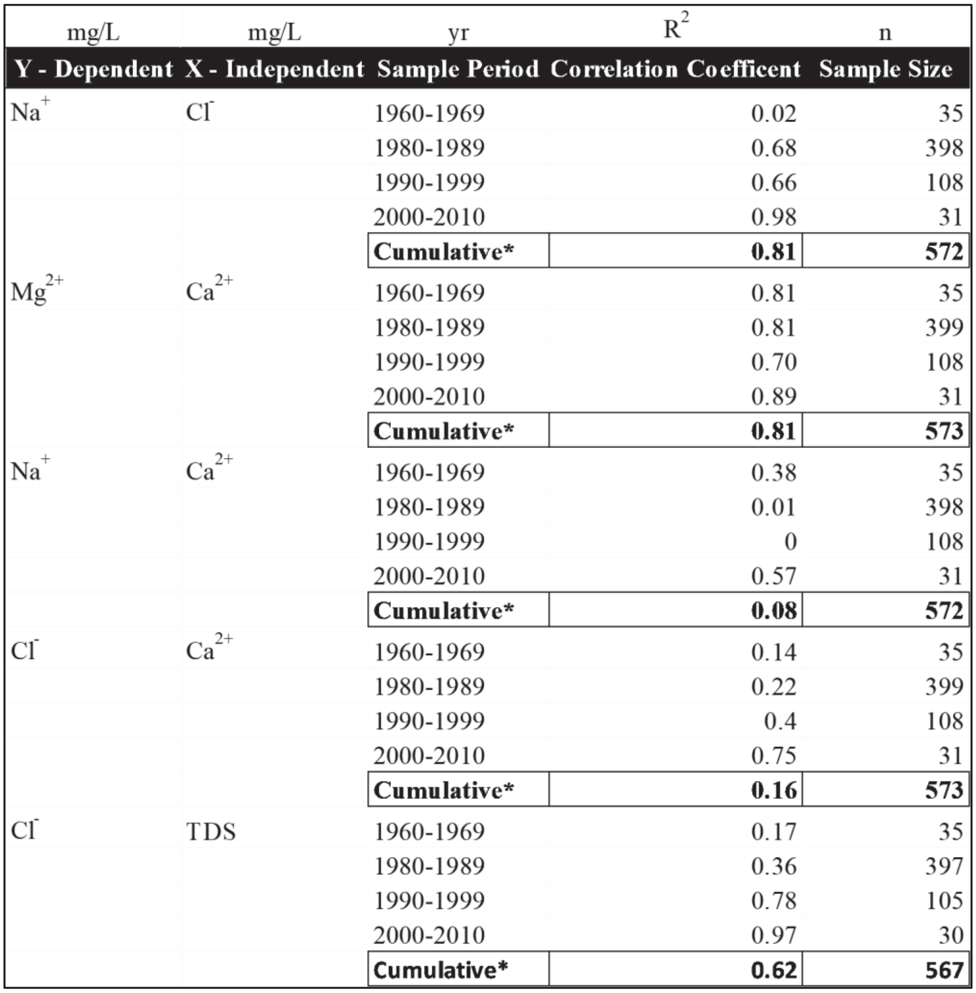
Regression analysis for Na^+ vs Cl^- ($r^2 = 0.81$, n = 572) indicates an overall strong correlation (Figure 7a). The strong correlation seen in the bivariate analysis indicates that the most substantial supplier for both Cl^- and Na^+ is coming from a singular source. The bivariate analysis of Ca^{2+} vs Mg^{2+} ($r^2 = 0.81$, n = 573), Na^+ vs Ca^{2+} ($r^2 = 0.08$, n = 572), Cl^- vs Ca^{2+} ($r^2 = 0.16$, n = 573) and Cl^- vs TDS ($r^2 = 0.62$, n = 567) are shown in Figures 7b – 7e. The correlations indicate that the presence of Ca^{2+} is generally not associated with the same source as Na^+ and Cl^-. Due to the fact there is a significant presence of Ca^{2+} producing rocks in the region, this suggests that the majority of Na^+ and Cl^- in the groundwater system are from an outside source, unrelated to geology. The consistent correlation in Ca^{2+} and Mg^{2+} is geological in nature. Previous groundwater composition studies have noted that Ca^{2+} and Mg^{2+} are ubiquitous in groundwater composition due to geologic weathering (Ismail et al., 2010). While Ca^{2+} vs Cl^- shows no correlation from 1960-2000, a good correlation seen in the 2000-2010 sample period ($r^2 = 0.75$, n = 31) (Table 4). The strong correlation is potentially evident of an influence from increased usage of $CaCl_2$ deicing material.

A decadal breakup of the Na^+ vs Cl^- data set shows a correlation that is increasing overtime (Figures 8a – 8d). The 1960-1969 data set shows no correlation ($r^2 = 0.02$, n = 35) while the most recent 2000-2010 data set has a near perfect correlation ($r^2 = 0.98$, n = 31). The increasing trend in correlation over time directly relates to increases in NaCl deicing application for New Jersey (Kelly & Mathos, 2014).

The analysis of Cl^- concentration in relevance to TDS gives insight into how the anionic composition of groundwater can be influenced from an external source. Since natural Cl^- increases of a substantial level occur on geologic timescales of thousands to millions of years, an increase seen over a sample period of 50-years would not be geologic in source, rather external. Chloride vs. TDS decade average plots clearly establish a trend of increasing correlation over time. Chloride vs. TDS has essentially no correlation ($r^2 = 0.18$, n = 35) in the 1960-1969 sample period. The correlation evolves exponentially with the 1980-1989 ($r^2 = 0.37$, n = 397) and 1990-1999 ($r^2 = 0.79$, n = 105) sample periods. In the most recent sample period, 2000-2010, Cl^- vs TDS shows a near perfect correlation ($r^2 = 0.97$, n = 30). Figures 9a - 9d show the correlation between Cl^- and TDS. The relationship establishes that Cl^- is continuingly becoming more abundant in the ionic composition of the samples. This indicates that Cl^- is increasing at a rate that the other major ions present are not, this is a result of a steady influx of Cl^- in the groundwater system. The increasing nature of Cl^- impact on TDS corresponds with increased rates of NaCl deicing application in the UPRB.

Table 3 displays the ionic composition of the various major ions present in the groundwater sampling. Generally, for all ions sampled there is an increase in concentration with time. The only exception is SO_4^{2-}, there is a decrease throughout the sample periods. Its apparent by standard deviation, maximum and minimum values, and data count in the ionic concentration table that there is a significant variance in the data set, which is likely due to the two different geologic settings of the UPRB.

Table 4. Regression analysis correlations for major ion to ion relationship in the Upper Passaic River Basin, New Jersey.



mg/L	mg/L	yr	R^2	n
Y - Dependent	**X - Independent**	**Sample Period**	**Correlation Coefficent**	**Sample Size**
Na^+	Cl^-	1960-1969	0.02	35
		1980-1989	0.68	398
		1990-1999	0.66	108
		2000-2010	0.98	31
		Cumulative*	**0.81**	**572**
Mg^{2+}	Ca^{2+}	1960-1969	0.81	35
		1980-1989	0.81	399
		1990-1999	0.70	108
		2000-2010	0.89	31
		Cumulative*	**0.81**	**573**
Na^+	Ca^{2+}	1960-1969	0.38	35
		1980-1989	0.01	398
		1990-1999	0	108
		2000-2010	0.57	31
		Cumulative*	**0.08**	**572**
Cl^-	Ca^{2+}	1960-1969	0.14	35
		1980-1989	0.22	399
		1990-1999	0.4	108
		2000-2010	0.75	31
		Cumulative*	**0.16**	**573**
Cl^-	TDS	1960-1969	0.17	35
		1980-1989	0.36	397
		1990-1999	0.78	105
		2000-2010	0.97	30
		Cumulative*	**0.62**	**567**

*Calculated using all data (1960-2010).

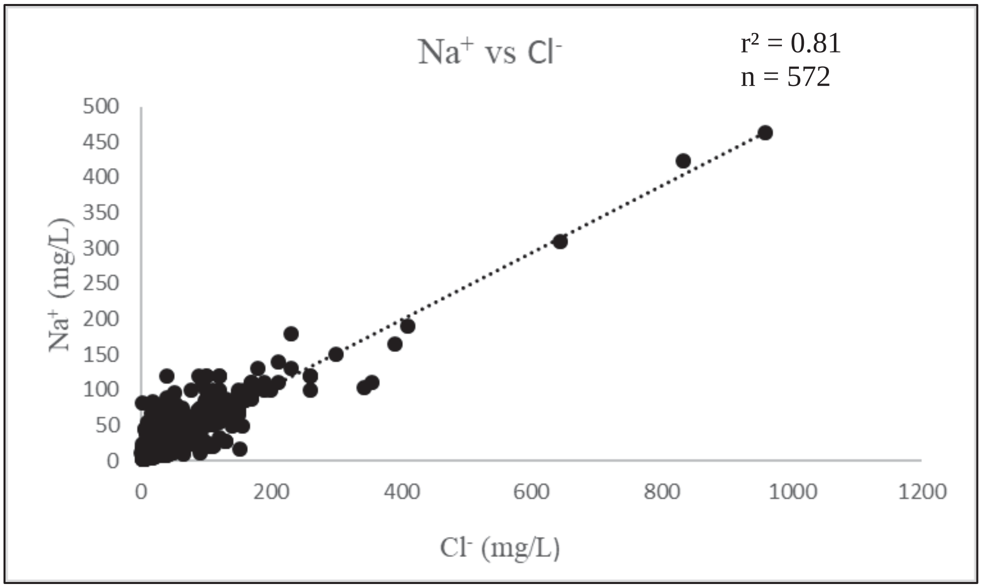


Figure 7a. Relationship between sodium and chloride concentrations for samples collected from 1960-2010 in the Upper Passaic River Basin, New Jersey.

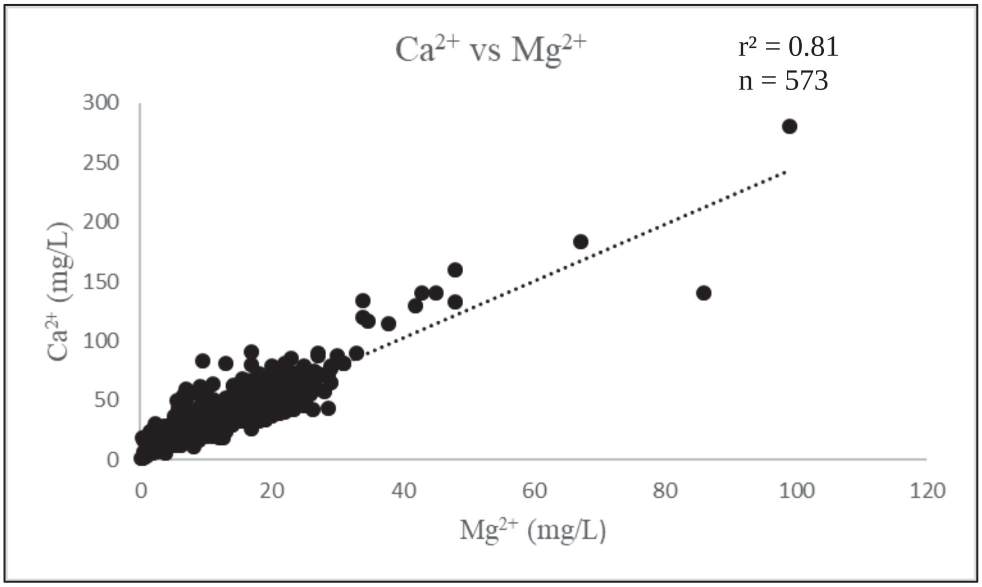


Figure 7b. Relationship between calcium and magnesium concentrations for samples collected from 1960-2010 in the Upper Passaic River Basin, New Jersey.

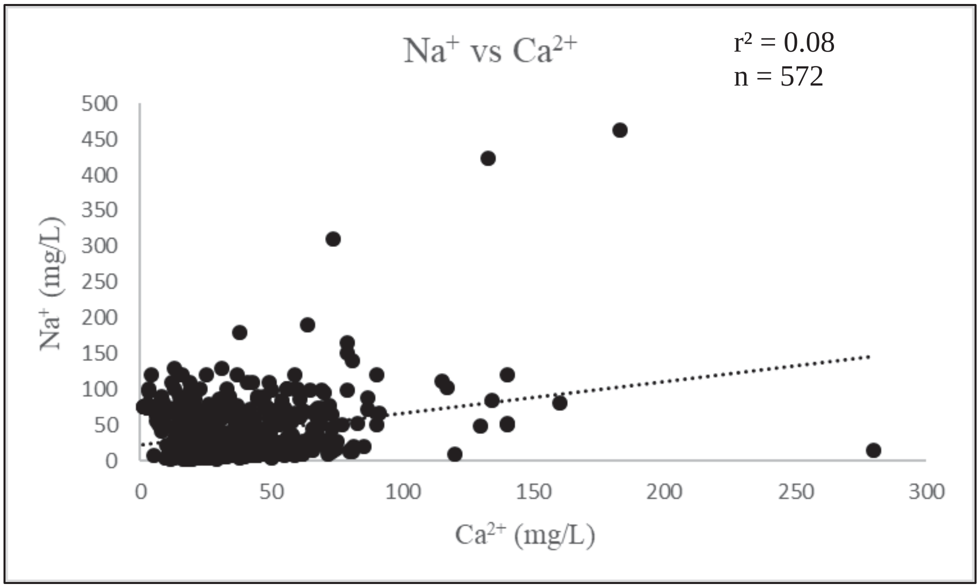


Figure 7c. Relationship between sodium and calcium concentrations for samples collected from 1960-2010 in the Upper Passaic River Basin, New Jersey.

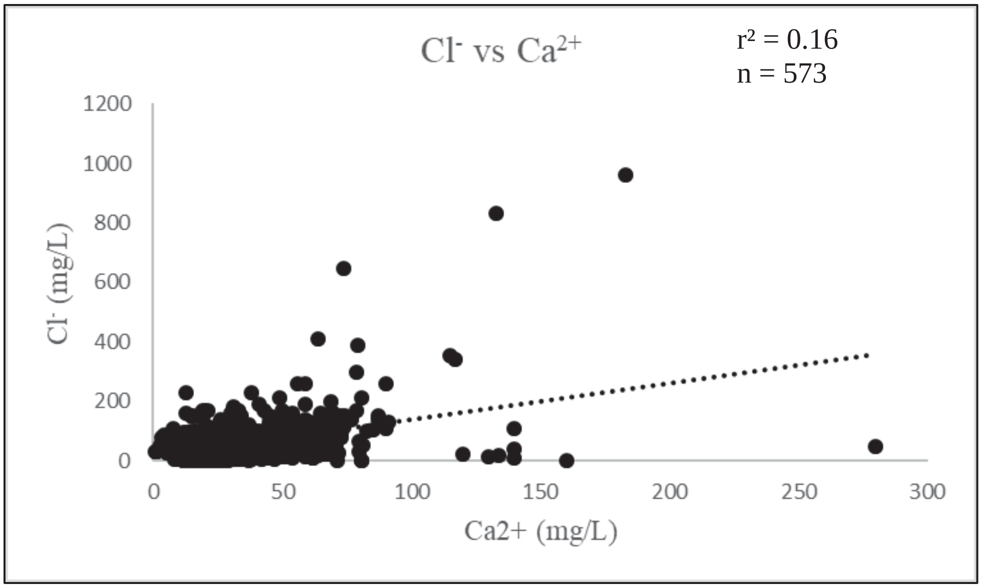


Figure 7d. Relationship between chloride and calcium concentrations for samples collected from 1960-2010 in the Upper Passaic River Basin, New Jersey.

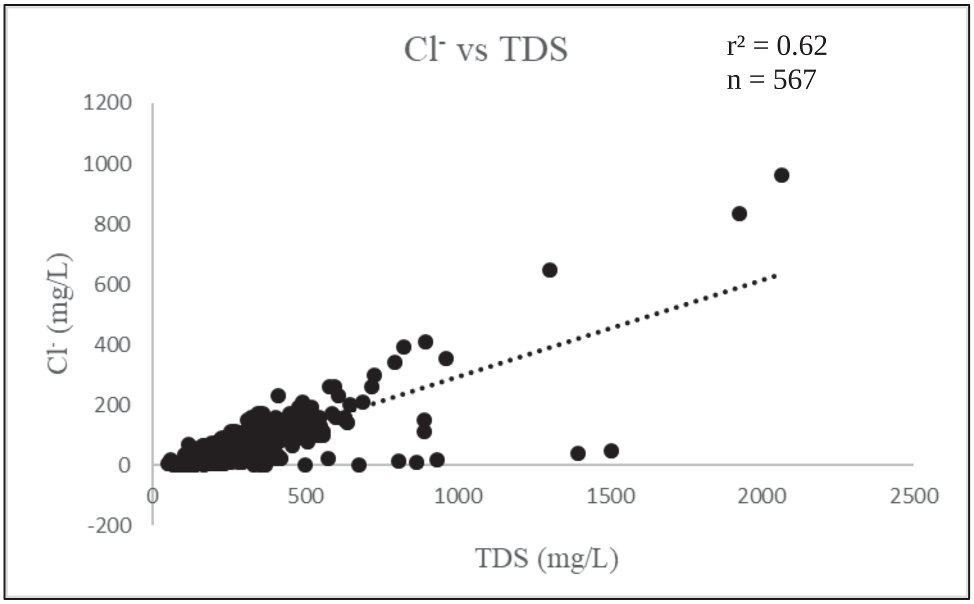


Figure 7e. Relationship between chloride and total dissolved solids concentrations for samples collected from 1960-2010 in the Upper Passaic River Basin, New Jersey.

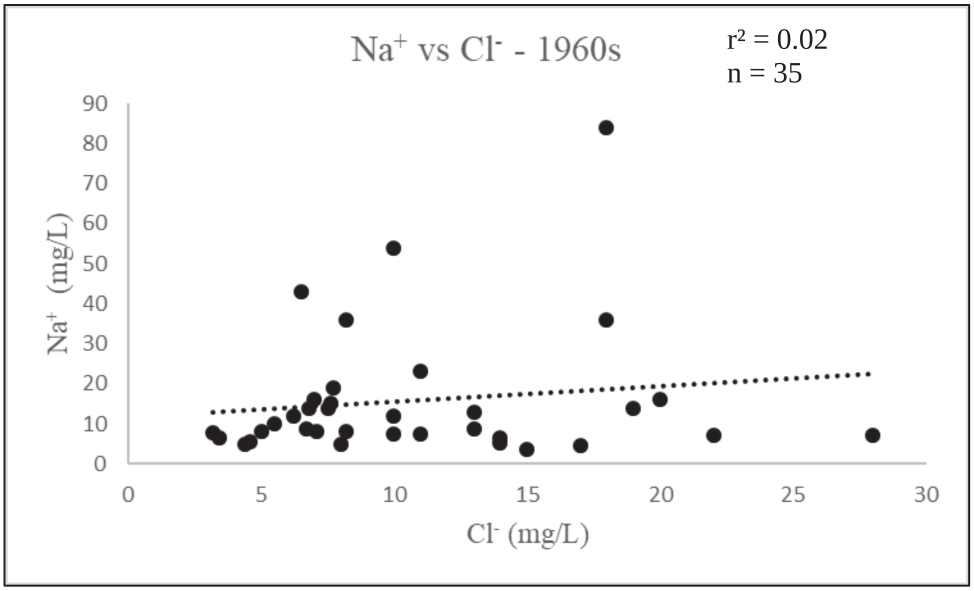


Figure 8a. Relationship between sodium and chloride concentrations for samples collected from 1960-1969 in the Upper Passaic River Basin, New Jersey.

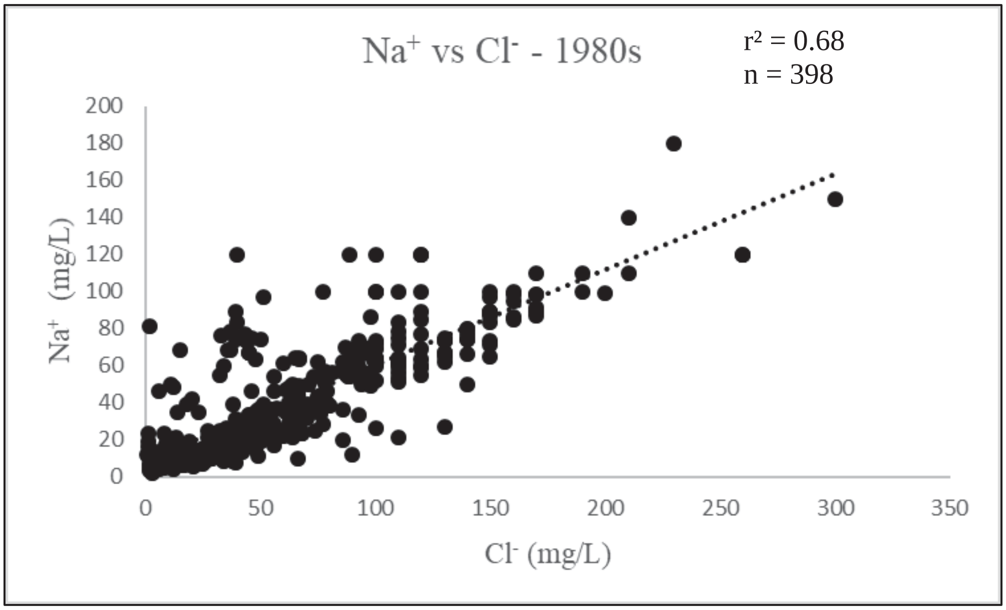


Figure 8b. Relationship between sodium and chloride concentrations for samples collected from 1980-1989 in the Upper Passaic River Basin, New Jersey.

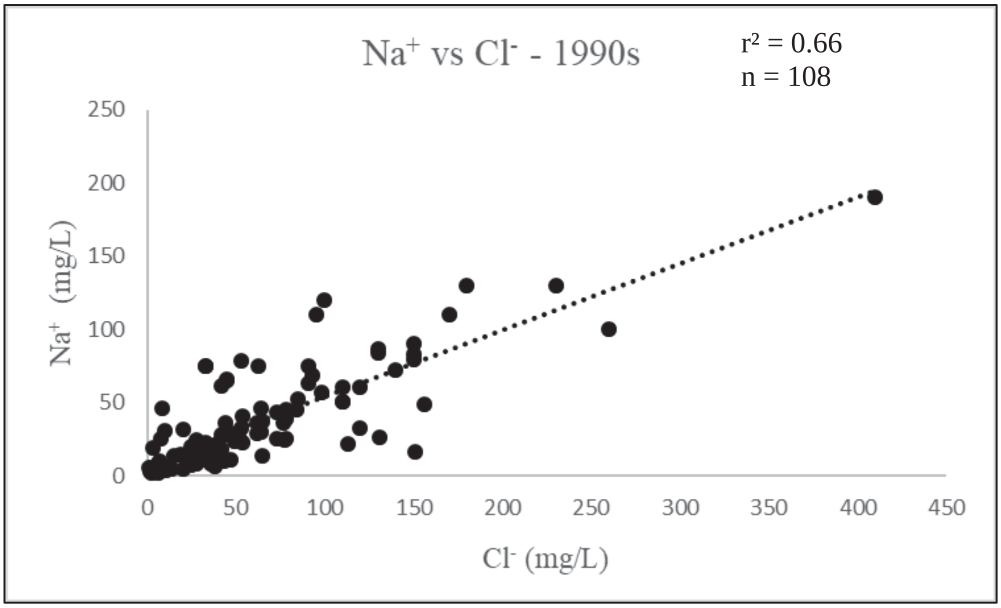


Figure 8c. Relationship between sodium and chloride concentrations for samples collected from 1990-1999 in the Upper Passaic River Basin, New Jersey.

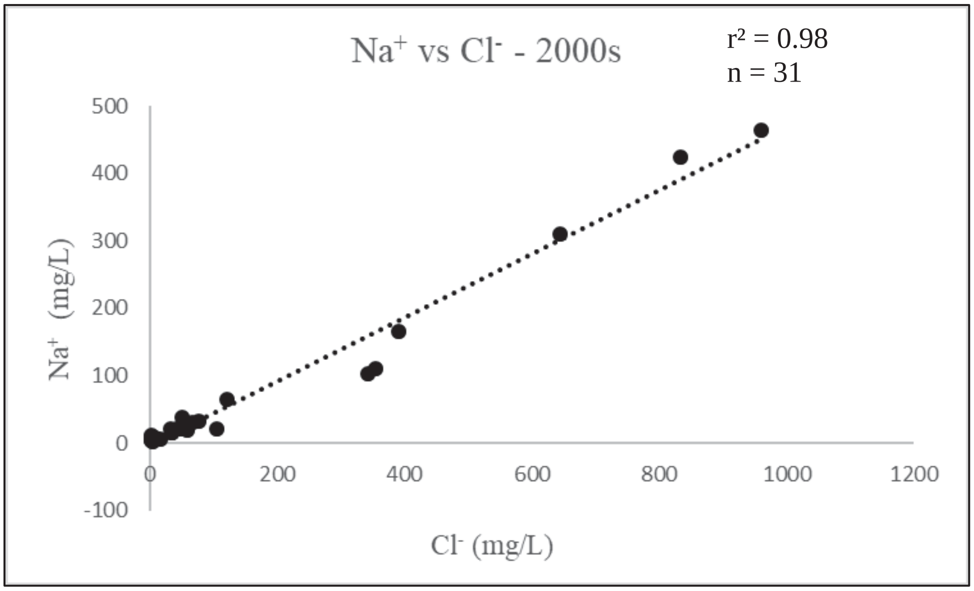


Figure 8d. Relationship between sodium and chloride concentrations for samples collected from 2000-2010 in the Upper Passaic River Basin, New Jersey.

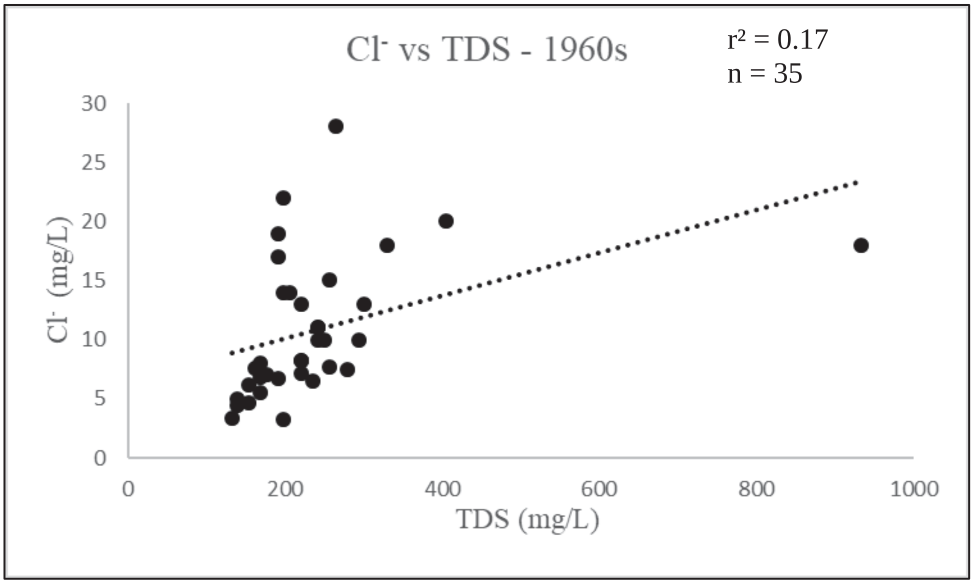


Figure 9a. Relationship between chloride and total dissolved solids concentrations for samples collected from 1960-1969 in the Upper Passaic River Basin, New Jersey.

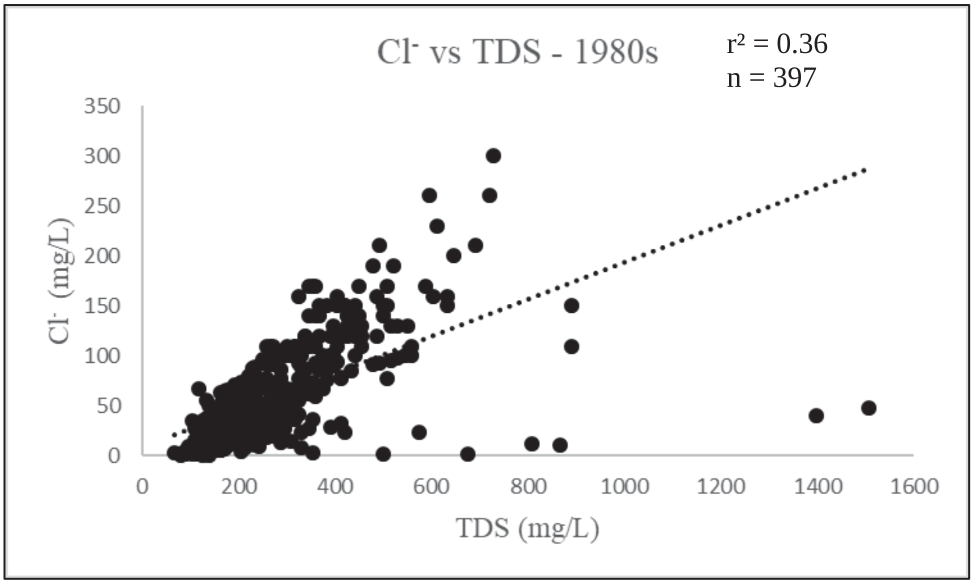


Figure 9b. Relationship between chloride and total dissolved solids concentrations for samples collected from 1980-1989 in the Upper Passaic River Basin, New Jersey.

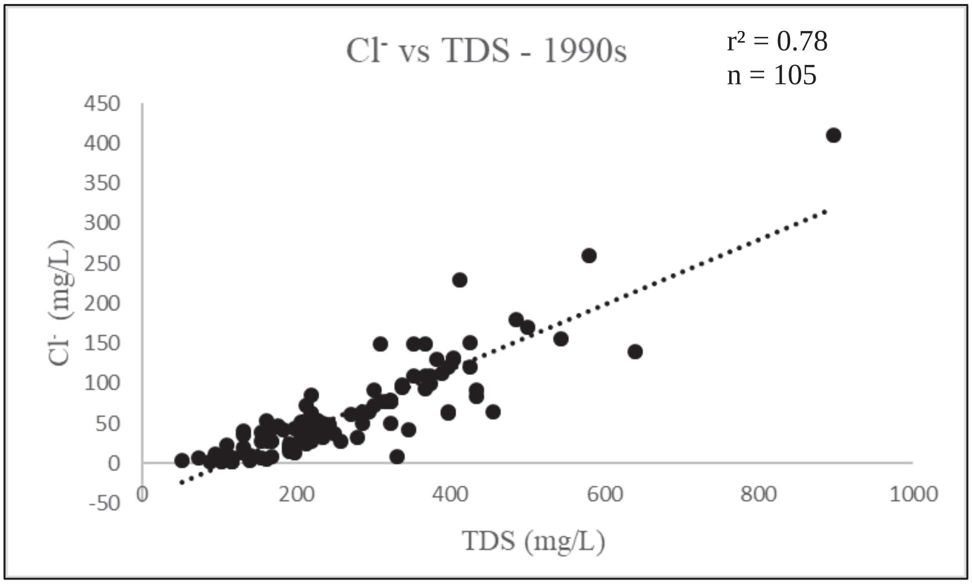


Figure 9c. Relationship between chloride and total dissolved solids concentrations for samples collected from 1990-1999 in the Upper Passaic River Basin, New Jersey.

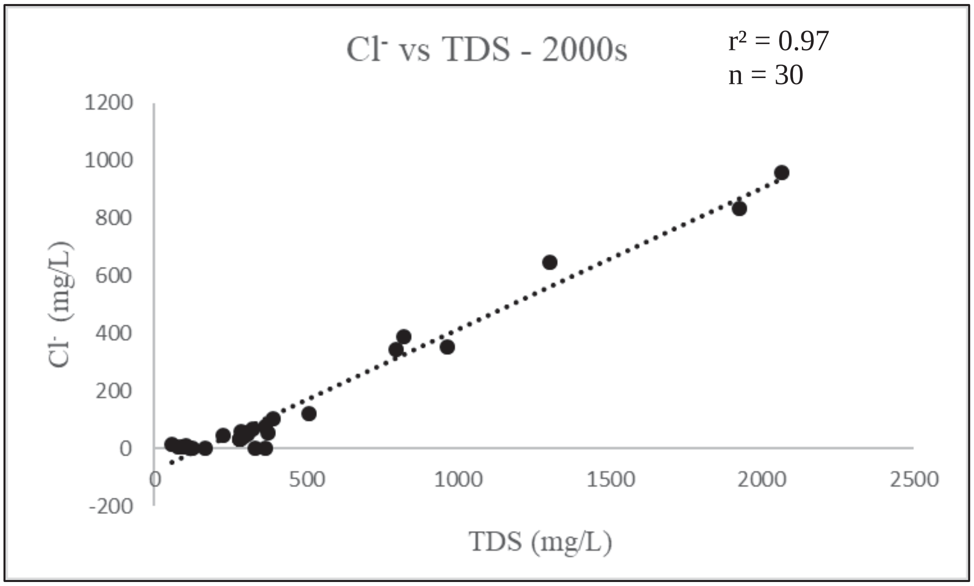


Figure 9d. Relationship between chloride and total dissolved solids concentrations for samples collected from 2000-2010 in the Upper Passaic River Basin, New Jersey.

4.2 Decade-averaged Statistical Analysis

Figures 10a and 10b show Na^+ and Cl^- averages increase significantly over the study period. The substantial increases seen with Na^+ and Cl^- are not observed with other major ions present in the groundwater system. Comparatively, Ca^{2+} and Mg^{2+} increase as a whole but fluctuate variably each decade. (Figures 10c and 10d). SO_4^{2-} averages show a precipitous decline in averaged concentration (Figure 10e), this is hypothesized to not be linked with geology or deicing. As for TDS, Figure 10f shows there is a moderate increase over time, reflecting the increased presence of ions observed in Na^{2+}, Cl^-, Ca^{2+}, and Mg^{2+} plots. The Schoeller diagram (Figure 11) confirms that Na^+ and Cl^- are increasing at a greater magnitude than the other major ions, while SO_4^{2-} is the only ion to decrease over time. The analysis of ionic concentration averages over the study period consistently show that Na^+ and Cl^- are increasing at higher rates compared to the other major ions, Ca^{2+}, Mg^{2+}, and SO_4^{2-}. This points to the likelihood that Na^+ and Cl^- concentrations are being influenced from an outside source.

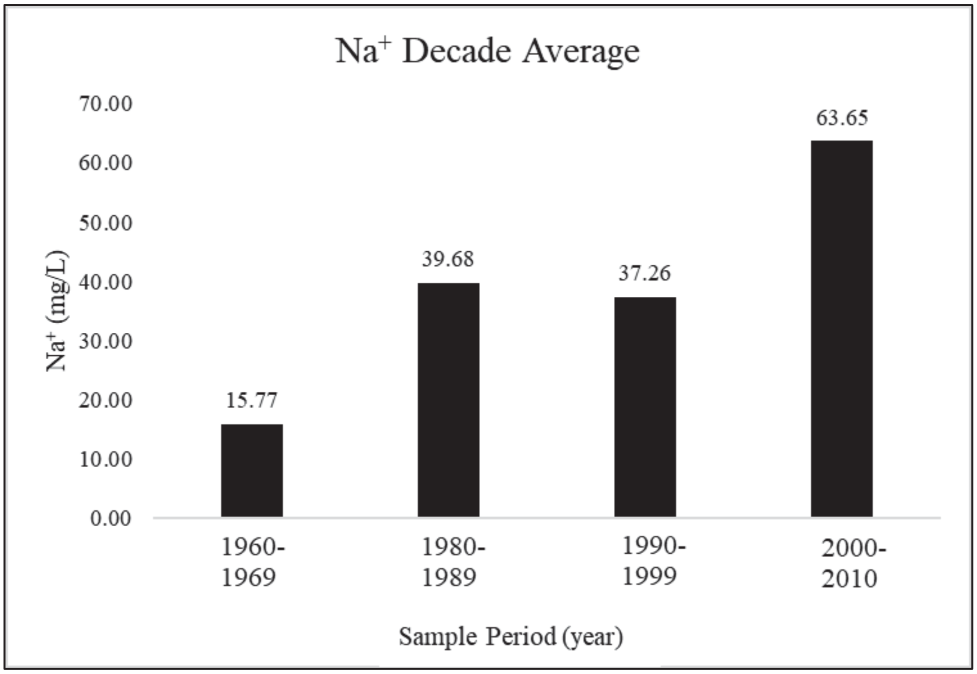


Figure 10a. Sodium ion concentration average for each decade from 1960-2010 in the Upper Passaic River Basin, New jersey (1970s excluded due to lack of data).

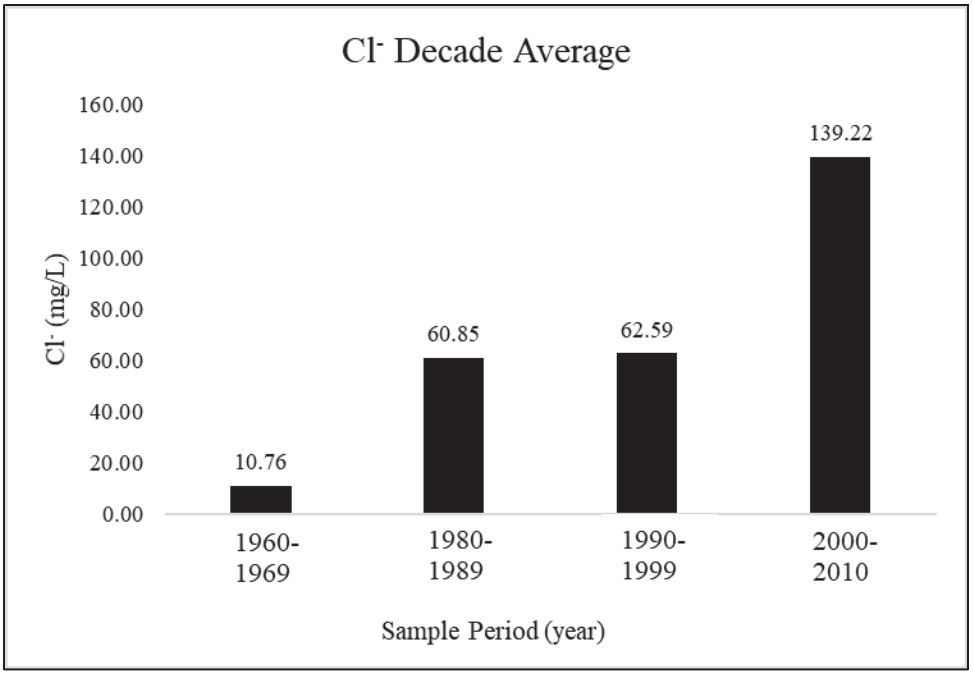


Figure 10b. Chloride ion concentration average for each decade from 1960-2010 in the Upper Passaic River Basin, New Jersey (1970s excluded due to lack of data).

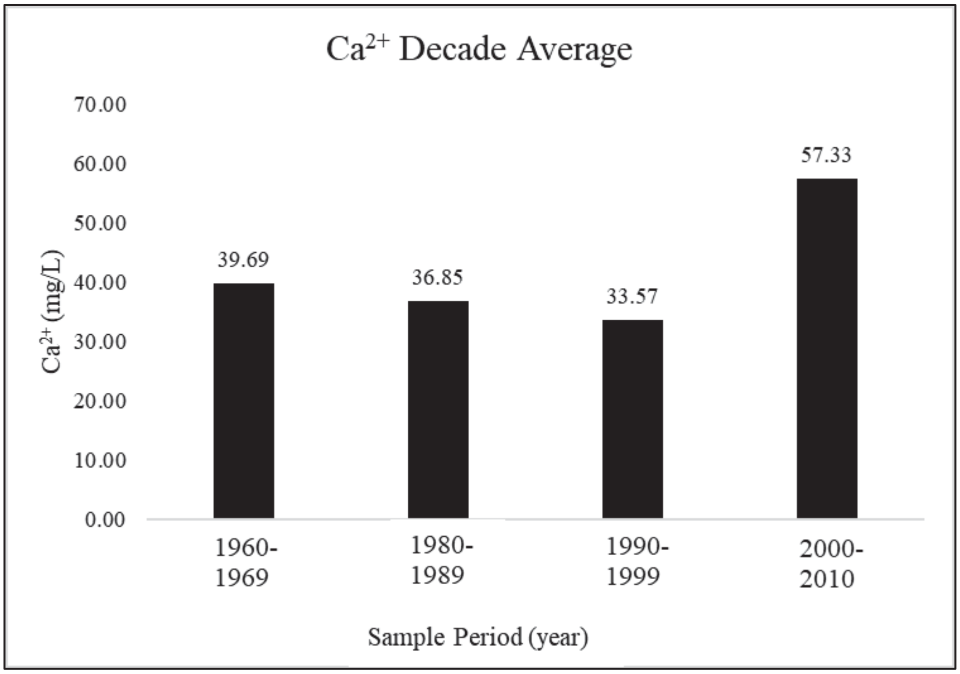


Figure 10c. Calcium ion concentration average for each decade from 1960-2010 in the Upper Passaic River Basin, New Jersey (1970s excluded due to lack of data).

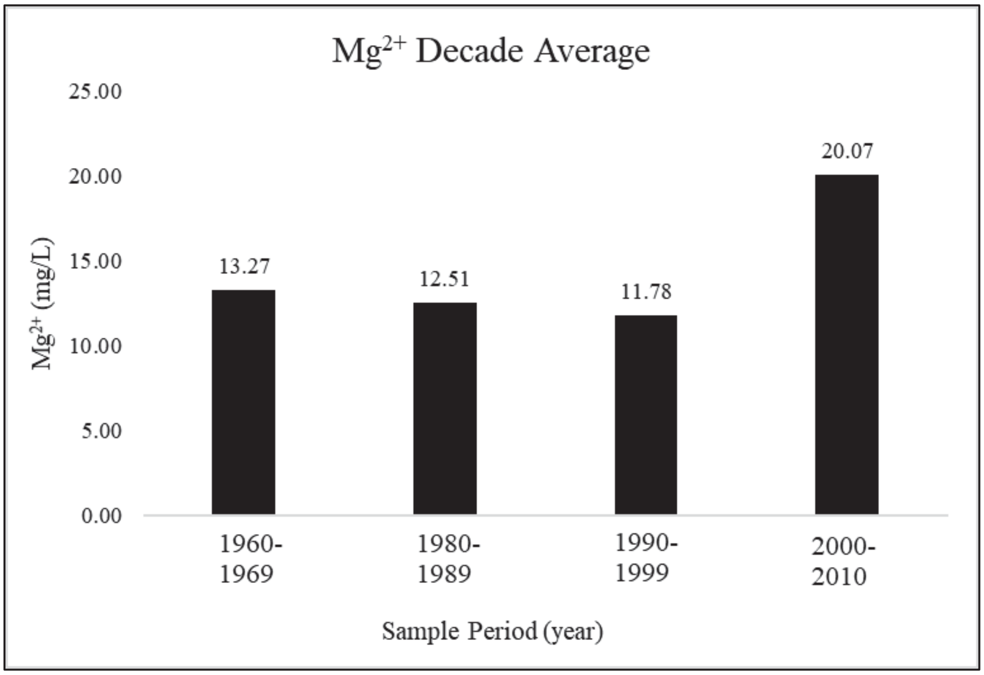


Figure 10d. Magnesium ion concentration average for each decade from 1960-2010 in the Upper Passaic River Basin, new Jersey (1970s excluded due to lack of data).

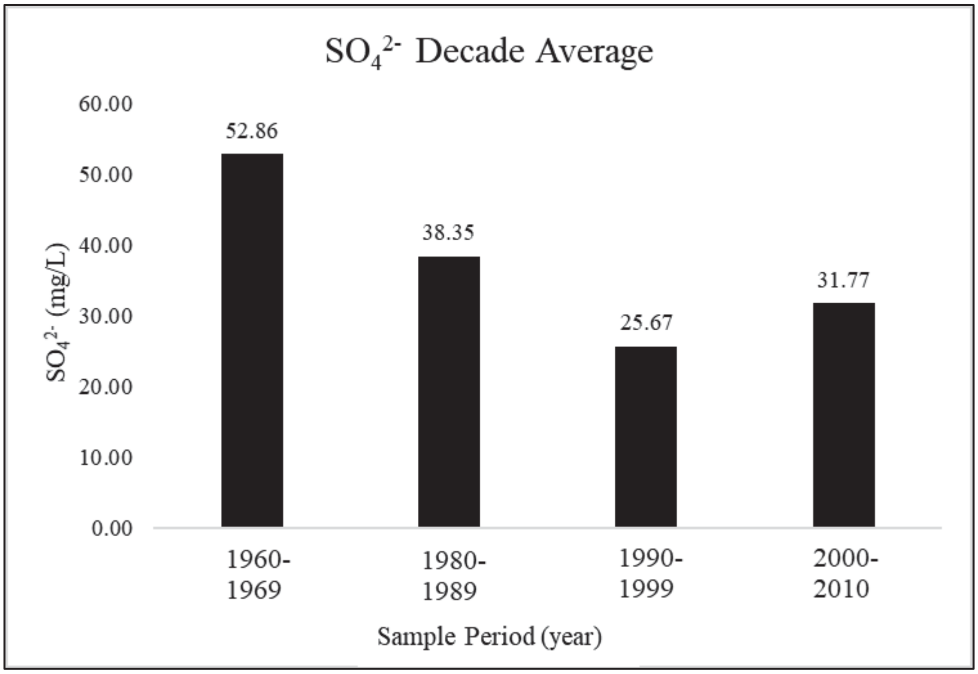


Figure 10e. Sulfate ion concentration average for each decade from 1960-2010 in the Upper Passaic River Basin, New Jersey (1970s excluded due to lack of data).

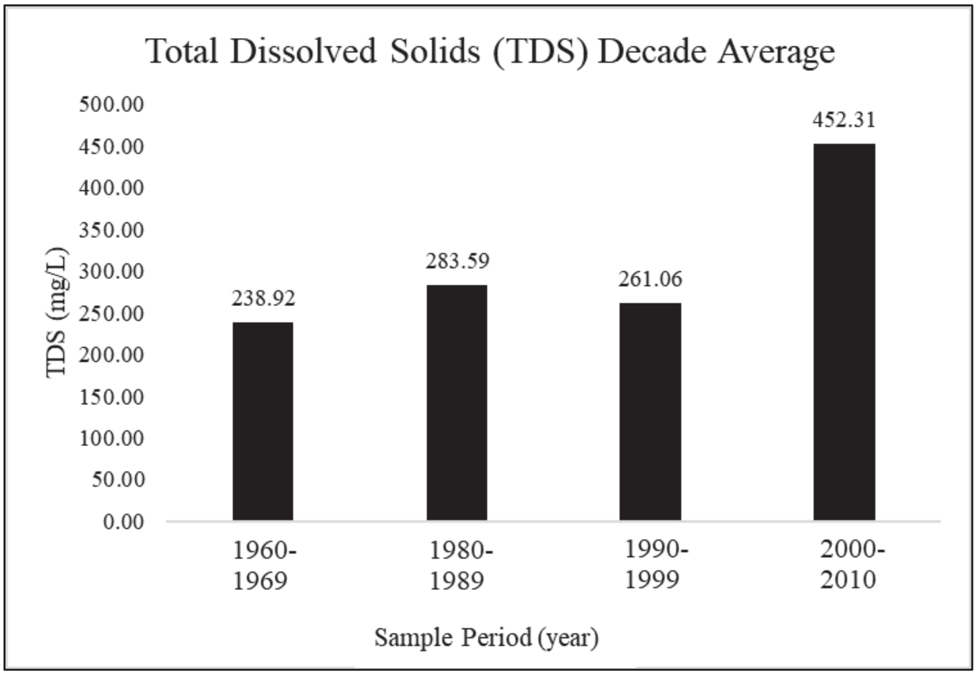


Figure 10f. Total dissolved solids concentration average for each decade from 1960-2010 in the Upper Passaic River Basin (1970s excluded due to lack of data).

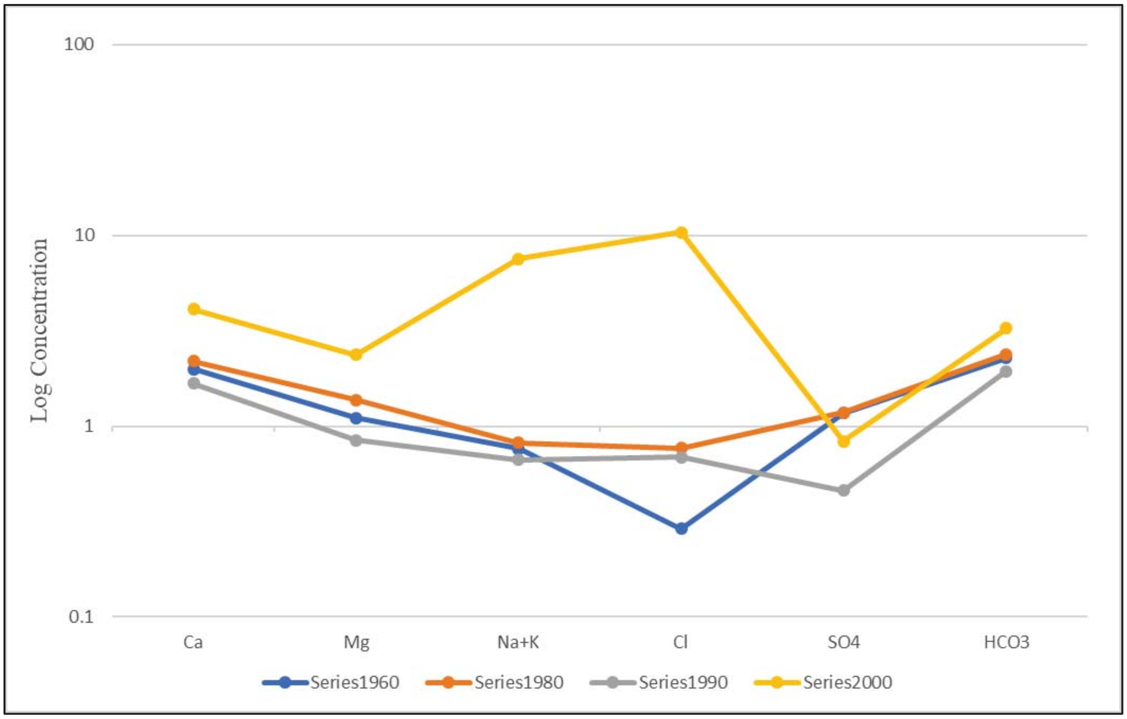


Figure 11. A Schoeller diagram depicting log concentrations of major ions for the 1960s, 1980s, 1990s and 2000s in the Upper Passaic River Basin, New Jersey.

4.3 Groundwater Species

Figure 12a shows the ionic composition of the UPRB groundwater samples from 1960-1969, dictating a clear freshwater classification. The diamond plot shows the water species is dominated by $Ca(HCO_3)_2$, representative of the upper zone, early in the natural evolution process. Figure 12b shows the progression of the composition in the 1980-1989 sample period. Influenced by an increased flux of Cl^-, a transition from a $Ca(HCO_3)_2$ dominated water species to a $Ca(HCO_3)_2$ + Cl^- species is seen. The change would indicate older water in terms of evolution, while the corresponding TDS continues to indicate freshwater. The piper diagram for 1990-1999 shows the water composition reverts to a single $Ca(HCO_3)_2$ species (Figure 12c), likely due to sample distribution being more significant in the metamorphic region of the UPRB. Figure 12d portrays the data set for 2000-2010, depicting an allocation of two contrasting groundwater species, $Ca(HCO_3)_2$ and NaCl. It can be deduced from these observations that the NaCl water species is an external component to the natural $Ca(HCO_3)_2$ dominant groundwater composition. The presence of the two varying dominant species is due to the contrasting geology of the UPRB. Specifically, the $Ca(HCO_3)_2$ species is representative of the metamorphic region. No chance in composition is seen due to the bedrocks low permeable nature. Contrastingly, the NaCl species shows that the groundwater samples in the sedimentary bedrock are reflective of external influences of Na^+ and Cl^- in the groundwater system. Throughout the sample period the average TDS remains below 1000 mg/L. Therefore, the groundwater for the UPRB is classified as freshwater, and in a natural setting should not show the observed levels of NaCl.

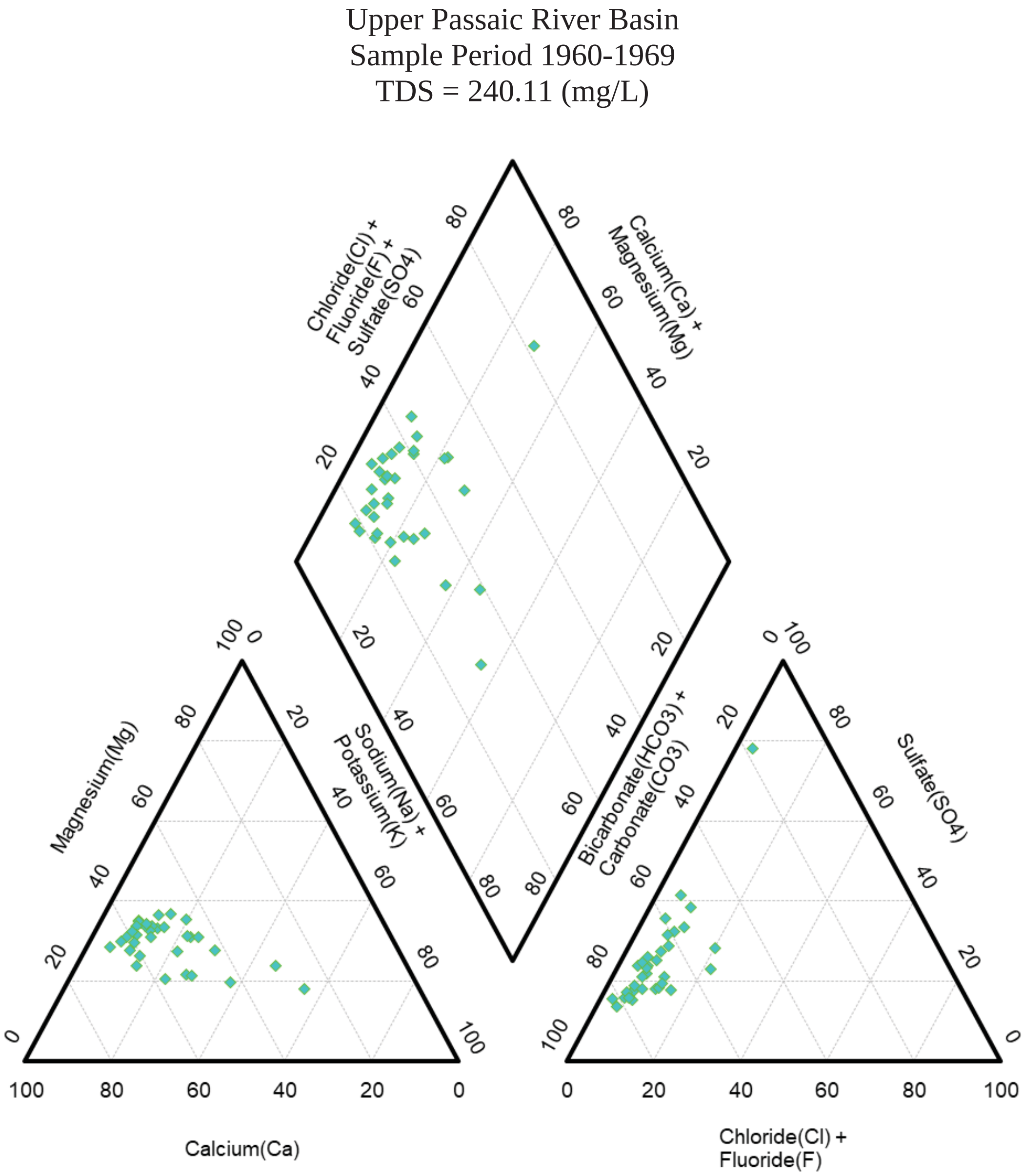


Figure 12a. Piper diagram showing ionic composition of groundwater samples from 1960-1969 in the Upper Passaic River Basin, New jersey.

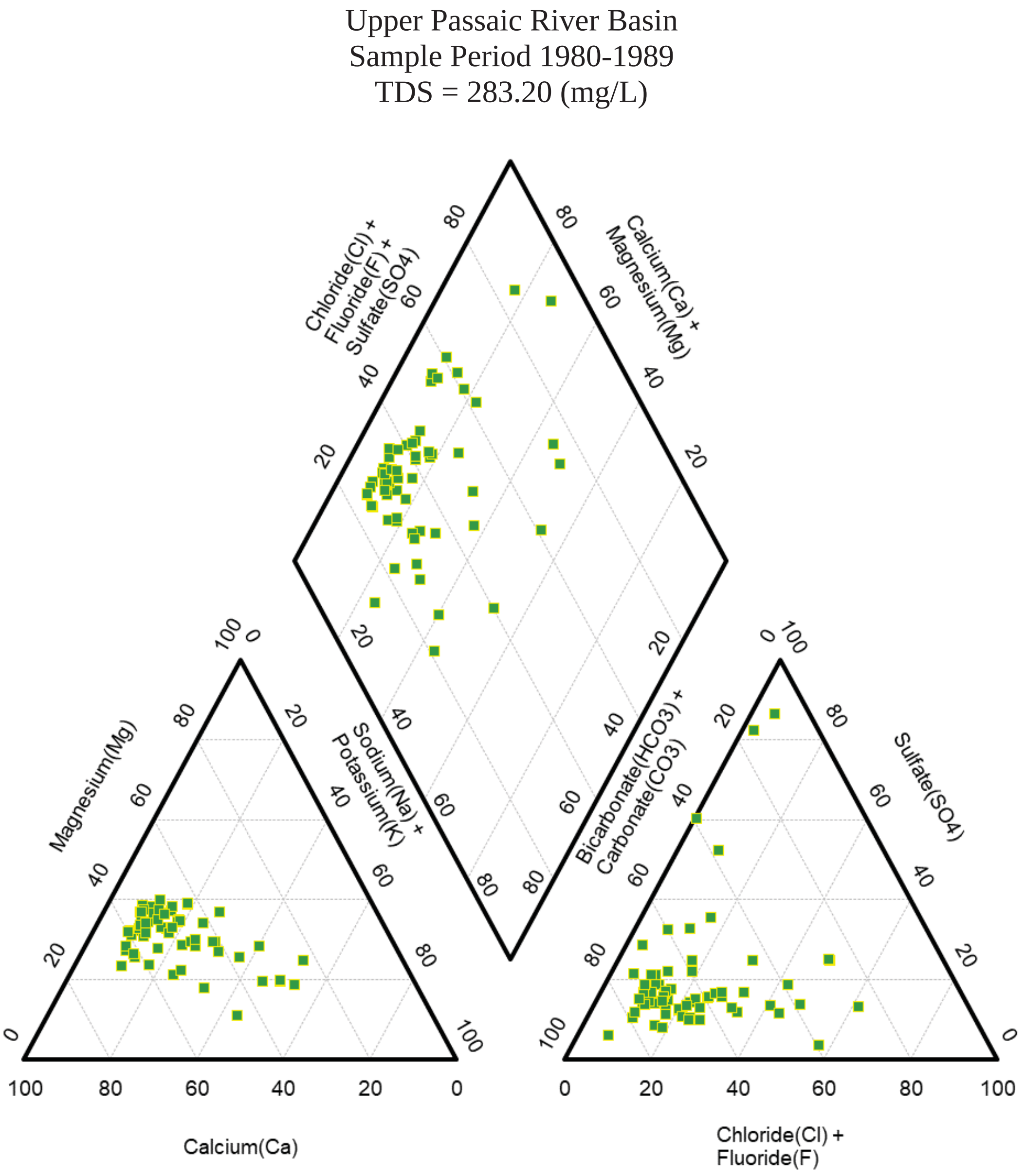


Figure 12b. Piper diagram showing ionic composition of groundwater samples from 1980-1989 in the Upper Passaic River Basin, New jersey.

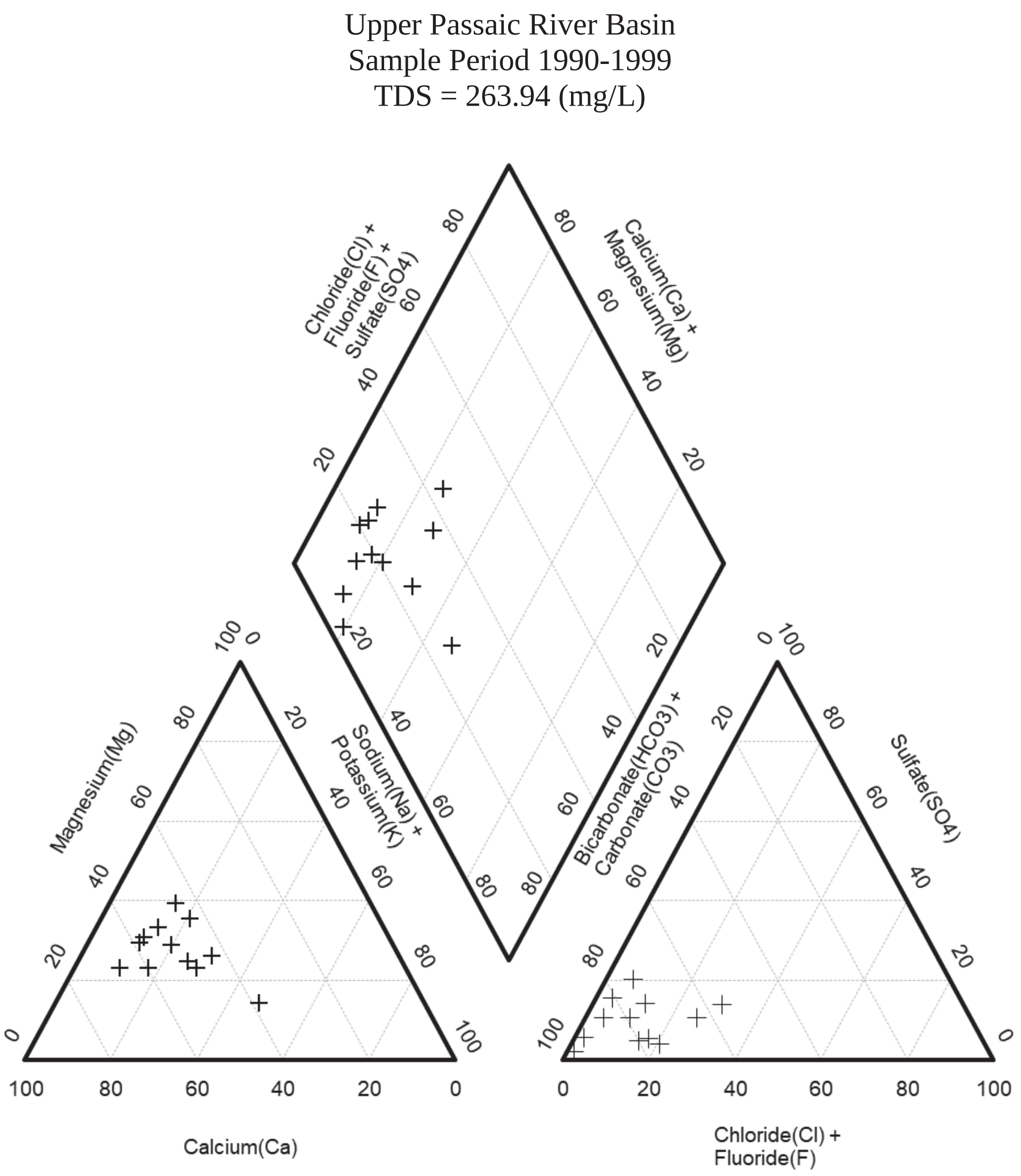


Figure 12c. Piper diagram showing ionic composition of groundwater samples from 1990-1999 in the Upper Passaic River Basin, New jersey.

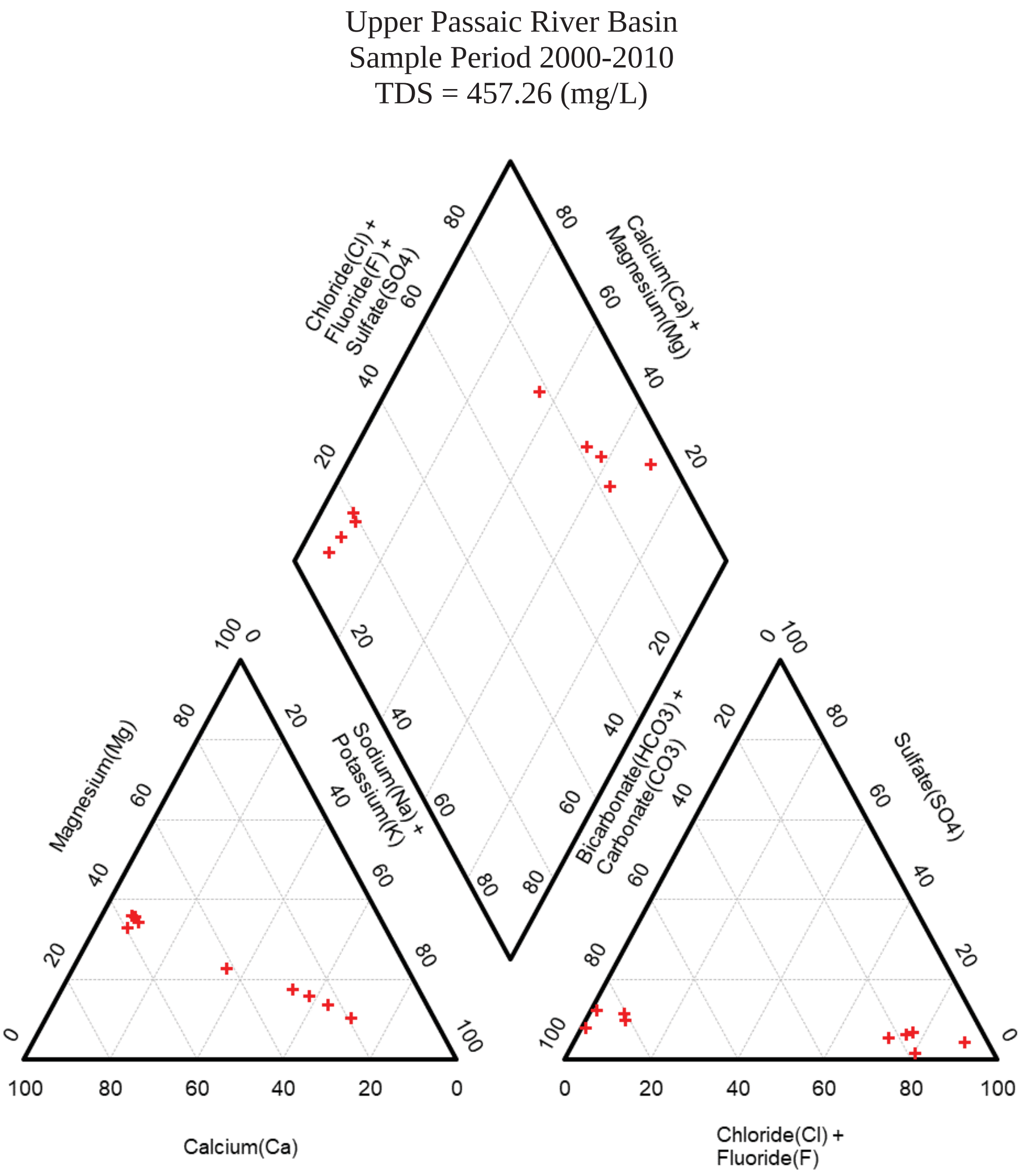
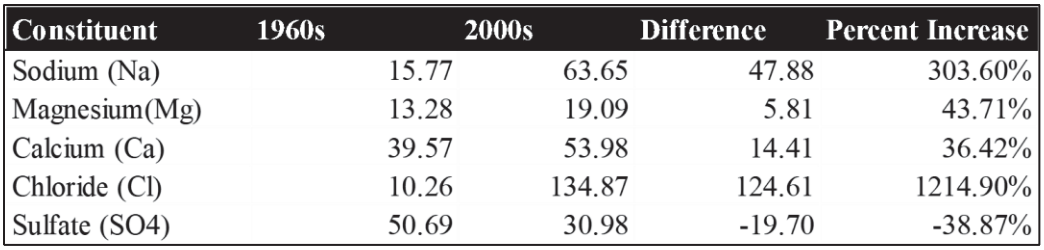


Figure 12d. Piper diagram showing ionic composition of groundwater samples from 2000-2010 in the Upper Passaic River Basin, New jersey.

4.4 95% Prediction Interval Analysis

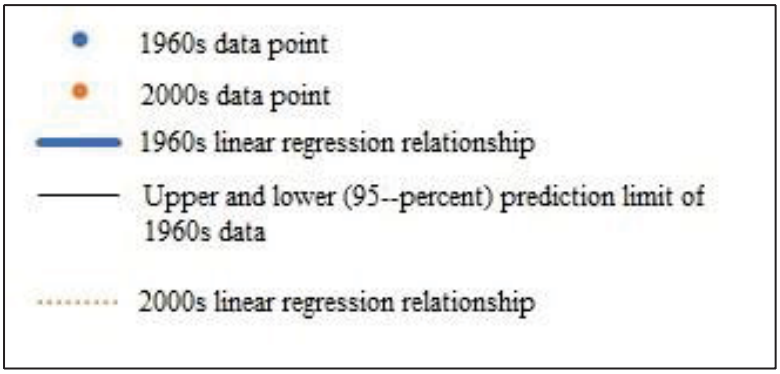
Table 5 shows the averages for the 1960-1969 and 2000-2010 measured sample sets, along with their difference and percent fluctuations. Chloride expresses the most notable change over time (Figure 13a) with an overall increase of 1,215%. Similarly to Cl^-, Na^+ increases at a substantial rate, with a percent increase of 304% (Figure 13b). Mg^{2+} and Ca^{2+} also show an overall increase of 44 and 36%, respectively. Although Mg^{2+} and Ca^{2+} increase, it is at a rate slower than originally predicted (Figures 13c and 13d show Mg^{2+} and Ca^{2+} 95% Prediction intervals). SO_4^{2-} is the only ion that does not reflect increase over time; instead a 39% decrease was calculated (Figure 13e). The analysis of 95% prediction intervals confirm that Na^+ and Cl^- increase at a statistically significant rate, more so than Mg^{2+}, Ca^{2+} and SO_4^{2-}, indicating an external influx of Na^+ and Cl^-.

Table 5. Calculated mean of major ion concentration for the Upper Passaic River Basin, New Jersey (concentrations in mg/L).



Constituent	1960s	2000s	Difference	Percent Increase
Sodium (Na)	15.77	63.65	47.88	303.60%
Magnesium(Mg)	13.28	19.09	5.81	43.71%
Calcium (Ca)	39.57	53.98	14.41	36.42%
Chloride (Cl)	10.26	134.87	124.61	1214.90%
Sulfate (SO4)	50.69	30.98	-19.70	-38.87%

Legend



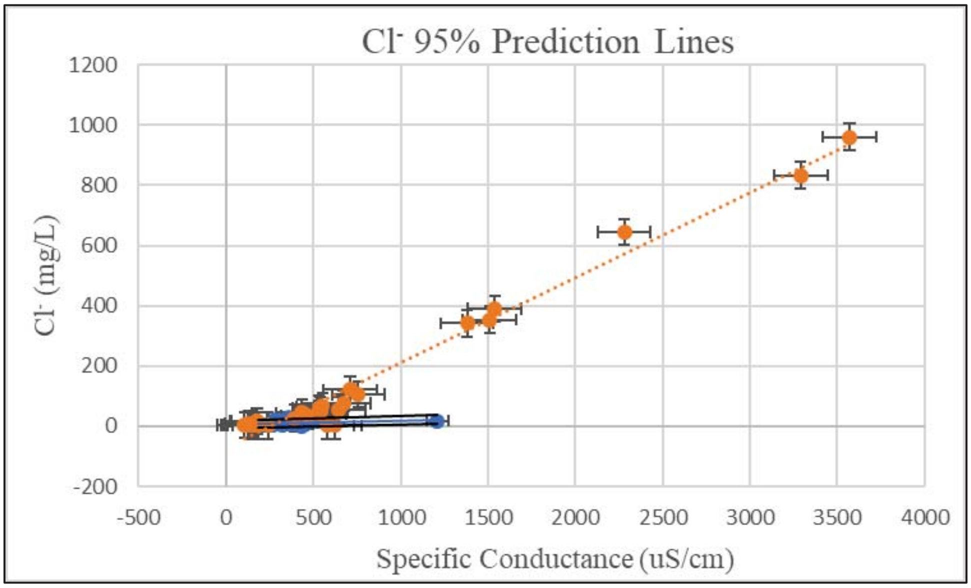


Figure 13a. Relationship between chloride and specific conductance for 1960s and 2000s data sets.

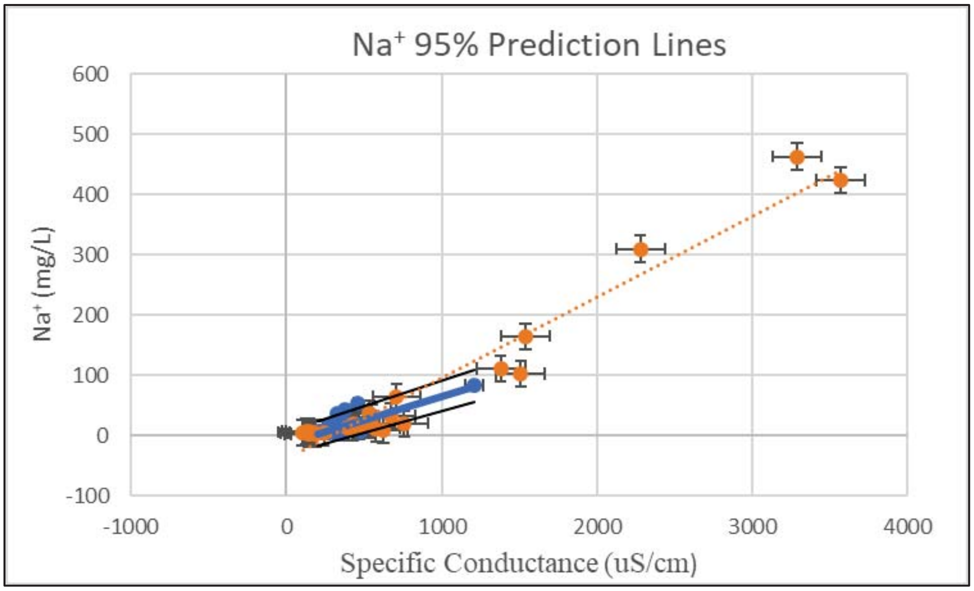


Figure 13b. Relationship between sodium and specific conductance for 1960s and 2000s data sets.

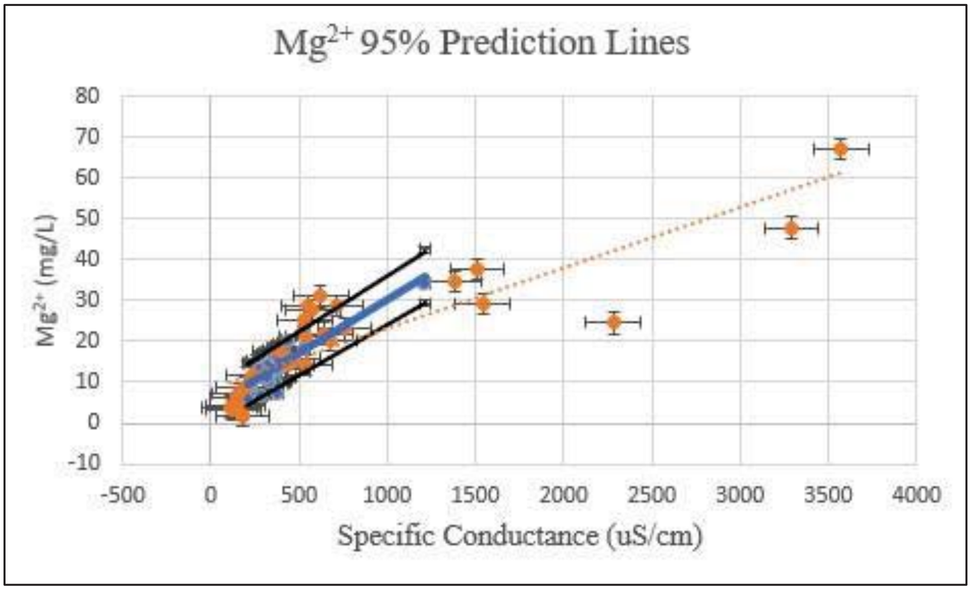


Figure 13c. Relationship between magnesium and specific conductance for 1960s and 2000s data sets.

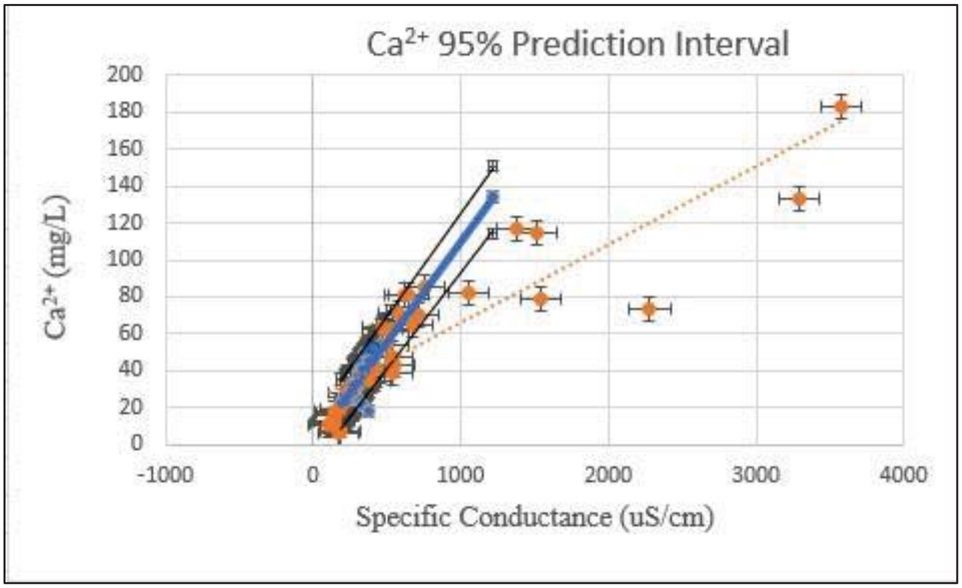


Figure 13d. Relationship between calcium and specific conductance for 1960s and 2000s data sets.

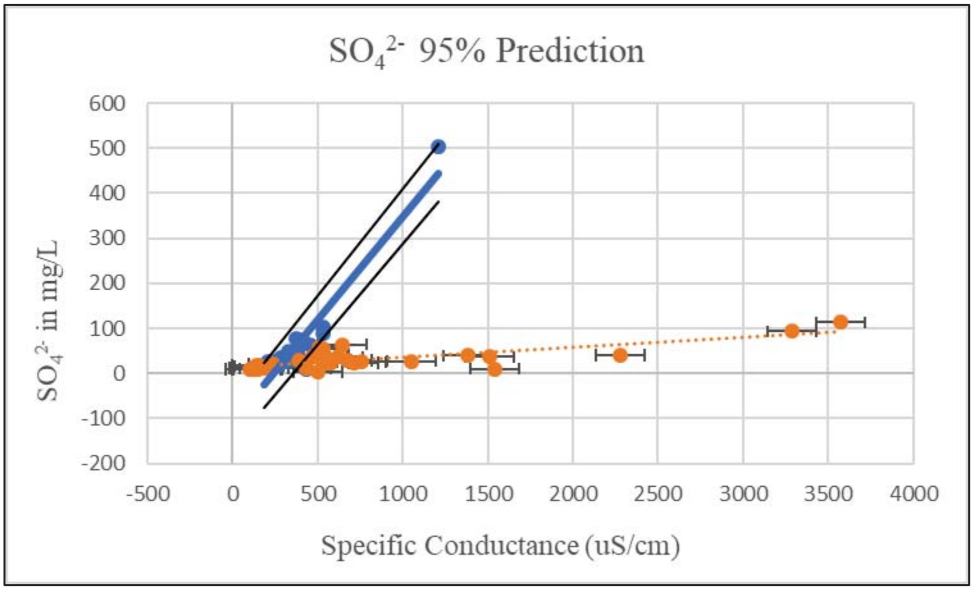


Figure 13e. Relationship between sulfate and specific conductance for 1960s and 2000s data sets.

4.5 Potentiometric and Ionic Concentration Maps

The ionic concentration maps provide a unique graphic on the changing dynamics of the groundwater system. By applying a contour system similar to what is commonly seen in hydraulic head analysis (Figures 14a – 14e), a visual representation of the ionic values is formulated. Figures 15a – 15e show concentrations throughout the UPRB in the 1960-1969 sample period. Notable trends include increased ionic concentrations being generally linear with lower hydraulic flow, indicating flow influences ionic patterns. Figures 16a – 16e show the ionic patterns for the 1980-1989 sample period. High concentration points can be observed in the northwestern and southeastern sections of the study area. Due to universal road cover and a high-variance in geologic underlay, it is unclear to the nature of the high concentration zones. It is hypothesized that due to the geographic and geologic nature of the specific regions recharge and discharge zones a relationship is likely prevalent in relation to high and low concentration areas. Figures 17a – 17e and 18a – 18e show concentration maps for 1990-1999 and 2000-2010 respectively. Similar trends are seen in both concentration maps.

5. Discussion

5.1 Impact of Deicing in the UPRB

By using a combination of geostatistical analysis and hydrochemical interpretation based on groundwater composition data, a strong understanding of groundwater alteration was obtained. The following was found to be true for the Upper Passaic River Basin.

1. Chlorides are an increasingly significant contributor to TDS over time and have increased at rates that would insinuate anthropogenic influence.

2. Sodium and chloride in the freshwater composition increase at rates that are not observed with other major ions.
3. Sodium vs chloride correlations increase over time, indicating a sole source is responsible for increases in concentrations.
4. Sodium and chloride show no correlation with other major ions commonly found in groundwater such as calcium and magnesium, indicating the main supplier are not from the same source. Therefore, sodium and chloride are likely from an external source.
5. Piper diagrams show a change in ionic composition over time that does not match natural groundwater evolution in a freshwater system, indicating external influence of NaCl.

5.2 SO_4^{2-} Trends from 1960 to 2010

A notable trend observed after data analysis was complete was the unprecedented drop in SO_4^{2-} concentrations. In most cases SO_4^{2-} concentrations in groundwater are linked to sulfide minerals such as gypsum, organic decomposition and influences from atmospheric SO_4^{2-} levels (Miao et al., 2011). In this case, it is hypothesized that the major decline in sulfate concentrations is directly related to sulfate atmospheric deposition. Sulfur dioxide (SO_2) emissions, through oxidation, are the main influencer on SO_4^{2-} levels in groundwater composition. SO_2 emissions have been in steady decline for the past half-century (National Atmospheric Deposition Program, 2018). The decrease in SO_2 emissions may be directly attributed to U.S environmental policies such as the EPA's Acid Rain Program, enforcing strict regulations on SO_2 producing power plants (Sulfur Dioxide Trends, 2017). The environmental policies enforced have led to a universal decrease in SO_2 emissions and SO_4^{2-} concentrations in groundwater samples throughout the northeastern United States.

5.3 Ionic Concentrations in the 1990s

An almost universal dip in ionic concentrations for the 1990-2000 data set is evident, only Cl^- continues to increase. Due to the sizeable amount of data for the 1990s, this isn't likely to be a data anomaly but rather a prominent physical variance. This is likely due to spatial distribution of the 1990-2000 well sites. The 1990-2000 data set has a sizable portion of sample sites in the northwestern metamorphic and igneous region of the UPRB, while the other data sets are more evenly distributed throughout the basin. The northwestern region is underlined by igneous and metaphoric bedrock, meaning permeability and porosity are lower than in sedimentary basins. Therefore, due to allocation of well sites being mainly in regions of low permeability and porosity, which have low storage capacity, ionic concentrations measurements are lower.

5.4 Inconsistencies

It is important to note that the data collected for this study is prone to significant spatial variability. While 573 well samples were recorded throughout the study period, the same wells were not continually sampled for each decade. As a result, the spatial distribution of the data set differs for each decade. This can be misleading when doing a direct comparison with various datasets. Inconsistences also arise when comparing the number of sample sites for each decade, the 1980s and 1990s sample periods had considerably more samples then the 1960s and 2000s. In relation, some sample sites were outliers and could easily skew results, specifically if the data samples were smaller. Outliers were included in the data set with an assumption that the unusually high TDS could be explained by an area difference in deicing amounts or variability in geologic influence.

6. Conclusion

In conclusion, it’s clear that application of NaCl for road deicing has had a significant impact on groundwater composition over time. The Upper Passaic River Basin is a heavily salted watershed management area because of the high density of roads and urban development. Increases in population and road mileage over the past 50 years have led to increases in road salt application rates not only in Northern New Jersey, but the United States in general. This impact can be seen in the groundwater quality of the UPRB.

Sodium and chloride correlations show that the most substantial supplier of NaCl is being produced from the same source. These correlations increase in strength over time, corresponding with increased rates from NaCl deicing application. Additional regression analysis indicates that the presence of Ca^{2+} does not show significant association with Na^+ and Cl^-, indicating separate origins and likely ruling out NaCl influence from natural sources. Furthermore, the statistically significant increase seen in Na^+ and Cl^- levels occur over a 50-year period, not on geologic timescales. In addition, the increasing bivariate correlation between Na^+ and Cl^- from 1960 to 2010 supports the hypothesis that Na^+ and Cl^- are originating from the same source. Therefore, the contamination of Na and Cl^- can be directly related with rates of deicing application. Piper analyses show that the groundwater is of a freshwater species, evident by TDS below 1000 mg/L and the predominant $Ca(HCO_3)_2$ composition. By the 2000-2010 sample period, the ionic composition shows a mix of $Ca(HCO_3)_2$ and NaCl predominant species. The predominant species can be attributed to both deicing and the geologic variation in setting of the UPRB. The $Ca(HCO_3)_2$ species is a result of groundwater samples in the metamorphic region, the composition stays consistent due to the low permeable nature of the setting. Contrarily, the NaCl species is representative of the sedimentary basin, showing an increased presence of NaCl in the system due to the high permeability of the setting allowing for seepage of deicing material into the groundwater system, resulting in an observable shift in composition. As a result, the geologic setting of the UPRB likely plays a significant role in the degree of contamination caused by deicing material.

While not as pronounced, evidence of potential $CaCl_2$ contamination can be seen in the correlation between calcium and chloride for the 2000-2010 sample period. Potential evidence of $CaCl_2$ influence can also be inferred by piper analysis and decade-averaged statistical analysis, by observing the change in composition and increases in concentrations of Ca^{2+} and Cl^-. While $CaCl_2$ application is significantly less prominent than NaCl, it is still a relevant deicing material commonly used in the UPRB.

The analysis of deicing application is of significance to better the understanding of anthropogenic influence on regional groundwater quality. Deicing groundwater analysis can identify regions that are prone to contamination due to deicing amount or geologic setting. In relation, better environment management techniques can be developed and implemented based on results of regional studies.

Future studies on groundwater composition in the UPRB should focus on framing a more complete picture, potentially incorporating 3D modeling to identify direct geologic and anthropogenic sources of ions. Ideally, the UPRB should be classified in two segments based on bedrock, this would allow for more accurate predictions due to clear assumptions based on sedimentary or metamorphic setting. Finally, a groundwater composition study using more consistent data would increase the accuracy of any geostatistical or hydrochemical analysis performed in the UPRB.

Literature Cited

Alley, W. M., 1993. *Regional ground-water quality*. New York: Van Nostrand Reinhold.

Anderson, W. Peter & Faust, D. Samuel., 1973. *Characteristics of Water Quality and Streamflow, Passaic River Basin Above Little Falls, New Jersey*. Retrieved from https://pubs.er.usgs.gov/ [Accessed 3 Dec 2018].

Bedrock Geologic Map of Northern New Jersey, Drake, Avery A. Jr., Volkert, Richard, A., Monteverde, Donald H., Herman, Gregory C., Houghton, Hugh F., Parker, Ronald A., and Dalton, Richard F., 1996, Scale 1 to 100,000, 4 cross sections, 2 sheets, size 56x40; 58x41. Map I-2540-A. Bedrock Geologic Map of Central and Southern New Jersey, Owens, James P., Sugarman, Peter J., Sohl, Norman F., Parker, Ronald A., Houghton, Hugh F., Volkert, Richard A., Drake, Avery A., Jr., and Orndorff, Randall C., 1998. Scale 1 to 100,000, 8 cross sections, 4 sheets, each size 58x41, I-2540-B

Czarnik, S. Teresa & Kozinski, Jane., 1994. *Groundwater Quality in The Central Part of The Passaic River Basin, Northeastern New Jersey, 1959-88*. Retrieved from https://pubs.er.usgs.gov/ [Accessed 3 Dec 2018]

Chebotarev I., 1955 *Metamorphism of Natural Waters in the Crust of Weathering*. Geochimica et Cosmochimica Acta, 8, 137-170

Corsi, S. R., Graczyk, D. J., Geis, S. W., Booth, N. L., & Richards, K. D., 2010. *A fresh look at road salt: aquatic toxicity and water-quality impacts on local, regional, and national scales*. Environmental science & technology, 44(19), 7376-7382.

Dalton, R.F., Herman, G.C., Monteverde, D.H., Pristas, R.S., Sugarman, P.J., and Volkert, R.A., 1999, New Jersey Department of Environmental Protection, Bedrock Geology and Topographic Base Maps of New Jersey: New Jersey Geological Survey CD Series CD 00-1; ARC/INFO (v. 7.1), scale 1: 100,000.

Dennis J. Low, Daniel J. Hippe, and Dawna Yannacci., 2002. *Geohydrology of Southeastern Pennsylvania.* U.S. Department of the Interior and U.S. Geological Survey.

Earle, Steven., 2015. *Physical Geology*. BC Campus.

Fetter, C. W., 2014. *Applied Hydrogeology*. 4th ed., Pearson Education Limited.

Freeze, Roy Allan, and John A Cherry., 1979 *Groundwater*. Prentice-Hall.

Foos, A., 2003. *Spatial distribution of road salt contamination of natural springs and seeps, Cuyahoga Falls, Ohio, USA*. Environmental Geology, 44(1), 14-19.

Godwin, K. S., Hafner, S. D., & Buff, M. F., 2003. *Long-term trends in sodium and chloride in the Mohawk River, New York: the effect of fifty years of road-salt application*. Environmental pollution, 124(2), 273-281.

Howard, K. W., & Haynes, J., 1993. *Groundwater contamination due to road de-icing chemicals—salt balance implications*. Geoscience Canada, 20(1).

Ismail Chenini, Boutheina Farhat & Abdallah Ben Mammou., 2010. *Identification of major sources controlling groundwater chemistry from a multilayered aquifer system*, Chemical Speciation & Bioavailability, 22:3, 183-189, DOI: 10.3184/095422910X12829228276711

Kelly, T.D., and Matos, G.R., comps., 2014, *Historical statistics for mineral and material commodities in the United States* (2016 version): U.S. Geological Survey Data Series 140, Retrieved from https://minerals.usgs.gov/minerals/pubs/historical-statistics/. [Accessed 21 Sep 2018]

Kelly, V.R., Findlay, S.E.G., Schlesinger, W.H., Chatrchyan, A.M., Menking, K., 2010. *Road Salt: Moving Toward the Solution*. The Cary Institute of Ecosystem Studies.

Kuemmel, D., and Hanbali, R., 1992. *Accident analysis of ice control operations*. Marquette University Department of Civil, Construction and Environmental Engineering. Milwaukee, WI

Kutner, M. H., Neter, J., Nachtsheim, C. J., Li, William., 2005, *Applied Linear Statistical Models, Fifth Edition*. McGraw – Hill Irwin.

Ludlum, David M., 1983. *The New Jersey Weather Book*. Rutgers University Press, New Brunswick.

Miao, Z., Brusseau, M. L., Carroll, K. C., Carreón-Diazconti, C., & Johnson, B., 2011. *Sulfate reduction in groundwater: characterization and applications for remediation*. Environmental geochemistry and health, 34(4), 539-50.

National Atmospheric Deposition Program (NRSP-3)., 2018. NADP Program Office, Wisconsin State Laboratory of Hygiene, 465 Henry Mall, Madison, WI 53706.

National Climatic Data Center., 2018. NOAA's 1981-2010 Climate Normals.

New Jersey Bureau of GIS., 2018. Retrieved from https://www.state.nj.us/dep/gis/stateshp.html [Accessed 12 Sep 2018]

New Jersey Year to Date Precipitation Departures., 2018. National Oceanic and Atmospheric Administration. Retrieved from https://www.weather.gov/marfc/Precipitation_Departures [Accessed 5 Nov 2018]

New Jersey Geographic Information Network. *Road Centerlines of New Jersey, New Jersey State Plane NAD83*. Published by Patrick McDonald, Published 01/25/2017

New Jersey Department of Environmental Protection., 2012. *Watershed Restoration.* Retrieved from: https://www.nj.gov/dep/watershedrestoration/wma6_info.html [Accessed 3 Nov 2018]

New Jersey Department of Environmental Protection., 2007 retrieved from: www.state.nj.us/dep/njgs/geodata/index.html [Accessed 3 Nov 2018]

New Jersey Department of Transportation., 2018. *Winter Readiness, Expenditures, About NJDOT*. [online] State.nj.us. Available at: https://www.state.nj.us/transportation/about/winter/expenditures.shtm [Accessed 1 Nov. 2018].

NIST/SEMATECH e-Handbook of Statistical Methods., 2003 retrieved from: http://www.itl.nist.gov/div898/handbook/, [Accessed 12 Dec 2018].

N.J. Geological Survey Digital Geodata Series DGS00-2
Compiled by Jeffrey L. Hoffman, March 2000
Trenton, N.J 08625

Olsen, P. E., 1980. *Triassic and Jurassic formations of the Newark Basin*. In Field studies of New Jersey geology and guide to field trips: 52nd annual meeting of the New York State Geological Association, ed. W. Manspeizer

Peters, N., & Turk, J., 1981. *INCREASES IN SODIUM AND CHLORIDE IN THE MOHAWK RIVER, NEW YORK, FROM THE 1950'S TO THE 1970'S ATTRIBUTED TO ROAD SALT*. Journal of The American Water Resources Association, 17(4), 586-598. doi: 10.1111/j.1752-1688. 1981.tb01264.x

Seltman, H. J., 2012. *Experimental design and analysis*. Online at: http://www. stat. cmu. edu/, hseltman/309/Book/Book. pdf.

Sulfur Dioxide Trends | US EPA". *US EPA*, 2017, https://www.epa.gov/air-trends/sulfur-dioxide-trends#sonat [Accessed 6 Nov 2018]

Tollo, R. P., 2004. *Proterozoic tectonic evolution of the Grenville orogen in North America* (Vol. 197). Geological Society of America.

United States Census Bureau., 2015, retrieved from https://planning.morriscountynj.gov/data/ [Accessed 1 Dec 2018]

U.S Climate Data., 2018, retrieved from https://www.usclimatedata.com/climate/new-jersey/united-states/3200 [Accessed 3 Dec 2018]

U.S. Geological Survey., 2016, National Water Information System data available on the World Wide Web (USGS Water Data for the Nation), accessed [2018], at URL [http://waterdata.usgs.gov/nwis/].

United States Geological Survey, Nevada Excel for Hydrology., 2018, retrieved from https://nevada.usgs.gov/tech/excelforhydrology/ [Accessed 18 May 2018]

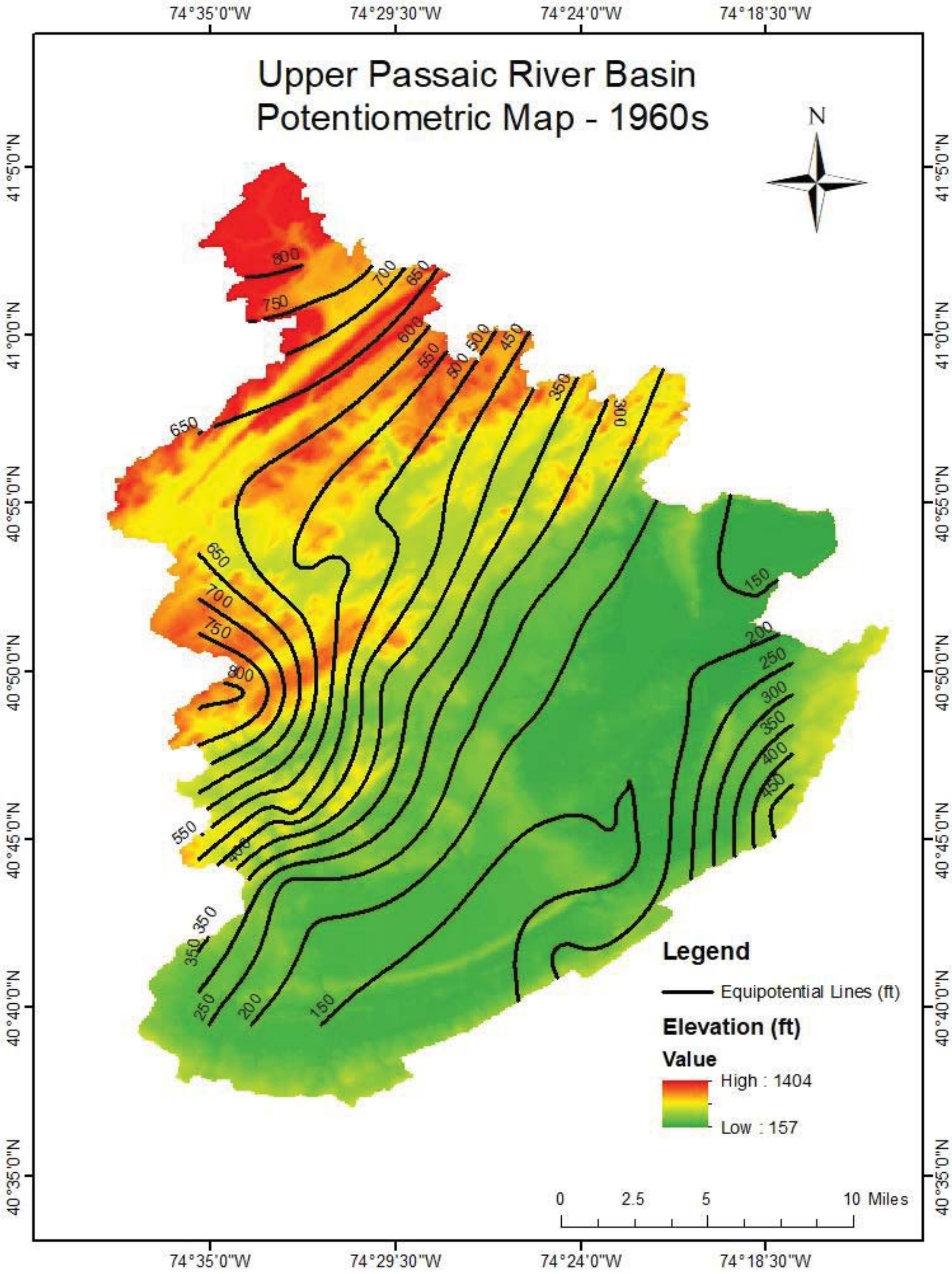


Figure 14a. Upper Passaic River Basin Potentiometric Map for the 1960-1969

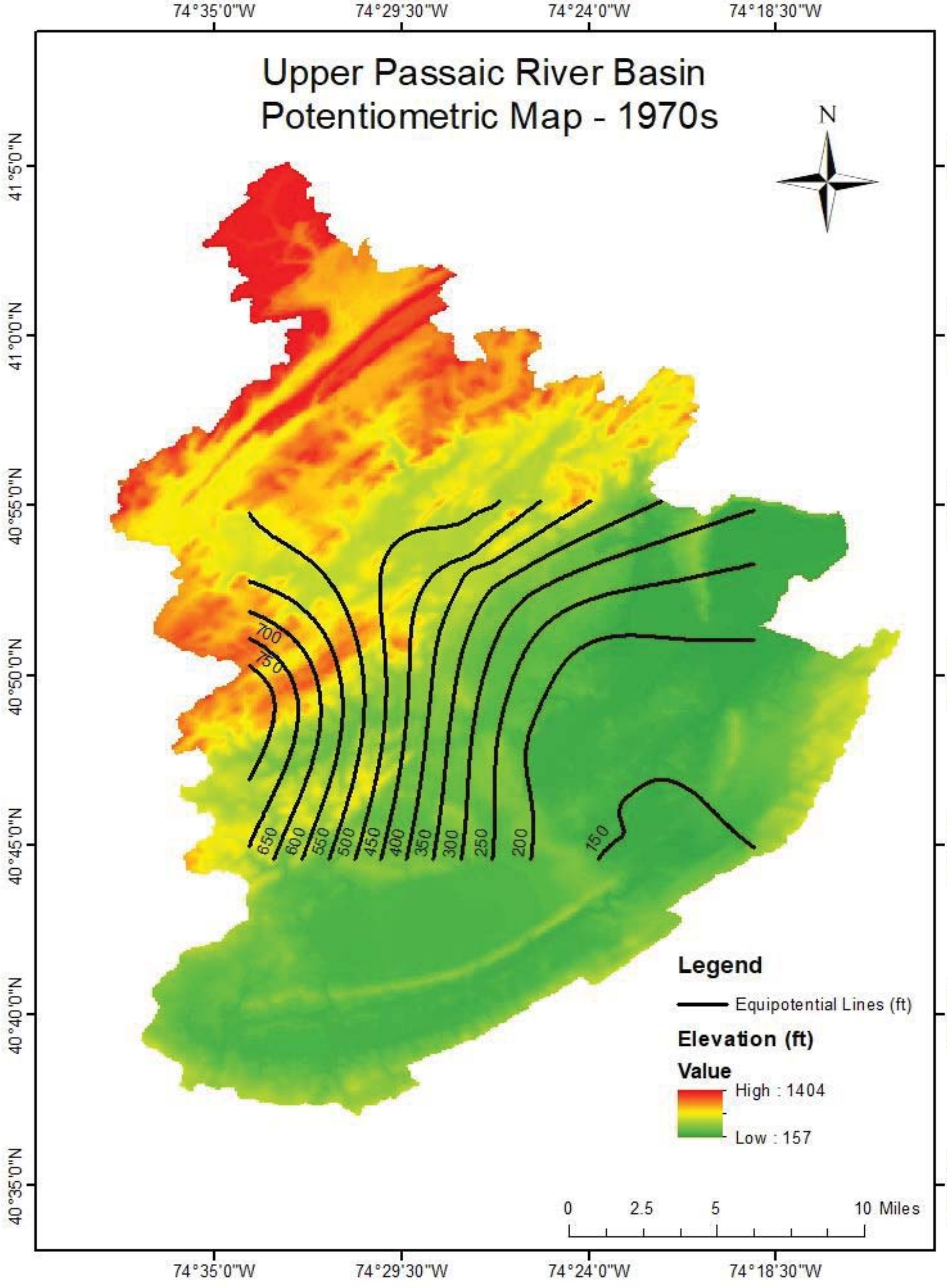


Figure 14b. Upper Passaic River Basin Potentiometric Map for 1970-1979.

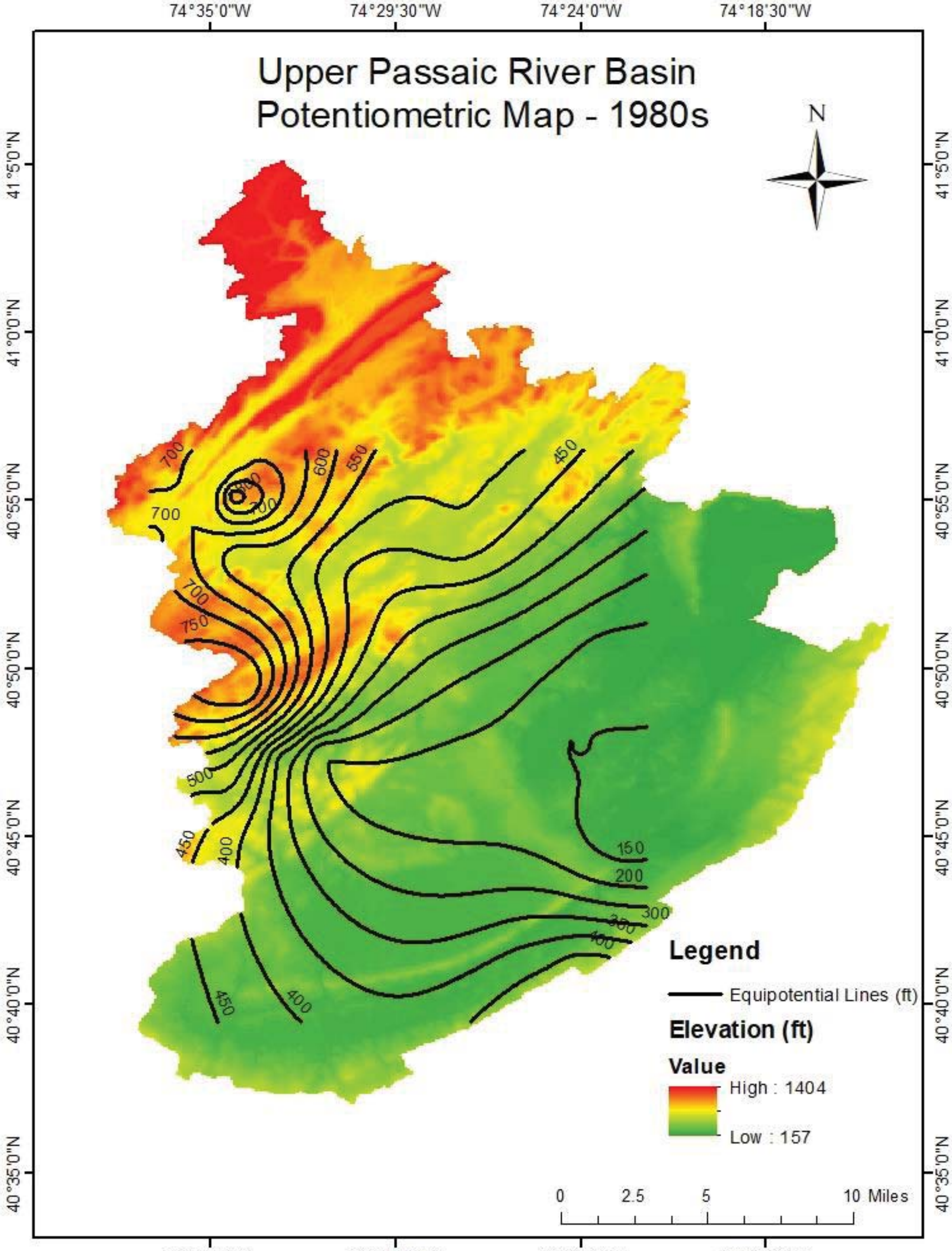


Figure 14c. Upper Passaic River Basin Potentiometric Map for 1980-1989

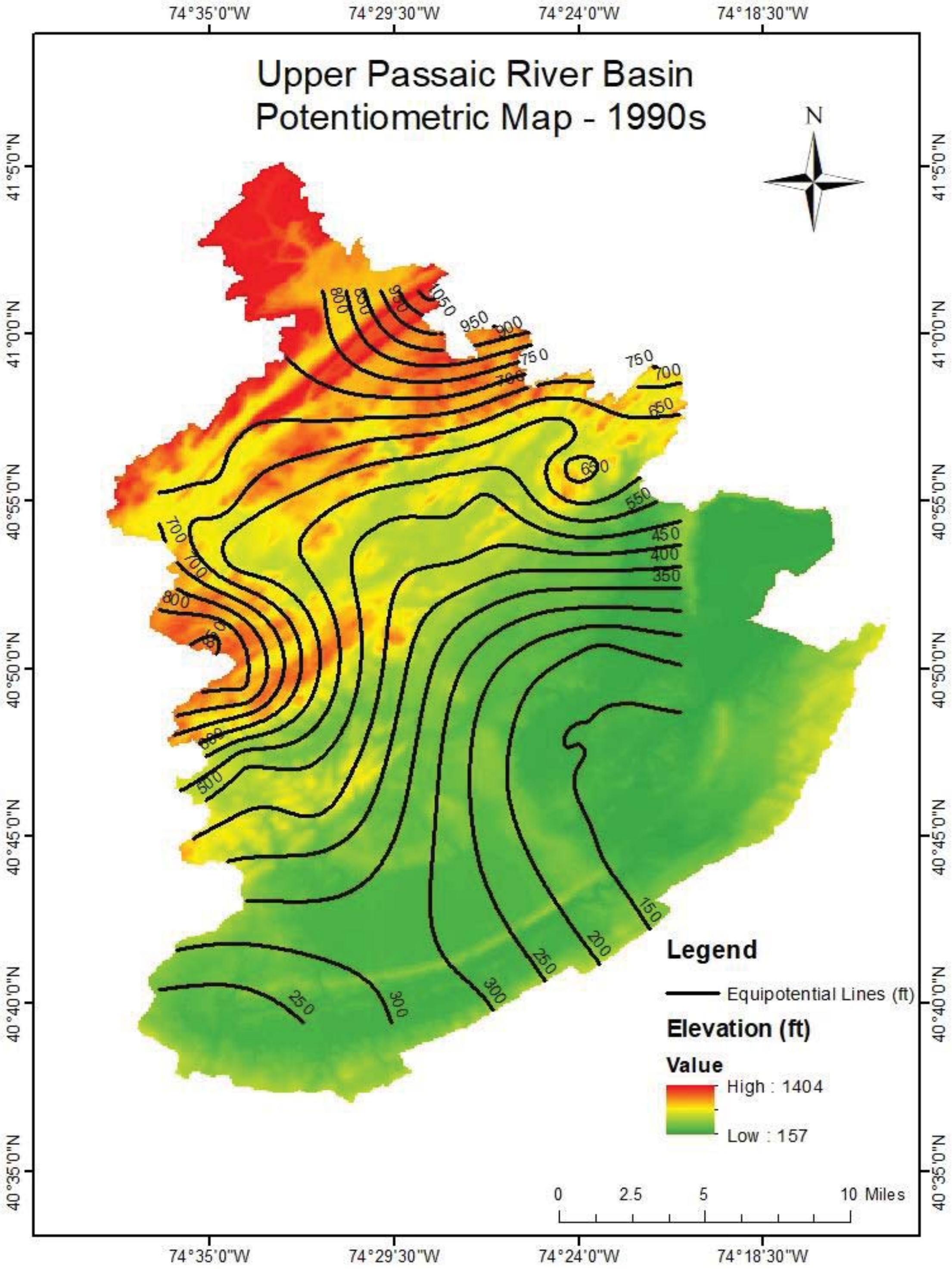


Figure 14d. Upper Passaic River Basin Potentiometric Map for 1990-1999

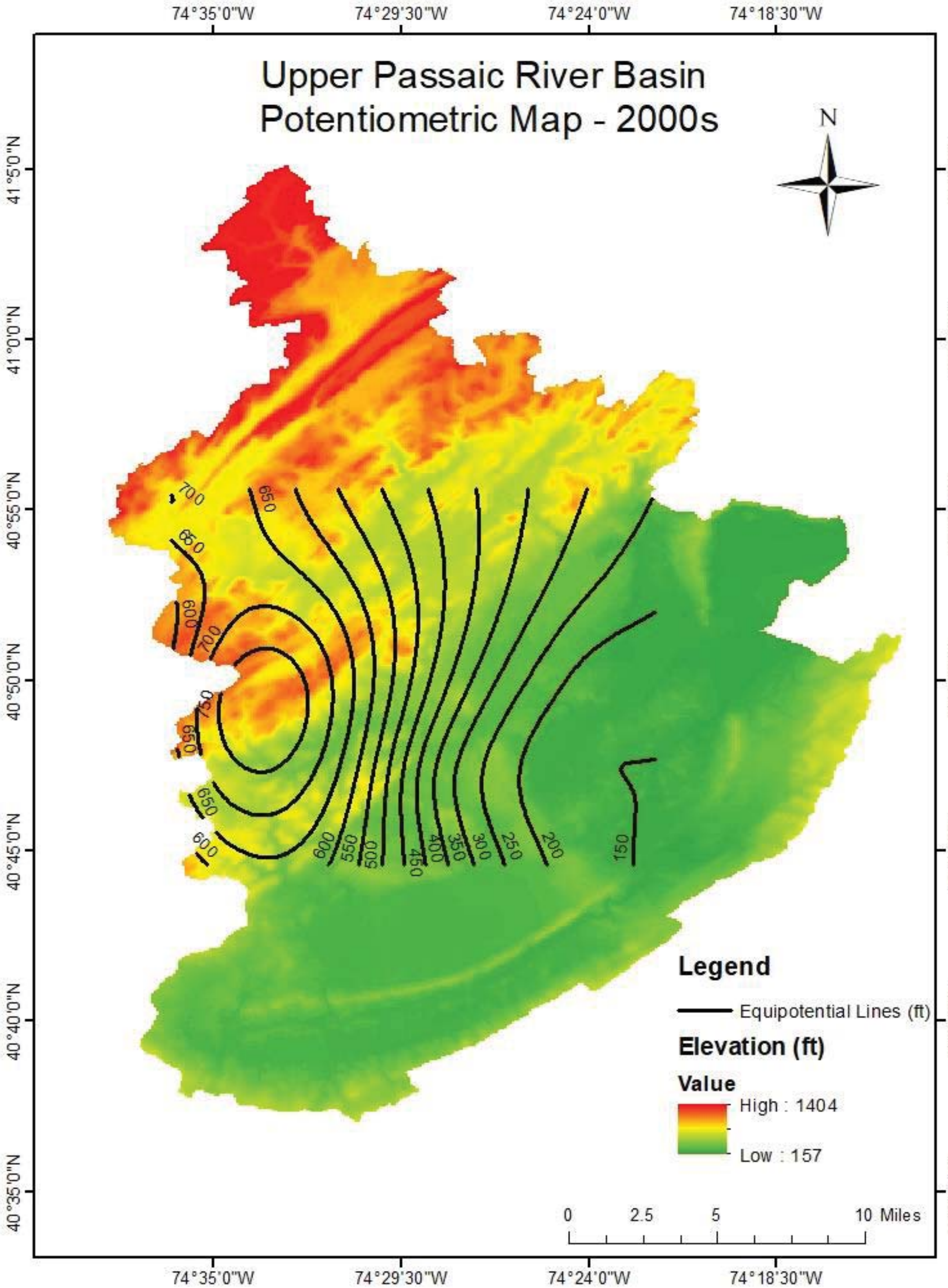


Figure 14e. Upper Passaic River Basin Potentiometric Map for 2000-2010

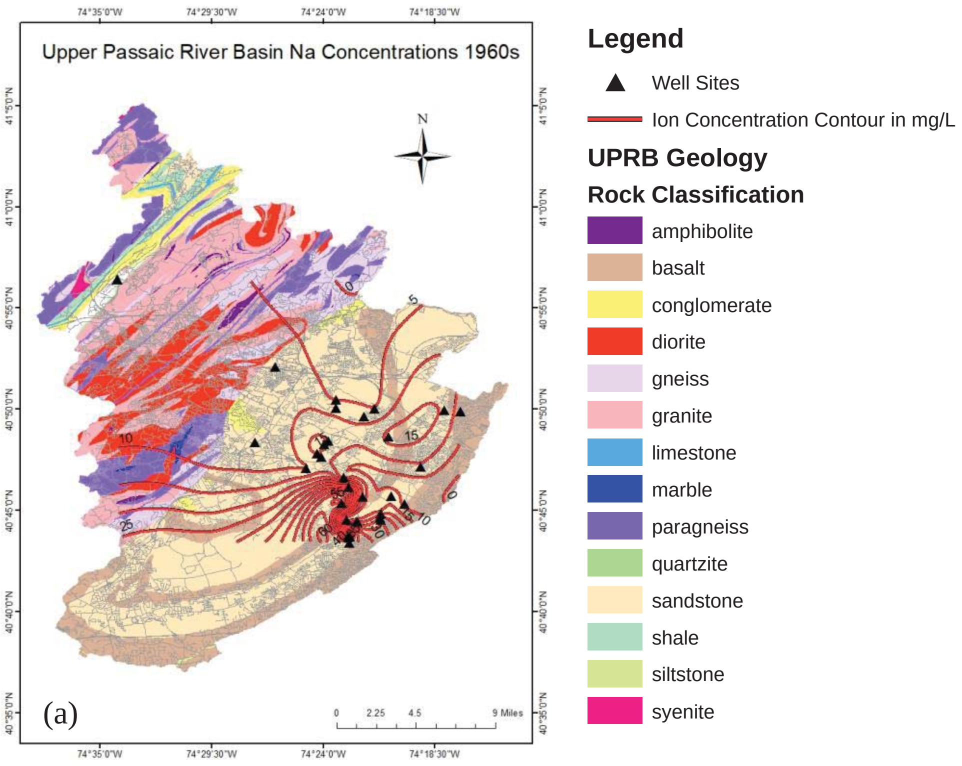
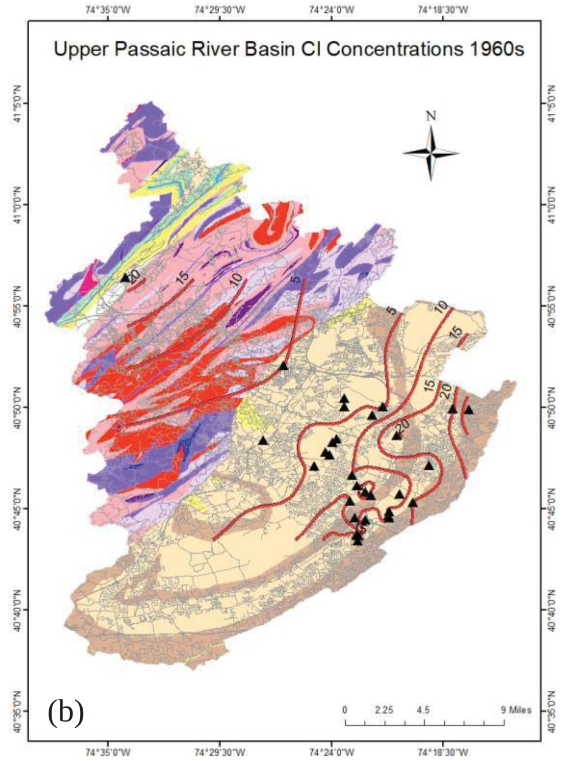
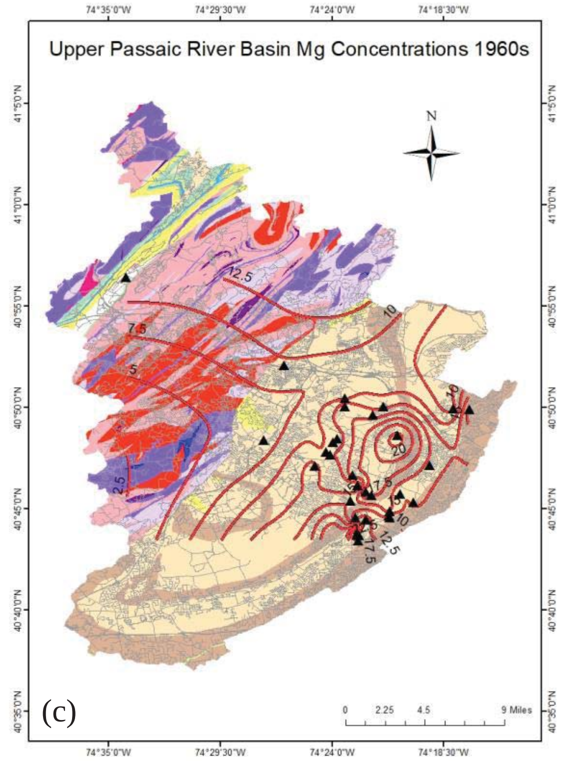
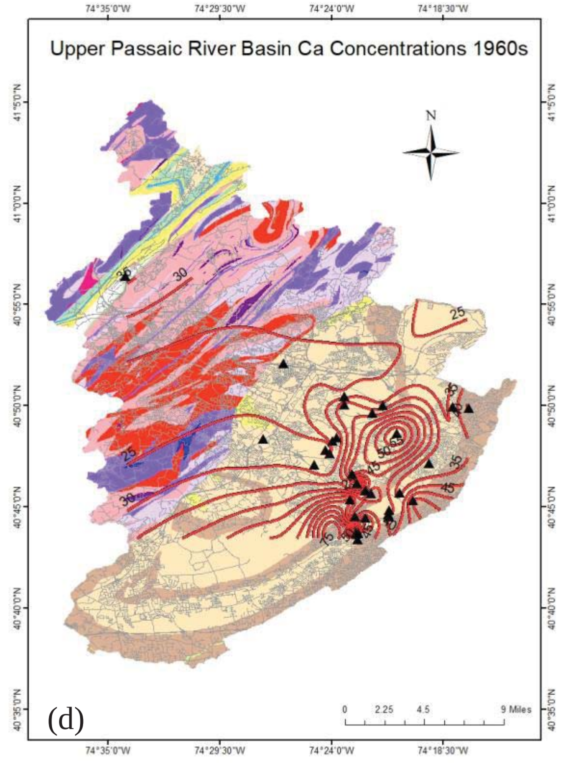
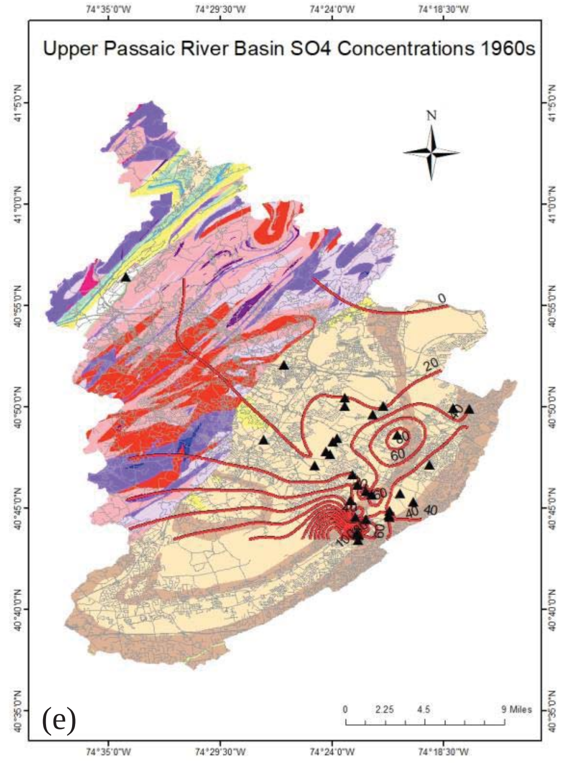


Figure 15a – 15e. Ionic distribution contour map for sodium (a), chloride (b), magnesium (c), calcium (d), and sulfate (e) for 1960-1969.


Upper Passaic River Basin Cl Concentrations 1960s
74°35'0"W
74°29'30"W
74°24'0"W
74°18'30"W
41°5'0"N
41°0'0"N
40°55'0"N
40°50'0"N
40°45'0"N
40°40'0"N
40°35'0"N
N
20
15
10
5
5
10
15
15
20
20
(b)
0
2.25
4.5
9 Miles


Upper Passaic River Basin Mg Concentrations 1960s
74°35'0"W
74°29'30"W
74°24'0"W
74°18'30"W
41°5'0"N
41°0'0"N
40°55'0"N
40°50'0"N
40°45'0"N
40°40'0"N
40°35'0"N
N
12.5
10
7.5
5
2.5
20
10
17.5
12.5
17.5
(c)
0
2.25
4.5
9 Miles


Upper Passaic River Basin Ca Concentrations 1960s
74°35'0"W
74°29'30"W
74°24'0"W
74°18'30"W
41°5'0"N
41°0'0"N
40°55'0"N
40°50'0"N
40°45'0"N
40°40'0"N
40°35'0"N
N
30
30
25
25
30
25
35
50
45
35
45
15
15
(d)
0
2.25
4.5
9 Miles


Upper Passaic River Basin SO4 Concentrations 1960s
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74°29'30"W
74°24'0"W
74°18'30"W
41°5'0"N
41°0'0"N
40°55'0"N
40°50'0"N
40°45'0"N
40°40'0"N
40°35'0"N
N
0
20
40
80
60
60
40
100
80
(e)
0
2.25
4.5
9 Miles

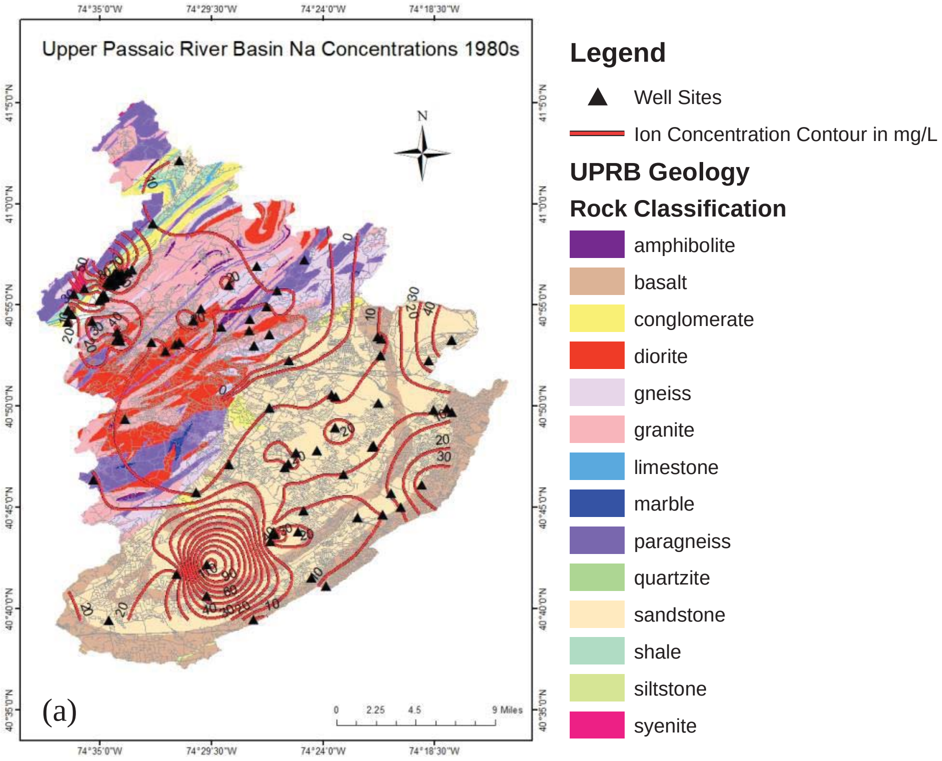
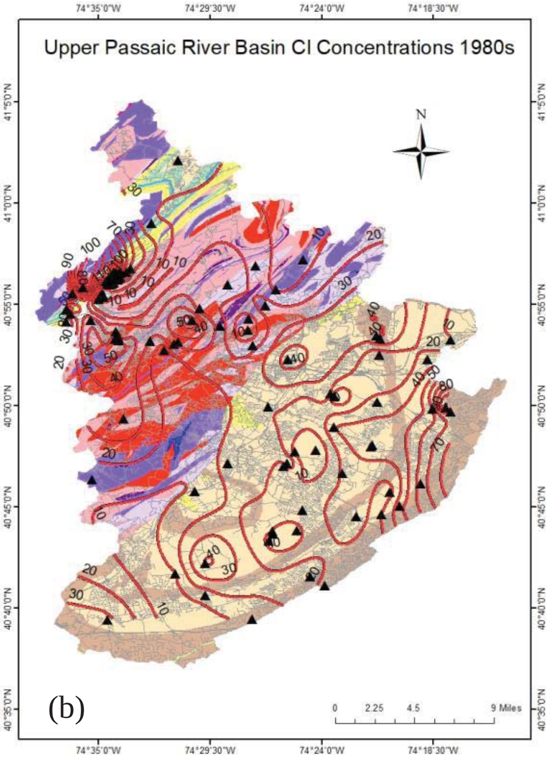
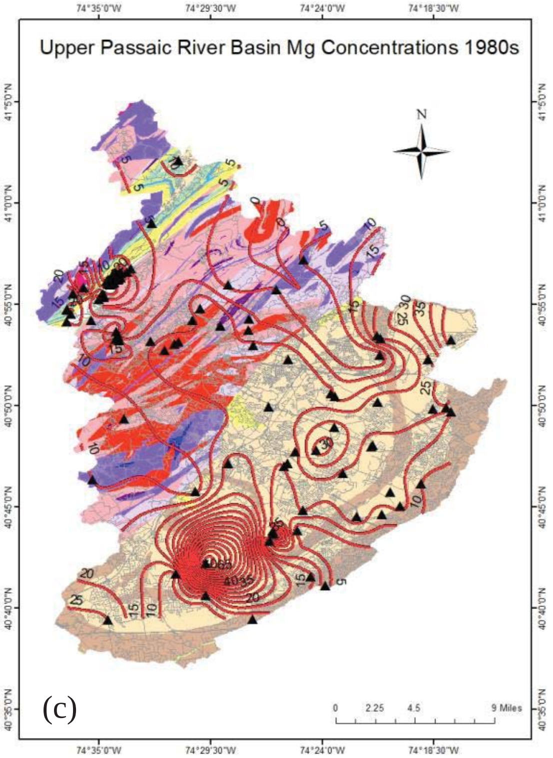


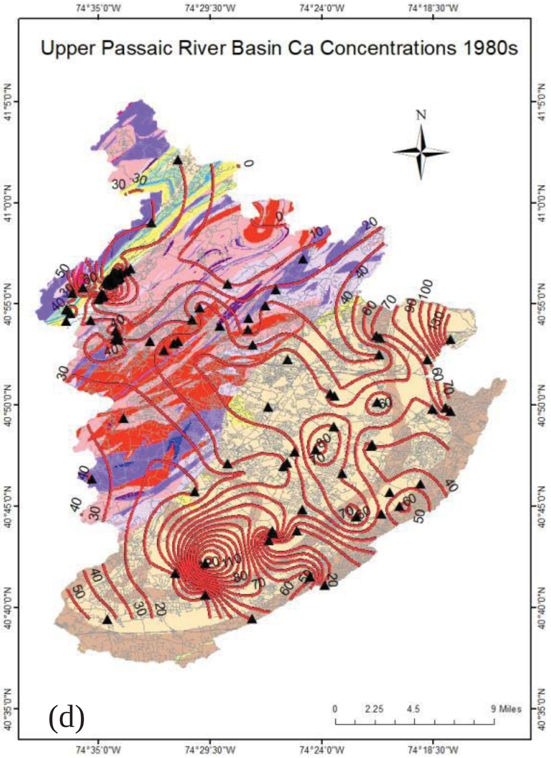
Figure 16a – 16e. Ionic distribution contour map for sodium (a), chloride (b), magnesium (c), calcium (d), and sulfate (e) for 1980-1989.


Upper Passaic River Basin Cl Concentrations 1980s
N
74°35'0"W
74°29'30"W
74°24'0"W
74°18'30"W
41°5'0"N
41°0'0"N
40°55'0"N
40°50'0"N
40°45'0"N
40°40'0"N
40°35'0"N
0
2.25
4.5
9 Miles

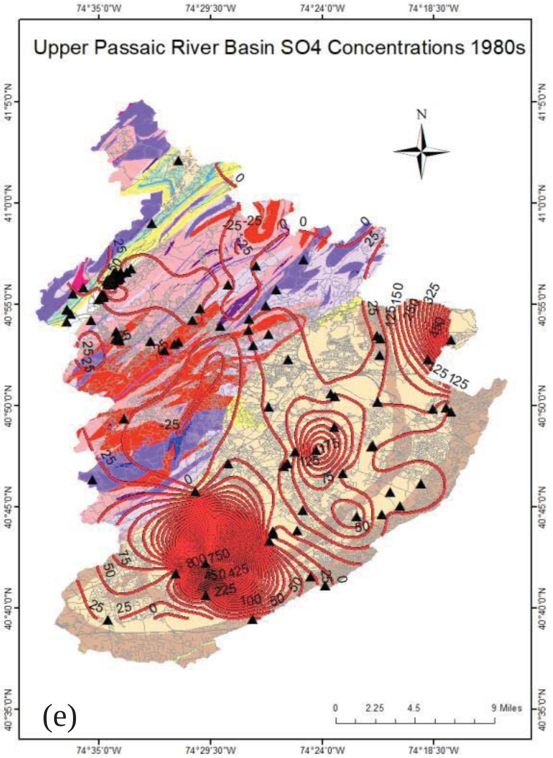
(b)


Upper Passaic River Basin Mg Concentrations 1980s
N
74°35'0"W
74°29'30"W
74°24'0"W
74°18'30"W
41°5'0"N
41°0'0"N
40°55'0"N
40°50'0"N
40°45'0"N
40°40'0"N
40°35'0"N
0
2.25
4.5
9 Miles

(c)


Upper Passaic River Basin Ca Concentrations 1980s
N
74°35'0"W
74°29'30"W
74°24'0"W
74°18'30"W
41°5'0"N
41°0'0"N
40°55'0"N
40°50'0"N
40°45'0"N
40°40'0"N
40°35'0"N
0
2.25
4.5
9 Miles

(d)


Upper Passaic River Basin SO4 Concentrations 1980s
N
74°35'0"W
74°29'30"W
74°24'0"W
74°18'30"W
41°5'0"N
41°0'0"N
40°55'0"N
40°50'0"N
40°45'0"N
40°40'0"N
40°35'0"N
0
2.25
4.5
9 Miles

(e)

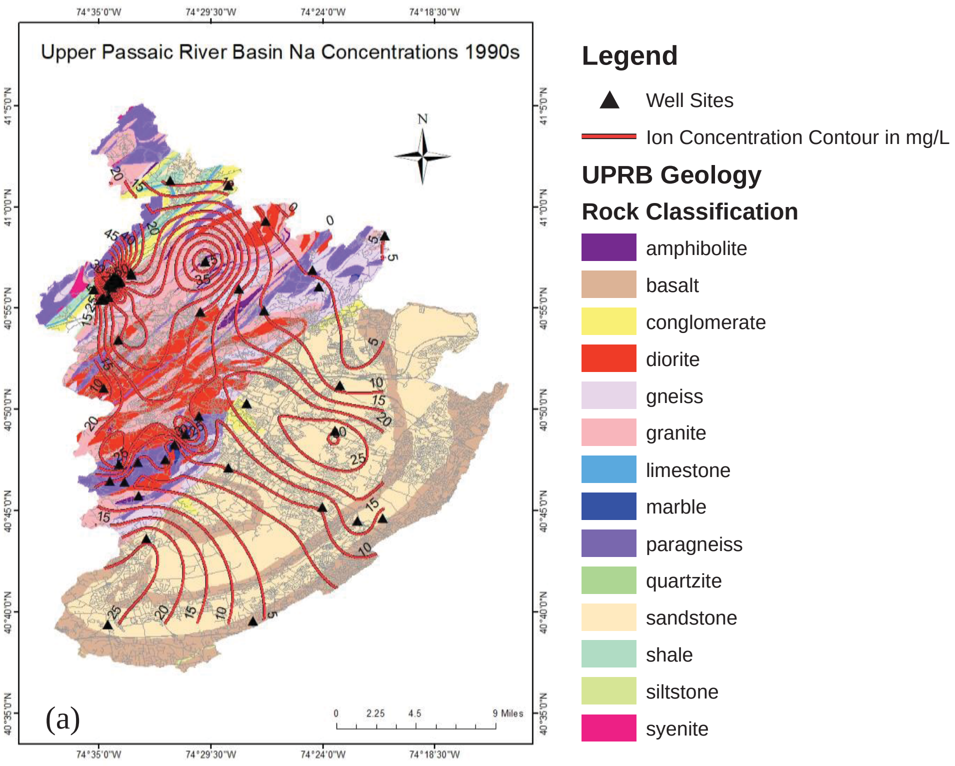
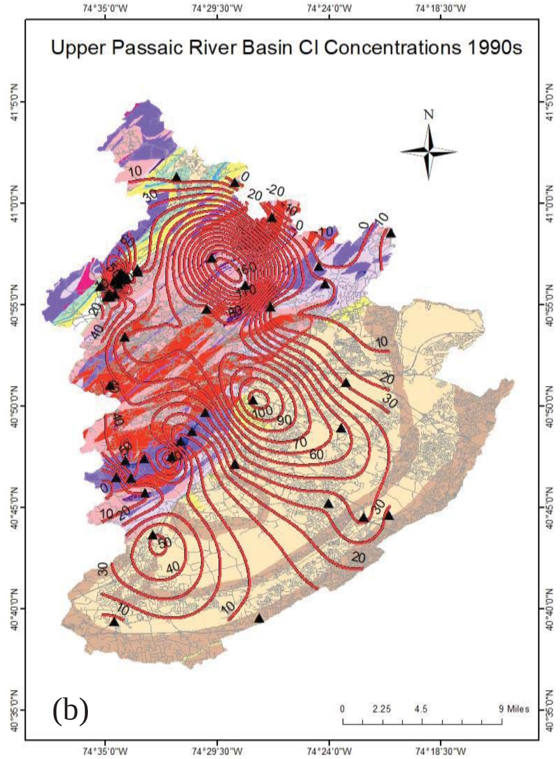
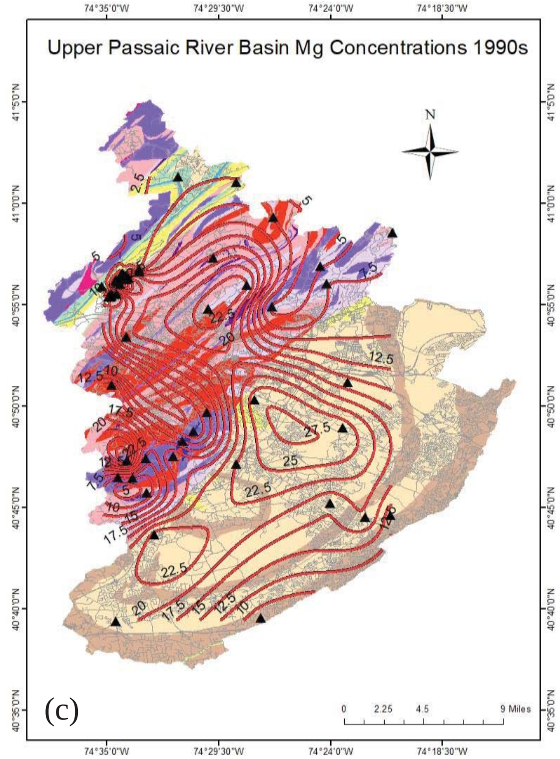
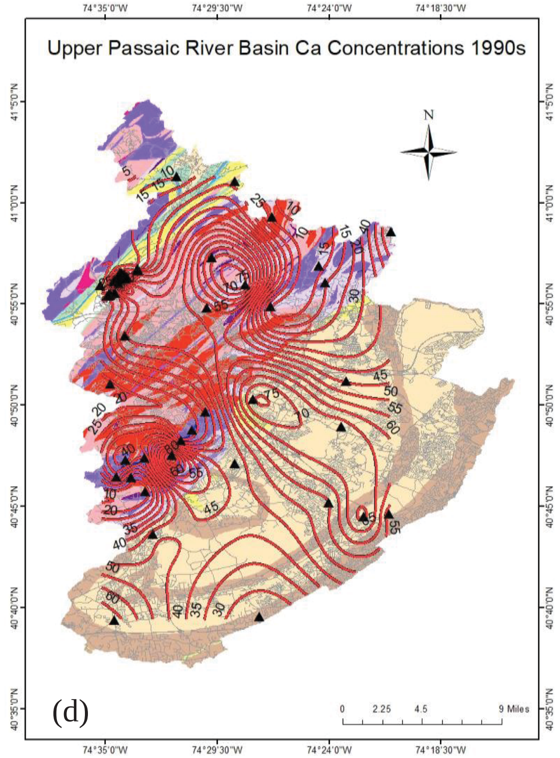
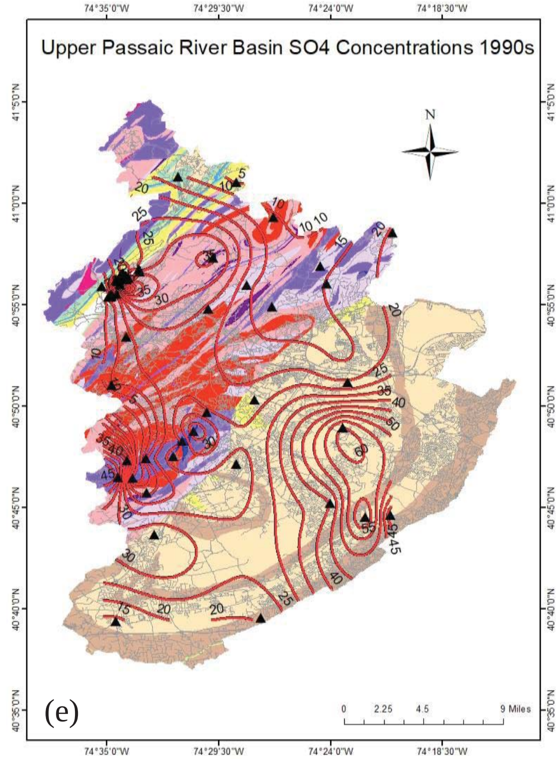


Figure 17a – 17e. Ionic distribution contour map for sodium (a), chloride (b), magnesium (c), calcium (d), and sulfate (e) for 1990-1999.


Upper Passaic River Basin Cl Concentrations 1990s
N
74°35'0"W
74°29'30"W
74°24'0"W
74°18'30"W
41°5'0"N
41°0'0"N
40°55'0"N
40°50'0"N
40°45'0"N
40°40'0"N
40°35'0"N
(b)
0
2.25
4.5
9 Miles


Upper Passaic River Basin Mg Concentrations 1990s
N
74°35'0"W
74°29'30"W
74°24'0"W
74°18'30"W
41°5'0"N
41°0'0"N
40°55'0"N
40°50'0"N
40°45'0"N
40°40'0"N
40°35'0"N
(c)
0
2.25
4.5
9 Miles


Upper Passaic River Basin Ca Concentrations 1990s
N
74°35'0"W
74°29'30"W
74°24'0"W
74°18'30"W
41°5'0"N
41°0'0"N
40°55'0"N
40°50'0"N
40°45'0"N
40°40'0"N
40°35'0"N
(d)
0
2.25
4.5
9 Miles


Upper Passaic River Basin SO4 Concentrations 1990s
N
74°35'0"W
74°29'30"W
74°24'0"W
74°18'30"W
41°5'0"N
41°0'0"N
40°55'0"N
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40°40'0"N
40°35'0"N
(e)
0
2.25
4.5
9 Miles

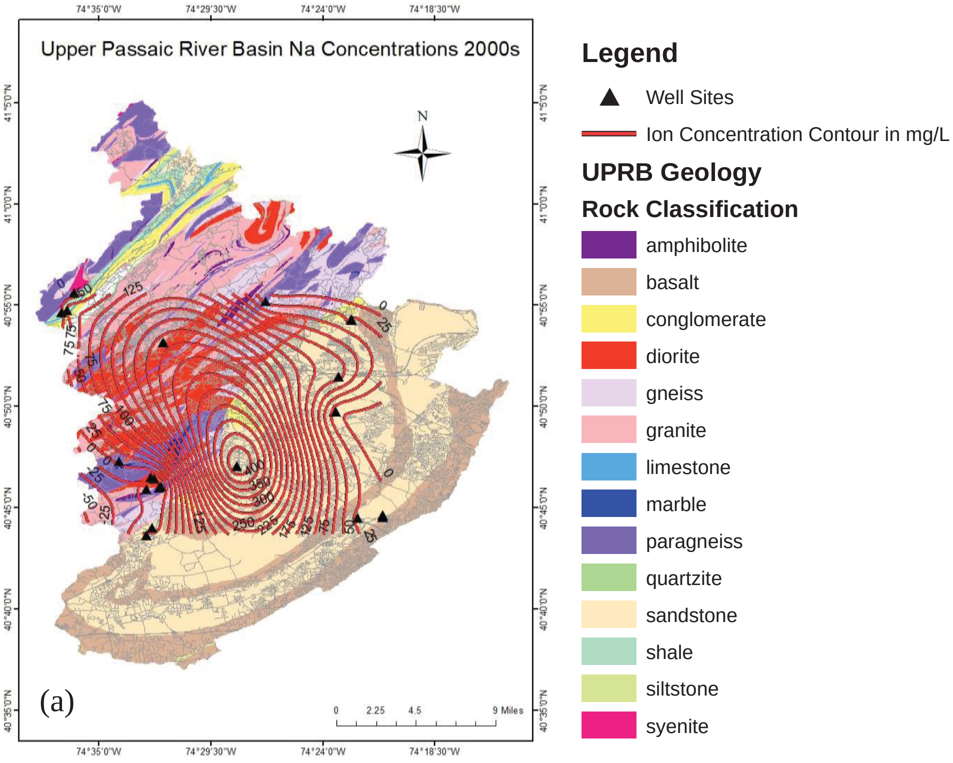
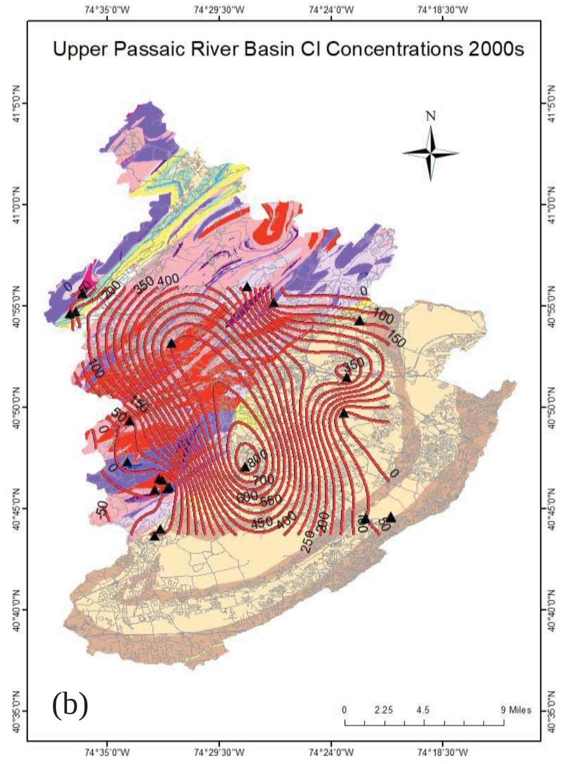
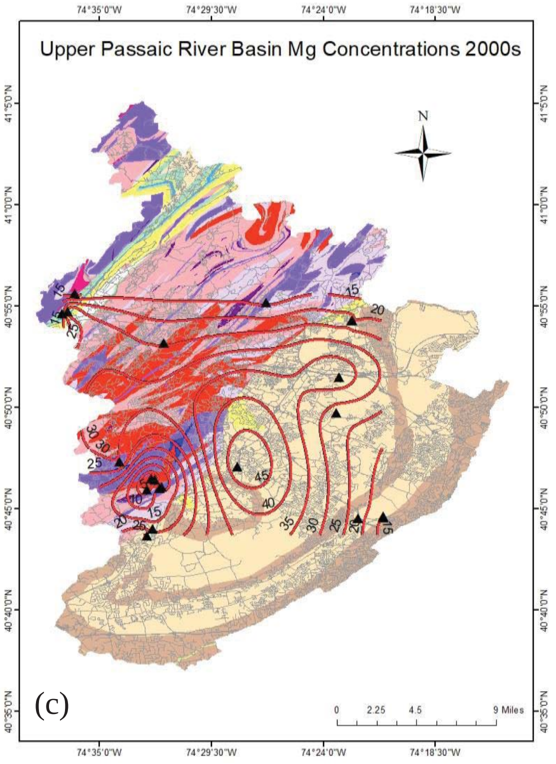


Figure 18a – 18e. Ionic distribution contour map for sodium (a), chloride (b), magnesium (c), calcium (d), and sulfate (e) for 2000-2010.



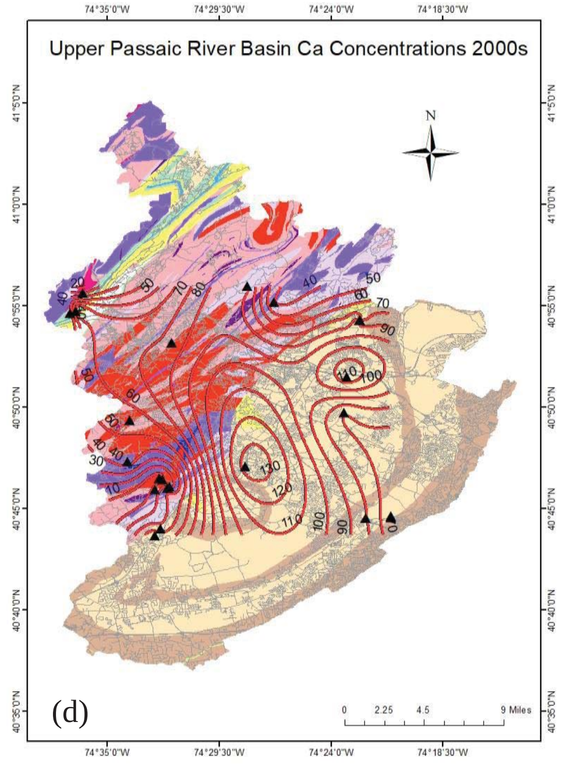
Upper Passaic River Basin Cl Concentrations 2000s

(b)



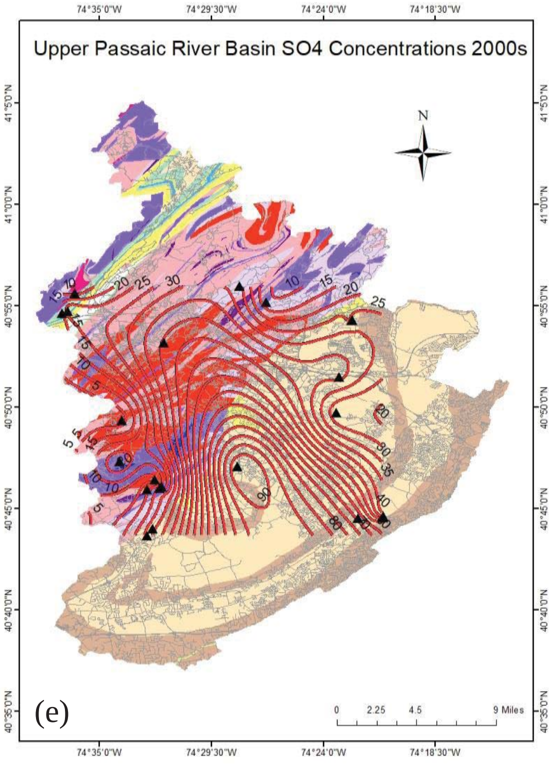
Upper Passaic River Basin Mg Concentrations 2000s

(c)



Upper Passaic River Basin Ca Concentrations 2000s

(d)



Upper Passaic River Basin SO4 Concentrations 2000s

(e)

Appendix 1. Groundwater ionic composition data for the Upper Passaic River Basin, samples measured by USGS**.**

Site Name	Sample Date	Latitude	Longitude	pH	Specific Conductance (µS/cm)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Cl (mg/L)	SO4 (mg/L)	TDS (mg/L)	HCO3 (mg/L)	CO3 (mg/L)	Na (mg/L)	F (mg/L)
130011-- Cwc E	2/24/1959	40.74427	-74.3535	7.9	375	40	13	0.8	7.7	77	257	124	0	19	0
130003-- Dickinson 3	2/24/1959	40.76121	-74.3677	7.9	415	47	18	0.5	7.5	73	279	154	0	14	0
130001-- PW 1A	2/25/1959	40.83152	-74.2871	7.4	345	40	15	0.4	11	46	243	126	0	7.6	0
270082-- 130	6/3/1964	40.9401	-74.569	7.9	187	33	11	0.7	8	24	169	124	0	5	0.1
270020-- Troy Meadows 1 Obs	12/17/1965	40.84093	-74.3893	7.8	230	28	9.2	0.8	4.4	20	140	114	0	5	0.1
270005-- Sandoz Obs	12/28/1965	40.80732	-74.396	7.5	278	27	11	0.9	6.8	29	169	126	0	14	0.1
270019-- Troy Meadows 2	1/11/1966	40.83399	-74.3896	7.5	321	37	14	1	3.2	25	199	166	0	7.9	0.1
270002-- W B Driver 1	1/22/1966	40.79399	-74.4013	7.4	262	25	12	0.8	6.2	23	154	126	0	12	0.1
270003-- W B Driver 2 Obs	3/17/1966	40.79677	-74.4049	7.9	274	27	11	0.6	7.6	21	162	134	0	15	N/A
270021-- Interpce Oep 1	4/12/1966	40.86788	-74.4396	7.9	222	24	9.5	0.6	5	17	140	106	0	8	0.1
270004-- Clemens Obs	5/17/1966	40.80454	-74.3993	7.8	294	26	11	0.6	7	34	177	130	0	16	0.2
130004-- Slough Brook 3	8/18/1966	40.76205	-74.3443	7.3	288	34	13	0.7	6.7	25	257	140	0	8.7	0
130015-- PW H	8/18/1966	40.75538	-74.3332	8	347	50	13	1.8	15	32	191	158	0	3.6	0
130012-- Cwc K5	8/19/1966	40.74771	-74.3527	7.6	358	44	15	0.8	10	40	243	164	0	12	0
130010-- Cwc 46	8/19/1966	40.74232	-74.3527	7.6	368	40	10	0.4	11	47	243	158	0	23	0.1
130008-- Cwc 50	8/19/1966	40.74093	-74.3724	8.1	407	53	14	0.8	13	67	302	155	0	13	0
130006-- Pool 4	8/31/1966	40.78566	-74.3199	7.8	306	32	14	0.7	13	31	405	124	0	8.7	0
130007-- PW 5	8/31/1966	40.81038	-74.3463	7.6	530	64	23	1.1	20	88	221	188	0	16	0
130002-- PW 8	9/1/1966	40.83241	-74.3001	7.6	281	32	6.9	0.3	19	36	191	84	0	14	0
130001-- PW 1A	9/1/1966	40.83152	-74.2871	8.1	345	42	16	0.5	28	40	265	122	0	7.2	0
270082-- 130	10/25/1966	40.9401	-74.569	7.6	187	39	12	0.9	14	29	206	139	0	5.4	0
270006-- Green Acres Obs	12/9/1966	40.82704	-74.3663	7.8	321	38	14	0.6	7.1	29	221	145	0	8.2	0
270008-- Greenhouse	12/14/1966	40.75621	-74.3849	7.9	455	54	15	1	10	64	294	213	0	54	0.1
270001-- Recreation Fld Obs	1/12/1967	40.74232	-74.3807	8	324	44	12	0.7	8.2	38	221	141	0	8	0
270012-- Briarwood School Obs	1/14/1967	40.7776	-74.3829	7.7	379	45	16	0.7	10	45	250	135	0	7.5	0
270016-- Morris Treat 2	1/17/1967	40.80621	-74.4563	7.7	206	27	6.3	0.6	3.4	25	132	96	0	6.5	0.1
270007-- Homestead	1/17/1967	40.83371	-74.3579	7.9	261	32	12	0.6	4.6	18	154	136	0	5.5	0
270014-- Exxon Obs	1/20/1967	40.78482	-74.414	7.9	268	28	13	0.6	5.5	22	169	138	0	10	0

270010-- Braidburn Club	3/2/1967	40.76927	-74.379	7.8	329	21	10	1	8.2	48	221	118	0	36	0.1
270082-- 130	12/13/1967	40.9401	-74.569	7.5	187	40	12	2.4	14	30	199	134	0	6.5	0
390316-- Ind 4	10/4/1968	40.72843	-74.3779	8.5	379	18	7.4	0.8	6.5	43	235	144	6	43	0.1
390308-- Ind 10	10/4/1968	40.72343	-74.3788	8.5	530	45	18	1.5	18	103	934	167	5	36	0.2
390315-- Ind 6	10/4/1968	40.72816	-74.3796	8.4	1210	134	34	1.5	18	505	331	136	6	84	0.3
270082-- 130	9/10/1969	40.9401	-74.569	8	187	38	11	1	17	28	191	134	0	4.5	0.3
270082-- 130	9/17/1971	40.9401	-74.569	7.6	187	41	12	1	22	28	199	129	0	7.2	0.2
270027-- Berkshire Valley 9 Obs	6/14/1983	40.92538	-74.6049	8.2	220	25	11	0.6	12	16	132	106	N/A	4.2	<.1
270003-- W B Driver 2 Obs	6/16/1983	40.79677	-74.4049	8.1	274	81	31	1.3	1.3	210	500	174	N/A	16	0.1
270087-- 305A	12/28/1983	40.94232	-74.5652	7.6	380	54	21	1.3	60	29	309	N/A	N/A	22	0.1
270268-- 151	1/5/1984	40.94177	-74.5663	8	555	56	26	1.7	93	11	360	N/A	N/A	33	<.1
270287-- E Obs	7/14/1984	40.88843	-74.5682	8.6	145	12	2.7	8.3	2.9	1.6	235	N/A	N/A	8.5	0.2
270290-- Tw 5	7/14/1984	40.88816	-74.5674	7.5	400	34	14	1.6	49	20	250	N/A	N/A	22	<.1
270302-- S11	7/14/1984	40.88704	-74.5668	6.8	386	34	13	1.5	45	23	353	N/A	N/A	23	0.1
270295-- Obs S4	7/14/1984	40.88843	-74.5682	6.5	365	32	12	2	41	19	191	N/A	N/A	21	0.1
270297-- Obs S6	7/15/1984	40.88788	-74.5696	6.6	440	40	15	2.1	64	25	265	N/A	N/A	31	<.1
270302-- S11	8/3/1984	40.88704	-74.5668	6.8	386	39	15	1.6	55	24	279	N/A	N/A	26	0.1
270295-- Obs S4	8/3/1984	40.88843	-74.5682	6.4	365	34	13	2.1	45	20	250	N/A	N/A	22	0.1
270297-- Obs S6	8/3/1984	40.88788	-74.5696	6.7	440	42	16	2.2	69	25	331	N/A	N/A	31	<.1
270287-- E Obs	8/4/1984	40.88843	-74.5682	7.7	145	12	5	0.9	2.2	3	88	N/A	N/A	6.5	0.2
270290-- Tw 5	8/4/1984	40.88816	-74.5674	7.2	400	48	19	1.7	62	22	346	N/A	N/A	24	<.1
270290-- Tw 5	8/20/1984	40.88816	-74.5674	7.3	400	48	18	1.7	60	29	316	N/A	N/A	25	<.1
270295-- Obs S4	8/20/1984	40.88843	-74.5682	6.6	365	36	13	2.1	51	27	257	N/A	N/A	24	0.1
270292-- Obs S1	8/21/1984	40.88788	-74.5677	6.7	195	20	7.2	1.1	30	16	147	N/A	N/A	14	0.1
270302-- S11	8/21/1984	40.88704	-74.5668	6.9	386	40	15	1.6	56	31	272	N/A	N/A	28	0.1
270297-- Obs S6	8/21/1984	40.88788	-74.5696	6.8	440	44	16	2.1	70	23	338	N/A	N/A	32	<.1
270297-- Obs S6	9/4/1984	40.88788	-74.5696	6.7	440	47	17	2.2	76	27	382	N/A	N/A	34	<.1
270306-- D6 Obs	9/4/1984	40.88788	-74.5696	7.5	605	62	24	1.6	77	31	412	N/A	N/A	28	<.1
270318-- P-4	9/5/1984	40.88788	-74.5677	6.7	255	22	7.8	1	31	18	147	N/A	N/A	18	0.1
270302-- S11	9/5/1984	40.88704	-74.5668	7	386	41	16	1.6	53	25	294	N/A	N/A	31	<.1
270295-- Obs S4	9/5/1984	40.88843	-74.5682	6.5	365	36	13	2.1	53	20	287	N/A	N/A	25	<.1
270290-- Tw 5	9/5/1984	40.88816	-74.5674	7.2	400	55	21	1.7	67	23	375	N/A	N/A	28	<.1
270292-- Obs S1	9/5/1984	40.88788	-74.5677	6.5	195	22	8	1.1	33	17	169	N/A	N/A	17	0.1
270318-- P-4	10/17/1984	40.88788	-74.5677	7	255	28	11	1.2	40	19	191	N/A	N/A	20	0.1

270306-- D6 Obs	10/17/1984	40.88788	-74.5696	7.6	605	58	23	1.5	68	29	368	N/A	N/A	23	<.1
270318-- P-4	11/15/1984	40.88788	-74.5677	7.1	255	25	10	1.1	40	19	162	N/A	N/A	18	<.1
270305-- D1 Obs	11/15/1984	40.88788	-74.5677	8	225	28	9.7	0.9	5.7	21	199	N/A	N/A	7.6	0.2
270306-- D6 Obs	11/16/1984	40.88788	-74.5696	7.7	605	54	22	1.3	56	29	324	N/A	N/A	17	<.1
270292-- Obs S1	12/20/1984	40.88788	-74.5677	6.8	195	25	9.8	0.9	39	19	177	N/A	N/A	19	<.1
270292-- Obs S1	1/18/1985	40.88788	-74.5677	6.7	195	20	7.9	0.9	38	17	140	N/A	N/A	17	0.1
270305-- D1 Obs	1/18/1985	40.88788	-74.5677	7.9	225	30	10	1	5.9	21	132	N/A	N/A	7.9	0.2
270318-- P-4	2/22/1985	40.88788	-74.5677	7.3	255	16	6.2	1.1	37	17	147	N/A	N/A	22	0.1
270297-- Obs S6	2/23/1985	40.88788	-74.5696	6.5	440	58	22	2.5	86	28	382	N/A	N/A	36	<.1
270306-- D6 Obs	2/23/1985	40.88788	-74.5696	7.5	605	59	23	1.4	64	30	316	N/A	N/A	21	<.1
270290-- Tw 5	3/29/1985	40.88816	-74.5674	8.1	400	37	18	1.5	56	18	235	N/A	N/A	23	<.1
270295-- Obs S4	3/30/1985	40.88843	-74.5682	7.2	365	25	9.9	1.1	43	18	177	N/A	N/A	20	<.1
270305-- D1 Obs	3/30/1985	40.88788	-74.5677	8.3	225	31	10	0.8	5.7	22	162	N/A	N/A	7.7	0.2
270290-- Tw 5	5/2/1985	40.88816	-74.5674	7.7	400	51	19	1.4	60	25	309	N/A	N/A	24	<.1
270305-- D1 Obs	5/2/1985	40.88788	-74.5677	8.3	225	32	10	0.9	5.8	25	154	N/A	N/A	8.2	0.2
270295-- Obs S4	5/2/1985	40.88843	-74.5682	7.1	365	27	10	1.3	46	19	191	N/A	N/A	23	<.1
270287-- E Obs	6/10/1985	40.88843	-74.5682	8.1	145	12	5.1	0.9	4.2	3.1	309	N/A	N/A	7.2	0.2
270290-- Tw 5	6/10/1985	40.88816	-74.5674	7.7	400	44	18	1.3	53	20	88	N/A	N/A	25	<.1
270290-- Tw 5	7/11/1985	40.88816	-74.5674	7.7	400	44	17	1.6	51	21	279	N/A	N/A	23	<.1
270270-- 12E	8/12/1985	40.9326	-74.5746	7.5	744	120	34	0.8	24	250	574	N/A	N/A	8.9	N/A
270097-- Obs 11	8/12/1985	40.93649	-74.5763	6	452	22	6.7	3.5	94	29	250	N/A	N/A	55	N/A
270100-- 12C	8/12/1985	40.93593	-74.5757	6.5	1020	59	19	3.5	260	35	596	N/A	N/A	120	N/A
270340-- 12H	8/12/1985	40.93565	-74.576	7.4	811	77	29	2.1	140	34	427	N/A	N/A	50	N/A
270098-- 12A	8/12/1985	40.93593	-74.5752	6.3	1280	79	25	5.9	300	74	728	N/A	N/A	150	N/A
270339-- 12I	8/13/1985	40.9351	-74.5757	7.4	806	62	22	2.9	87	27	368	N/A	N/A	70	N/A
270341-- 12F	8/13/1985	40.93538	-74.5752	7	1330	90	33	3.7	260	93	721	N/A	N/A	120	N/A
270304-- Caf 5 Obs	8/13/1985	40.94149	-74.5688	6.3	683	26	11	2.6	140	16	346	N/A	N/A	80	N/A
270342-- 12G	8/13/1985	40.93565	-74.5749	6.8	866	53	24	2.1	150	43	441	N/A	N/A	73	N/A
270269-- 12D	8/13/1985	40.93538	-74.5752	7.4	785	59	24	1.7	140	28	427	N/A	N/A	66	N/A
270333-- 130-3	8/13/1985	40.9401	-74.569	6.1	625	4.2	1	2	89	67	331	N/A	N/A	120	N/A
270099-- 12B	8/13/1985	40.93593	-74.5754	6.5	940	59	23	2.6	190	56	522	N/A	N/A	100	N/A
270326-- 10-2	8/14/1985	40.94177	-74.5707	5.4	512	13	4.2	2.5	96	44	250	N/A	N/A	67	N/A
270239-- Obs I	8/14/1985	40.93732	-74.5696	7.2	770	47	20	3.5	130	37	397	N/A	N/A	73	0.1
270327-- 24-1	8/14/1985	40.94232	-74.5702	6.2	487	27	6.1	2.1	61	26	235	N/A	N/A	47	N/A

270282-- H-1(S)	8/14/1985	40.93871	-74.5704	6.1	328	16	6.4	3.3	45	21	147	N/A	N/A	28	N/A
270331-- 34-1	8/14/1985	40.94065	-74.5693	6	409	19	5.3	2.7	62	22	191	N/A	N/A	40	N/A
270281-- H-3(M)	8/14/1985	40.93871	-74.5704	9.3	189	18	0.3	1.2	1.4	14	88	N/A	N/A	11	N/A
270334-- 92-1	8/14/1985	40.93982	-74.5693	6.9	773	56	15	2.5	100	33	375	N/A	N/A	63	N/A
270335-- 92-2	8/14/1985	40.9401	-74.5696	6	392	17	5.8	1.4	66	20	177	N/A	N/A	34	N/A
270242-- Caf 1 Obs	8/14/1985	40.93982	-74.5699	7.2	226	25	8.8	2.5	2.6	7.9	110	N/A	N/A	3.4	N/A
270243-- Caf 2	8/14/1985	40.93982	-74.5699	6.4	550	3.3	0.7	1	77	37	287	N/A	N/A	100	N/A
270337-- 64-1	8/15/1985	40.94038	-74.5718	6.7	250	14	4.5	1.1	28	18	110	N/A	N/A	16	N/A
270336-- 31-1	8/15/1985	40.94065	-74.5707	6.2	542	26	5.2	1.8	92	28	265	N/A	N/A	63	N/A
270095-- 9C Obs	8/15/1985	40.94121	-74.5713	6.8	638	37	5.5	4.6	37	85	353	N/A	N/A	78	0
270330-- 31-3A	8/15/1985	40.94093	-74.5707	6.2	403	23	2	2.1	56	21	206	N/A	N/A	46	N/A
270094-- Obs 9B	8/15/1985	40.94093	-74.571	6.7	816	37	5.2	4.9	120	50	456	N/A	N/A	120	N/A
270329-- 31-2	8/15/1985	40.94177	-74.5696	6.2	645	29	5.1	2.5	120	28	338	N/A	N/A	77	N/A
270082-- 130	8/15/1985	40.9401	-74.569	7.6	187	45	15	1.2	53	25	257	N/A	N/A	25	N/A
270328-- 31-4	8/15/1985	40.94232	-74.5696	6.4	800	45	9	1.3	150	9	419	N/A	N/A	89	N/A
270338-- 12J	8/16/1985	40.93427	-74.5752	6.6	792	61	21	2	130	93	287	N/A	N/A	62	N/A
270332-- 112	8/16/1985	40.93899	-74.5674	7.2	553	40	22	3.1	63	35	132	N/A	N/A	30	N/A
270245-- Caf 4 Obs	8/16/1985	40.93982	-74.5699	7.8	220	29	13	0.8	3.6	13	515	N/A	N/A	3.5	N/A
270244-- Caf 3	8/16/1985	40.93982	-74.5699	8	206	24	7.6	0.6	12	17	110	N/A	N/A	5.7	N/A
270249-- 65-4	8/16/1985	40.93899	-74.5715	7.6	793	58	26	1.5	120	24	390	N/A	N/A	55	N/A
270267-- 129-Ob	8/16/1985	40.94093	-74.5682	6.3	613	23	6.2	2.9	110	26	302	N/A	N/A	62	N/A
270093-- Obs 9A	8/16/1985	40.94149	-74.5704	6.4	660	23	3.3	2.8	110	56	360	N/A	N/A	100	N/A
270246-- 65-1	8/21/1985	40.93899	-74.5715	8.2	281	22	11	1.5	10	15	147	126	N/A	14	N/A
270248-- 65-3	8/21/1985	40.93899	-74.5715	8.3	246	20	3.1	0.8	11	14	110	N/A	N/A	14	N/A
270280-- H-2(D)	8/21/1985	40.93871	-74.5704	9.3	341	27	12	7.3	16	19	147	N/A	N/A	11	N/A
270307-- Dh-3	8/21/1985	40.93538	-74.5774	7	424	26	9.5	1.5	34	28	177	N/A	N/A	20	N/A
270195-- PW 1	11/25/1985	40.87482	-74.3527	8.5	217	30	2.2	0.4	13	36	206	N/A	N/A	9.8	<.1
270059-- PW 6	11/25/1985	40.90371	-74.5068	6.6	385	30	13	1.4	53	27	169	221	N/A	24	0.1
270353-- PW3	11/26/1985	40.89443	-74.569	7.8	536	46	18	2.4	38	22	235	257	N/A	39	0.2
270827-- PW 2	11/26/1985	40.90343	-74.5902	7.9	408	29	12	0.7	45	21	221	123	N/A	33	<.1
270035-- PW 5	11/26/1985	40.89865	-74.4839	8.1	395	45	19	1.2	26	18	221	201	N/A	8	0.1
270136-- PW 3	11/26/1985	40.87871	-74.5296	8.1	388	44	17	1.3	15	25	302	174	N/A	10	0.1
270191-- PW 5	11/26/1985	40.88291	-74.4569	8.3	331	39	16	1	17	27	206	174	N/A	6.4	0.1
270291-- PW5	11/26/1985	40.88816	-74.5674	7.5	460	43	16	2.3	35	23	265	184	N/A	26	0.1

270357-- PW4	11/26/1985	40.88593	-74.541	8.2	330	34	14	1	29	17	177	138	N/A	9.9	0.2
270189-- PW 4	11/26/1985	40.90482	-74.4599	7.5	250	27	11	N/A	6.7	20	169	150	N/A	6.5	<.1
270913-- White Rock 2	11/27/1985	41.03524	-74.5179	6.1	247	20	11	0.8	28	15	140	82	N/A	9.6	0.2
270080-- PW 7	11/27/1985	40.91343	-74.5002	7.7	424	43	19	1.9	26	26	243	184	N/A	12	0.1
270030-- PW 5	11/27/1985	40.91538	-74.4464	6.9	291	31	12	1.3	24	20	177	138	N/A	9.8	0.1
270657-- Dom	11/27/1985	40.93288	-74.4771	6.2	209	10	4	1.5	27	16	125	43	N/A	21	<.1
270541-- Dom 1	11/27/1985	40.95343	-74.4154	6.1	159	14	5.6	0.8	7.2	22	103	38	N/A	8.3	<.1
270321-- Geonics 2	12/4/1985	40.89566	-74.4607	8.5	226	26	11	0.8	2.9	26	125	N/A	N/A	3.6	0.1
270287-- E Obs	12/17/1985	40.88843	-74.5682	8.2	145	13	5	1.3	2.3	4.6	81	84	N/A	7	<1
270188-- PW 4	1/7/1986	40.89207	-74.4443	6.7	342	35	15	1.1	19	30	184	104	N/A	8.6	<.1
270936-- Mussiker	1/7/1986	40.8226	-74.5632	6.4	247	22	8.3	1.4	38	3.1	132	45	N/A	8.2	<.1
270275-- Pressure Relief	1/14/1986	40.88399	-74.5218	8	394	45	17	1.1	33	18	213	N/A	N/A	10	0.2
270686-- 339	1/14/1986	40.88566	-74.5179	8	394	45	17	1.1	33	18	213	157	N/A	10	0.2
270325-- Valley Rd 3	1/17/1986	40.92843	-74.4377	8.1	195	22	5.1	2	9.2	14	103	79	N/A	10	0.5
270923-- Dom	1/27/1986	40.98343	-74.5399	8.5	275	30	7.2	0.5	23	16	140	99	N/A	9.8	0.1
270278-- 176-Sh	2/19/1986	40.94315	-74.5604	6.5	425	26	8.8	1.9	80	23	221	57	N/A	38	0.2
270911-- Dom	2/19/1986	40.93038	-74.5965	8	674	65	29	1.6	110	42	346	152	N/A	21	<.1
130090-- Hollywood 6	3/12/1986	40.8876	-74.2938	7.8	1200	130	42	1.4	12	490	809	N/A	N/A	48	N/A
270012-- Briarwood School Obs	9/16/1986	40.7776	-74.3829	7.5	379	59	19	0.9	21	47	279	176	<1	10	0.1
270015-- 2 Obs	9/17/1986	40.79538	-74.4224	8.3	455	46	18	1.2	8.6	47	331	201	<1	17	0.2
270020-- Troy Meadows 1 Obs	9/18/1986	40.84093	-74.3893	7.9	230	42	14	0.8	4.4	49	206	145	<1	7.4	0.2
270153-- Lidgerwood 5	4/21/1987	40.78538	-74.4771	7.3	421	42	21	1.3	23	28	228	162	<1	11	<.1
130052-- TW11/Ltwd 7	5/11/1987	40.79955	-74.3598	7.5	400	38	18	0.7	36	29	235	143	N/A	14	0.1
130055-- PW 9	8/10/1987	40.80077	-74.3582	7.7	375	41	18	0.8	35	29	228	128	N/A	12	0.2
130052-- TW11/Ltwd 7	8/10/1987	40.79955	-74.3598	7.5	400	36	18	0.9	35	29	250	137	<1	13	0.1
130047-- Canoe Brook 1	8/11/1987	40.75038	-74.336	8	455	61	16	0.6	37	30	287	209	N/A	11	0.1
130004-- Slough Brook 3	8/11/1987	40.76205	-74.3443	8	288	43	18	0.8	17	34	235	160	N/A	11	0.1
130059-- Canoe Brook 6	8/11/1987	40.76871	-74.319	8.1	461	46	10	0.3	54	37	309	140	N/A	35	0.1
130082-- PW 17	8/12/1987	40.83032	-74.3087	8.1	451	49	22	0.9	49	52	309	118	N/A	11	0.1
130072-- PW 6	8/12/1987	40.82843	-74.2938	7.7	463	58	16	0.4	66	29	397	127	N/A	10	0.1
130073-- PW 7	8/12/1987	40.83143	-74.298	7.5	589	73	24	0.8	90	32	279	157	N/A	12	0.1
270194-- 2-Westminster	8/13/1987	40.89066	-74.3549	7.7	388	62	20	0.4	37	32	316	185	N/A	9.5	0.1
130093-- PW 4	8/14/1987	40.87121	-74.3129	8	600	68	24	1.2	23	170	419	157	N/A	35	0.2
271112-- Great Swamp Nwr Hq	8/14/1987	40.70343	-74.496	7.5	1510	140	86	0.7	40	850	1397	101	N/A	120	0.2

130063-- Cwc K2	8/18/1987	40.74399	-74.351	8	345	51	13	0.6	16	35	235	N/A	N/A	9.7	160
130009-- Cwc 51	8/18/1987	40.74193	-74.3718	8	520	72	18	1	27	95	346	201	N/A	17	0.1
130063-- Cwc K2	8/18/1987	40.74399	-74.351	8	345	52	13	0.6	16	35	235	N/A	N/A	9.3	N/A
130090-- Hollywood 6	8/19/1987	40.8876	-74.2938	7.9	1200	140	43	1.4	11	480	868	111	N/A	50	0.2
270148-- PW 5	8/20/1987	40.83593	-74.3543	7.8	506	66	23	1.2	24	50	331	238	N/A	15	0.1
270147-- PW 2	8/20/1987	40.81566	-74.3899	7.8	582	70	27	1.2	29	110	390	N/A	N/A	23	0.1
130063-- Cwc K2	8/21/1987	40.74399	-74.351	N/A	345	48	12.4	0.6	20	30	N/A	N/A	N/A	9.7	160
350045-- Ind	8/28/1987	40.65705	-74.576	7.8	447	45	25	1	32	27	287	218	N/A	22	<.1
270178-- 8-3	8/31/1987	40.84291	-74.3931	7.9	378	49	17	1	22	34	302	173	N/A	9.7	0.1
270045-- PW 17	8/31/1987	40.87121	-74.4277	7.8	477	55	19	1.1	43	33	250	N/A	N/A	N/A	N/A
270158-- Sand Springs	9/1/1987	40.7626	-74.5046	6.8	177	18	8.2	0.8	10	15	118	72	N/A	7.7	0.1
270979-- Stirling Lake	9/1/1987	40.67732	-74.4957	8.1	499	26	17	0.7	15	88	309	206	N/A	68	0.5
270188-- PW 4	9/2/1987	40.89207	-74.4443	6.8	342	31	14	1	18	35	206	104	N/A	8.5	0.1
270191-- PW 5	9/2/1987	40.88291	-74.4569	8.2	331	39	16	0.9	16	25	199	175	N/A	6.7	0.1
270162-- Wing	9/3/1987	40.83191	-74.4443	8	384	54	17	1	21	31	235	165	N/A	9.5	0.1
271109-- Main	9/4/1987	40.78324	-74.4316	7.5	303	33	15	0.9	15	29	191	157	N/A	15	0.2
390180-- Ind 1	9/16/1987	40.69232	-74.4093	7.4	426	61	16	0.4	25	32	287	196	N/A	14	0.1
350046-- Dom 1	9/16/1987	40.6576	-74.4571	7.8	334	51	11	1	12	25	213	160	N/A	9.3	0.1
270974-- 10-3	10/19/1987	40.94177	-74.5707	6.3	220	18	12	0.3	2.9	5.7	103	N/A	N/A	1.7	0.1
270969-- 10-4	10/19/1987	40.94177	-74.5707	8.6	415	30	13	1.8	52	24	221	N/A	N/A	29	0.2
270968-- 10-3A	10/19/1987	40.94177	-74.5707	7.6	188	24	4.2	2.6	10	24	132	N/A	N/A	12	0.1
270971-- 39-2	10/20/1987	40.93427	-74.5713	8.3	315	36	10	1	34	25	184	N/A	N/A	8.5	0.2
270937-- 41-1	10/20/1987	40.93732	-74.5674	6.4	295	15	6.1	1.2	45	18	169	N/A	N/A	33	0.2
270970-- 39-1	10/20/1987	40.93427	-74.5713	8.6	285	14	3.9	2.3	18	34	162	N/A	N/A	39	0.3
270938-- 41-2	10/20/1987	40.93732	-74.5674	6.6	330	17	7.3	1.2	48	19	177	N/A	N/A	34	0.1
270939-- 41-3	10/21/1987	40.93649	-74.5682	8.6	172	19	4.2	0.6	4.1	12	96	N/A	N/A	8.6	0.2
270944-- 112-1	10/21/1987	40.93954	-74.5668	6.5	440	24	13	3.2	65	30	235	N/A	N/A	35	0.1
270945-- 112-2	10/21/1987	40.93954	-74.5668	6.1	210	14	3.3	1.6	35	16	125	N/A	N/A	18	0.1
270327-- 24-1	10/22/1987	40.94232	-74.5702	6.4	487	28	3.8	1.8	46	23	213	N/A	N/A	46	0.2
270973-- 95-2	10/22/1987	40.93565	-74.5749	8.9	280	8.3	1.9	1.3	5.8	26	154	N/A	N/A	46	0.6
270954-- I-2	10/22/1987	40.93732	-74.5702	8.1	490	48	16	1.1	86	31	287	N/A	N/A	20	0.1
270239-- Obs I	10/22/1987	40.93732	-74.5696	7.7	770	55	24	1.6	140	35	449	N/A	N/A	74	0.1
270337-- 64-1	10/22/1987	40.94038	-74.5718	6.8	250	18	5.8	0.8	25	8.1	125	N/A	N/A	15	0.2
270964-- 31-5	10/22/1987	40.94149	-74.5693	6.2	700	34	5.2	4.6	150	17	368	N/A	N/A	89	0.1

270942-- 41-8	10/22/1987	40.9376	-74.5677	7	418	30	12	1.3	55	18	221	N/A	N/A	34	0.1
270304-- Caf 5 Obs	10/23/1987	40.94149	-74.5688	6.4	683	30	10	2.9	160	18	405	N/A	N/A	86	0.1
270242-- Caf 1 Obs	10/23/1987	40.93982	-74.5699	7.2	226	23	8.2	2.6	2	9.4	118	N/A	N/A	3.5	0.2
270940-- 41-4	10/23/1987	40.93677	-74.5685	8.6	158	19	1.3	0.4	3.3	11	96	N/A	N/A	10	0.3
270941-- 41-5	10/23/1987	40.93677	-74.5685	7.6	560	55	20	1.6	120	32	405	N/A	N/A	60	0.1
270095-- 9C Obs	10/23/1987	40.94121	-74.5713	6.6	638	43	5.8	5.6	20	28	257	N/A	N/A	42	0.9
270963-- 31-2A	10/26/1987	40.94177	-74.5696	6.5	760	49	9.6	4	210	17	493	N/A	N/A	110	0.1
270959-- 111-2	10/26/1987	40.94038	-74.5688	6.3	295	17	3.8	2.8	39	17	154	N/A	N/A	31	0.1
270958-- 111-1	10/26/1987	40.94038	-74.5688	6.1	480	20	6.6	3.4	91	27	265	N/A	N/A	60	0.1
270967-- 34-2	10/26/1987	40.94093	-74.5693	6.2	395	18	2.4	3.1	73	13	206	N/A	N/A	54	0.1
270280-- H-2(D)	10/26/1987	40.93871	-74.5704	9.2	341	26	12	5.1	11	15	N/A	N/A	N/A	6.8	0.1
270249-- 65-4	10/27/1987	40.93899	-74.5715	7.7	793	56	24	1.8	130	28	449	N/A	N/A	67	0.1
270331-- 34-1	10/27/1987	40.94065	-74.5693	6.2	409	16	4.6	2.7	49	21	177	N/A	N/A	36	0.1
270330-- 31-3A	10/27/1987	40.94093	-74.5707	6.7	403	11	0.79	1.5	44	31	235	N/A	N/A	73	0.4
270281-- H-3(M)	10/27/1987	40.93871	-74.5704	9.2	189	16	0.44	0.9	0.8	9.9	81	N/A	N/A	12	0.2
270336-- 31-1	10/27/1987	40.94065	-74.5707	6.3	542	20	4.4	1.1	66	22	235	N/A	N/A	45	0.1
270282-- H-1(S)	10/27/1987	40.93871	-74.5704	6.3	328	20	8.2	1.4	63	25	199	N/A	N/A	33	0.1
270953-- 112-10	10/28/1987	40.93815	-74.5696	6.6	440	24	4.1	3.1	110	22	272	N/A	N/A	59	0.1
270952-- 112-9	10/28/1987	40.93815	-74.5696	8.3	540	44	22	1.3	53	27	309	N/A	N/A	34	0.1
270248-- 65-3	10/28/1987	40.93899	-74.5715	8.5	246	17	2.1	0.5	2.5	9.5	103	N/A	N/A	11	0.2
270951-- 112-8	10/28/1987	40.93871	-74.5688	7	610	20	4.5	3.5	170	12	346	N/A	N/A	89	0.1
270948-- 112-5	10/28/1987	40.93899	-74.5679	7.8	235	16	7.3	2.6	18	22	162	N/A	N/A	13	0.1
270246-- 65-1	10/28/1987	40.93899	-74.5715	8.3	281	23	12	1.6	11	15	147	N/A	N/A	12	0.1
270093-- Obs 9A	10/28/1987	40.94149	-74.5704	7.7	660	17	2.9	3.7	48	28	235	N/A	N/A	63	0.1
270961-- Obs 9D	10/29/1987	40.94065	-74.5713	7.3	495	8.5	0.99	1.5	40	42	265	N/A	N/A	83	0.6
270962-- Obs 9E	10/29/1987	40.94065	-74.5713	7.2	720	25	3.6	5	120	43	441	N/A	N/A	120	0.3
270245-- Caf 4 Obs	10/29/1987	40.93982	-74.5699	7.7	220	32	11	1.2	15	17	169	N/A	N/A	13	0.1
270094-- Obs 9B	10/29/1987	40.94093	-74.571	7.7	816	8.3	1.1	1.7	39	41	294	N/A	N/A	89	0.6
270243-- Caf 2	10/29/1987	40.93982	-74.5699	6.8	550	3.2	0.7	0.7	51	45	302	N/A	N/A	97	0.2
270960-- Caf-6	10/29/1987	40.93982	-74.5699	7.6	395	32	15	1.3	46	26	221	N/A	N/A	22	0.2
270244-- Caf 3	10/30/1987	40.93982	-74.5699	8	206	26	9.7	0.8	9.7	17	125	N/A	N/A	5.1	0.2
270946-- 112-3	10/30/1987	40.93899	-74.5679	8	800	67	21	1.3	91	110	478	N/A	N/A	65	0.1
270947-- 112-4	10/30/1987	40.93899	-74.5679	7.6	900	61	21	1.5	98	110	530	N/A	N/A	86	0.2
270949-- 112-6	10/30/1987	40.93871	-74.5688	N/A	N/A	41	21	1.8	91	56	375	N/A	N/A	67	0.1

270950-- 112-7	10/30/1987	40.93871	-74.5688	N/A	N/A	41	13	1.1	42	49	250	N/A	N/A	23	0.2
270956-- 92-4	11/2/1987	40.93954	-74.5693	6.6	600	26	12	1.8	110	50	331	N/A	N/A	71	0.2
270957-- 92-5	11/2/1987	40.93954	-74.5693	5.7	395	6.1	1.9	1.5	65	41	213	N/A	N/A	64	0.2
270955-- 92-3	11/2/1987	40.93954	-74.5693	8.8	375	37	16	0.9	36	28	206	N/A	N/A	10	0.1
270083-- 302D	11/3/1987	40.94232	-74.566	7.5	565	50	22	1.7	66	22	309	N/A	N/A	31	0.1
270267-- 129-Ob	11/16/1987	40.94093	-74.5682	6.2	613	32	7.6	4.1	140	27	265	N/A	N/A	74	0.1
270333-- 130-3	11/16/1987	40.9401	-74.569	5.9	625	7.6	2.2	2.6	110	28	360	N/A	N/A	83	0.1
270278-- 176-Sh	11/17/1987	40.94315	-74.5604	6.2	425	20	7.7	1.7	54	37	199	50	N/A	36	0.3
270278-- 176-Sh	11/19/1987	40.94315	-74.5604	6.2	425	20	7.8	1.7	53	37	206	50	N/A	36	0.3
350008-- Gs Th 6	12/3/1987	40.6951	-74.5207	8.2	256	23	9.9	0.8	9.3	26	169	128	N/A	18	0.2
270084-- 430A	12/8/1987	40.94571	-74.5572	5.7	255	13	3.8	1.3	39	37	140	N/A	N/A	25	0.3
270084-- 430A	12/10/1987	40.94571	-74.5572	5.7	255	14	3.9	1.2	45	35	147	N/A	N/A	27	0.2
270150-- Great Swamp 4 Obs	12/18/1987	40.73038	-74.4207	7.7	203	21	3.1	1	7.9	12	213	116	N/A	23	0.7
270152-- Niles Park 1 Obs	12/19/1987	40.74732	-74.416	N/A	324	46	15	1	15	42	228	172	N/A	11	0.4
271111-- Convent 3	2/25/1988	40.78593	-74.4285	7.9	507	64	22	1	41	34	324	211	N/A	16	N/A
271110-- Convent 2	3/8/1988	40.78593	-74.4285	8.6	338	24	13	0.6	14	31	221	138	18	35	N/A
270196-- 3-Lee Ct	5/5/1988	40.88871	-74.3521	7.4	325	55	20	6.7	39	35	302	180	<1	7.7	0.1
390387-- MW2	6/9/1988	40.68538	-74.3977	6.7	195	18	7.3	0.5	16	13	154	55	N/A	7.2	0.2
270158-- Sand Springs	8/16/1988	40.7626	-74.5046	6.7	177	19	9	0.8	11	15	118	N/A	N/A	8.5	0.1
Wetland site F at edge of landfill nr Green Villag	5/18/1989	40.72194	-74.4436	6.1	192	11	8.2	0.3	8.1	25	125	N/A	N/A	14	0.1
Wetland site B-C at edge of landfill nr Green Vill	5/19/1989	40.72778	-74.4397	6.9	440	160	48	27	2	2	677	N/A	N/A	81	0.1
Wetland site A at edge of landfill nr Green Villag	5/19/1989	40.73	-74.4406	6.8	420	62	9.1	10	10	2	243	N/A	N/A	8.6	0.1
271139-- Mendham Test4-Franklin	6/6/1989	40.7726	-74.589	7.3	305	39	10	1.2	13	40	228	167	<.1	21	0.3
270239-- Obs I	6/15/1989	40.93732	-74.5696	7.5	770	48	21	1.3	130	43	427	N/A	N/A	75	0.1
270954-- I-2	6/16/1989	40.93732	-74.5702	7.7	490	53	18	0.8	100	30	390	N/A	N/A	26	0.1
270974-- 10-3	6/16/1989	40.94177	-74.5707	6	220	22	4.5	2.4	4.5	25	140	N/A	n/A	13	0.1
270326-- 10-2	6/16/1989	40.94177	-74.5707	5.5	512	7.9	2.7	1.8	56	25	132	N/A	N/A	54	0.1
270939-- 41-3	6/19/1989	40.93649	-74.5682	8.5	172	22	4.9	0.5	9.1	14	96	N/A	N/A	8.5	0.2
270941-- 41-5	6/19/1989	40.93677	-74.5685	7.6	560	52	20	1.5	120	34	412	N/A	N/A	63	0.1
270940-- 41-4	6/19/1989	40.93677	-74.5685	8.6	158	21	1.4	0.3	5.1	12	96	N/A	N/A	11	0.3

270948-- 112-5	6/19/1989	40.93899	-74.5679	6.4	235	16	6.6	2.5	11	18	118	N/A	N/A	11	0.1
270947-- 112-4	6/20/1989	40.93899	-74.5679	7.4	900	60	19	1.5	100	140	559	N/A	N/A	100	0.1
270946-- 112-3	6/20/1989	40.93899	-74.5679	7.8	800	71	21	1.7	95	130	515	N/A	N/A	70	0.6
270095-- 9C Obs	6/20/1989	40.94121	-74.5713	6.5	638	50	5.6	6.6	60	50	360	N/A	N/A	61	1
270093-- Obs 9A	6/20/1989	40.94149	-74.5704	6.2	660	41	8.6	5.4	190	26	478	N/A	N/A	110	0.1
270958-- 111-1	6/21/1989	40.94038	-74.5688	5.8	480	22	7.3	3.3	100	22	279	N/A	N/A	64	0.1
270959-- 111-2	6/21/1989	40.94038	-74.5688	6.2	295	22	4	2.5	51	18	191	N/A	N/A	38	0.1
270957-- 92-5	6/21/1989	40.93954	-74.5693	6.1	395	3.6	0.97	1.1	46	39	221	N/A	N/A	75	0.2
270956-- 92-4	6/21/1989	40.93954	-74.5693	6.5	600	21	10	1.7	110	32	316	N/A	N/A	78	0.2
270955-- 92-3	6/21/1989	40.93954	-74.5693	7.9	375	39	17	1	40	28	228	N/A	N/A	14	0.1
270938-- 41-2	6/22/1989	40.93732	-74.5674	6.5	330	19	8.1	1.2	53	18	199	N/A	N/A	36	0.2
270937-- 41-1	6/22/1989	40.93732	-74.5674	6.3	295	17	6.6	1.3	50	18	191	N/A	N/A	34	0.1
270097-- Obs 11	6/22/1989	40.93649	-74.5763	6.1	452	22	6.3	2	79	24	221	N/A	N/A	46	N/A
270334-- 92-1	6/22/1989	40.93982	-74.5693	N/A	773	67	17	3.7	150	33	507	N/A	N/A	71	0.1
270094-- Obs 9B	6/22/1989	40.94093	-74.571	6.2	816	81	13	7.7	210	39	691	N/A	N/A	140	0.2
270336-- 31-1	6/22/1989	40.94065	-74.5707	6.1	542	24	4.5	1.2	71	15	191	N/A	N/A	39	0.1
270340-- 12H	6/22/1989	40.93565	-74.576	7.4	811	60	27	2.2	130	28	456	N/A	N/A	65	N/A
270951-- 112-8	6/23/1989	40.93871	-74.5688	5.7	610	19	4.1	3.2	170	32	360	N/A	N/A	110	0.1
270949-- 112-6	6/23/1989	40.93871	-74.5688	7.6	N/A	40	12	0.8	38	40	228	N/A	N/A	22	0.2
270950-- 112-7	6/23/1989	40.93871	-74.5688	8.1	N/A	37	20	1.9	90	48	360	N/A	N/A	68	0.1
270339-- 12I	6/23/1989	40.9351	-74.5757	6.4	806	72	27	2.9	140	32	500	N/A	N/A	77	N/A
270243-- Caf 2	6/23/1989	40.93982	-74.5699	6.6	550	3.4	0.89	0.6	43	26	228	N/A	N/A	77	1
270960-- Caf-6	6/23/1989	40.93982	-74.5699	7.7	395	37	18	1.5	68	26	265	N/A	N/A	24	0.1
270962-- Obs 9E	6/24/1989	40.94065	-74.5713	6.3	720	38	5.8	5.9	230	37	610	N/A	N/A	180	0.2
270961-- Obs 9D	6/24/1989	40.94065	-74.5713	6.7	495	9.8	1.2	1.5	37	24	213	N/A	N/A	68	0.6
270961-- Obs 9D	6/24/1989	40.94065	-74.5713		495	9.9	1.2	1.5	36	24	221	N/A	N/A	68	0.6
270942-- 41-8	6/24/1989	40.9376	-74.5677	6.9	418	26	12	1.2	55	19	221	N/A	N/A	36	0.1
270945-- 112-2	6/26/1989	40.93954	-74.5668	6	210	16	3.7	1.4	30	18	125	N/A	N/A	21	0.1
270944-- 112-1	6/26/1989	40.93954	-74.5668	6.4	440	24	12	3.3	75	23	257	N/A	N/A	43	0.1
270327-- 24-1	6/26/1989	40.94232	-74.5702	6.1	487	25	4	1.5	48	19	199	N/A	N/A	35	0.1
270333-- 130-3	6/26/1989	40.9401	-74.569	5.6	625	8.7	2.6	2.9	75	32	228	N/A	N/A	62	0.1
270966-- 31-7	6/27/1989	40.94177	-74.5696	6	457	27	5.4	6	67	17	257	N/A	N/A	49	0.1
270963-- 31-2A	6/27/1989	40.94177	-74.5696	6.1	760	33	6.4	3.3	150	14	405	N/A	N/A	100	0.2
270267-- 129-Ob	6/27/1989	40.94093	-74.5682	5.9	613	32	8	4.1	150	24	382	N/A	N/A	83	0.1

270331-- 34-1	6/27/1989	40.94065	-74.5693	6	409	17	4.6	2.8	50	19	169	N/A	N/A	35	0.1
270270-- 12E	6/27/1989	40.9326	-74.5746	7.7	744	80	22	0.8	32	120	412	N/A	N/A	12	N/A
270953-- 112-10	6/28/1989	40.93815	-74.5696	5.7	440	20	3.3	2	71	29	206	N/A	N/A	50	0.1
270952-- 112-9	6/28/1989	40.93815	-74.5696	7	540	36	17	1.1	50	23	243	N/A	N/A	32	0.1
270330-- 31-3A	6/28/1989	40.94093	-74.5707	6.4	403	6.5	0.46	1.1	34	20	184	N/A	N/A	60	0.5
270964-- 31-5	6/28/1989	40.94149	-74.5693	5.9	700	25	4.3	3.6	78	16	257	N/A	N/A	57	0.1
270337-- 64-1	6/28/1989	40.94038	-74.5718	6.1	250	13	4.2	0.6	35	16	103	N/A	N/A	21	0.1
270967-- 34-2	6/29/1989	40.94093	-74.5693	5.5	395	17	2.5	3.3	89	12	235	N/A	N/A	61	0.1
270304-- Caf 5 Obs	6/29/1989	40.94149	-74.5688	5.7	683	33	11	2.9	170	14	449	N/A	N/A	91	0.1
270335-- 92-2	6/29/1989	40.9401	-74.5696	5.4	392	13	5.3	0.9	46	20	154	N/A	N/A	26	0.1
270332-- 112	6/29/1989	40.93899	-74.5674	6.3	553	33	18	2.9	33	38	250	N/A	N/A	24	0.1
270338-- 12J	6/30/1989	40.93427	-74.5752	7	792	31	8.1	1.4	93	25	324	N/A	N/A	59	N/A
270282-- H-1(S)	6/30/1989	40.93871	-74.5704	5.7	328	19	7.5	1.1	63	16	184	N/A	N/A	29	0.1
270341-- 12F	6/30/1989	40.93538	-74.5752	7.3	1330	42	16	2.4	100	45	390	N/A	N/A	72	N/A
270307-- Dh-3	7/5/1989	40.93538	-74.5774	6.2	424	23	8.9	1	29	16	184	N/A	N/A	17	N/A
270269-- 12D	7/6/1989	40.93538	-74.5752	8	785	48	19	1.5	75	26	338	N/A	N/A	42	N/A
270342-- 12G	7/6/1989	40.93565	-74.5749	6.5	866	40	17	2.8	98	43	375	N/A	N/A	56	N/A
270099-- 12B	7/6/1989	40.93593	-74.5754	7.6	940	69	25	4.2	200	53	647	N/A	N/A	99	N/A
270098-- 12A	7/6/1989	40.93593	-74.5752	6.6	1280	50	18	2.8	170	56	507	N/A	N/A	98	N/A
271281-- 70-3	7/6/1989	40.93427	-74.5757	7.2	1020	65	24	4.5	160	59	603	N/A	N/A	98	N/A
270100-- 12C	7/7/1989	40.93593	-74.5757	6.7	1020	47	12	3.6	120	31	427	N/A	N/A	89	N/A
271282-- 70-4	7/7/1989	40.93427	-74.5757	7.3	1040	70	24	5.3	160	68	633	N/A	N/A	95	N/A
271280-- 70-2	7/12/1989	40.93427	-74.5757	7.2	1860	280	99	1.6	48	820	1508	N/A	n/A	15	N/A
271276-- 70-1A	7/12/1989	40.93343	-74.576	7.3	539	42	16	1.3	63	29	338	N/A	N/A	48	N/A
271298-- 95-4	7/12/1989	40.93649	-74.5746	6.2	486	21	9	3.8	92	30	257	N/A	N/A	54	N/A
271271-- B18-1	7/12/1989	40.93704	-74.5752	5.6	488	16	6.5	7.7	99	32	272	N/A	N/A	63	N/A
271297-- 95-3	7/13/1989	40.93621	-74.5749	5.9	584	35	7.7	4.9	100	52	309	N/A	N/A	63	N/A
271289-- 36-1	7/13/1989	40.93538	-74.574	8.3	367	59	7	0.8	12	89	243	N/A	N/A	7.6	N/A
271285-- Wg3-3	7/13/1989	40.93482	-74.5754	7.1	471	22	6.8	2	67	24	302	N/A	N/A	63	N/A
271290-- 36-2	7/13/1989	40.93538	-74.574	7.5	781	60	24	4.7	110	52	456	N/A	N/A	61	N/A
271284-- Wg3-2	7/13/1989	40.93482	-74.5754	7.3	1040	79	20	4.5	170	60	588	N/A	N/A	98	N/A
271291-- 36-3	7/13/1989	40.93538	-74.574	6.4	597	41	16	4.4	89	68	360	N/A	N/A	54	N/A
271294-- Wg11-3	7/14/1989	40.93538	-74.5743	7.6	912	73	25	4.9	150	39	500	N/A	N/A	65	N/A
271292-- Wg11-1	7/14/1989	40.93538	-74.5743	7.3	833	63	23	2.8	120	56	485	N/A	N/A	69	N/A

271293-- Wg11-2	7/14/1989	40.93538	-74.5743	6	832	54	10	4	160	110	485	N/A	N/A	85	N/A
271279-- 82-3	7/18/1989	40.93427	-74.5729	8.7	224	24	1.5	0.4	1.2	12	140	N/A	N/A	23	N/A
271222-- 24-5	7/20/1989	40.94232	-74.5702	N/A	N/A	20	7.9	1.4	120	36	338	N/A	N/A	85	0.1
271278-- 82-2	7/24/1989	40.93427	-74.5729	7	851	90	27	3.6	110	92	559	N/A	N/A	51	N/A
271277-- 82-1	7/24/1989	40.93427	-74.5729	7.2	1060	87	30	5.8	150	100	633	N/A	N/A	88	N/A
271272-- 80-1	7/24/1989	40.93343	-74.5727	7.2	802	73	22	3.6	77	89	507	N/A	N/A	45	N/A
271273-- 80-2	7/24/1989	40.93343	-74.5727	6.3	457	45	14	3.3	40	52	309	N/A	N/A	25	N/A
271295-- MW12-K	7/25/1989	40.93565	-74.5752	7.8	698	52	24	1.7	110	35	405	N/A	N/A	56	N/A
271296-- MW12-L	7/25/1989	40.93565	-74.5752	7.5	676	56	22	1.9	94	29	405	N/A	N/A	50	N/A
271283-- Wg3-1	7/25/1989	40.93482	-74.5754	7.2	1150	140	45	2.2	110	300	890	N/A	N/A	53	N/A
271286-- Wg9-1	7/26/1989	40.9351	-74.5749	7.4	689	83	9.4	2.2	100	42	441	N/A	N/A	52	N/A
271287-- Wg9-2	7/26/1989	40.9351	-74.5749	7.4	921	91	17	2.4	130	70	552	N/A	N/A	67	N/A
271288-- Wg9-3	7/26/1989	40.9351	-74.5749	7.1	817	69	18	4	130	68	530	N/A	N/A	73	N/A
271260-- 3548-1	8/1/1989	40.92427	-74.5796	6.7	362	47	15	1.9	18	34	257	N/A	N/A	9.8	N/A
271258-- 3548-2	8/1/1989	40.92399	-74.5793	6.9	340	40	10	1.3	22	35	228	N/A	N/A	11	N/A
271264-- 1180-2	8/1/1989	40.92454	-74.5807	6.7	463	53	16	3.3	20	20	265	N/A	N/A	12	N/A
271261-- 1181-1	8/2/1989	40.92427	-74.5802	6.8	356	46	16	2.2	28	25	257	N/A	N/A	14	N/A
271263-- 1180-1	8/2/1989	40.92454	-74.5807	8.3	214	29	8.1	0.6	10	12	140	N/A	N/A	6.2	N/A
271246-- 1179-5	8/2/1989	40.9226	-74.5802	7.6	400	38	14	1.2	35	27	228	N/A	N/A	24	N/A
271257-- 1181-2	8/2/1989	40.92371	-74.5804	6.7	268	34	11	1.5	10	20	177	N/A	N/A	6.7	N/A
271254-- 1181-3	8/2/1989	40.92343	-74.5802	6.6	358	44	11	2.2	16	19	243	N/A	N/A	11	N/A
271251-- 1179-4A	8/2/1989	40.92315	-74.5807	8.7	202	25	1.9	0.3	1.2	7	125	N/A	N/A	19	N/A
271250-- 1179-4	8/2/1989	40.92315	-74.5807	6.8	497	50	17	1.6	27	23	294	N/A	N/A	25	N/A
271243-- 1178-1	8/3/1989	40.92065	-74.5838	6.5	171	15	5.4	0.6	8.4	20	110	N/A	N/A	6.3	N/A
271244-- 1179-3	8/3/1989	40.92232	-74.5824	7.3	228	25	11	0.7	8.3	18	132	N/A	N/A	4.6	N/A
271249-- 1179-2	8/3/1989	40.9226	-74.5824	7.8	164	25	6.5	0.3	1.9	7	103	N/A	N/A	5.8	N/A
271248-- 1179-1	8/3/1989	40.9226	-74.5824	8.1	185	23	6.9	0.7	1.8	9	118	N/A	N/A	6.5	N/A
271245-- 1179-6	8/4/1989	40.9226	-74.5796	6.5	441	25	9.3	1.4	19	28	191	N/A	N/A	19	N/A
271266-- 1179A-3	8/4/1989	40.92454	-74.581	6.7	389	52	15	1.8	18	14	250	N/A	N/A	12	N/A
271262-- 1179A-2	8/4/1989	40.92427	-74.5813	6.7	330	42	13	2.5	14	20	287	N/A	N/A	6.8	N/A
271259-- 1179A-1	8/4/1989	40.92399	-74.5813	6.6	360	39	11	1.8	11	11	235	N/A	N/A	6.6	N/A
271184-- Com	8/23/1989	40.90232	-74.6099	7.9	310	34	15	0.8	12	19	184	N/A	N/A	7.3	<.1
271188-- Institutional 1	8/24/1989	40.91232	-74.6096	6.9	570	50	22	1.7	66	21	353	N/A	N/A	45	0.1
271187-- Dom	8/24/1989	40.91204	-74.6102	8.2	170	22	9.4	0.5	1.9	12	118	N/A	N/A	4	0.1

271185-- Dom 1	8/24/1989	40.90871	-74.6068	7.9	430	43	19	1.4	33	19	265	N/A	N/A	23	0.1
271247-- 1179-7	9/5/1989	40.9226	-74.581	6.5	397	35	13	1.2	27	21	206	N/A	N/A	17	N/A
270432-- Dom 1	9/27/1989	40.94843	-74.4543	6.3	161	15	6.6	1	16	12	110	54	<.1	6.2	0.1
271203-- 41-18	11/8/1989	40.93732	-74.5693	N/A	N/A	23	2.5	0.5	4.9	14	125	N/A	N/A	5.4	0.2
271202-- 41-17	11/8/1989	40.93732	-74.5693	N/A	N/A	45	18	1.4	74	28	353	N/A	N/A	36	0.1
271201-- 41-16	11/8/1989	40.93732	-74.5693	N/A	N/A	44	19	1.3	100	32	397	N/A	N/A	60	0.1
271210-- 41-23	11/9/1989	40.93871	-74.5674	N/A	N/A	5.3	3.9	2.7	25	43	213	N/A	N/A	7	0.1
271209-- 41-22	11/9/1989	40.93871	-74.5674	N/A	N/A	68	18	1.2	85	98	434	N/A	N/A	57	0.1
271208-- 41-21	11/13/1989	40.93871	-74.5674	N/A	N/A	47	19	1.2	79	24	412	N/A	N/A	40	0.2
271213-- 92-9	11/14/1989	40.93899	-74.5699	N/A	N/A	20	7.1	1.3	110	21	257	N/A	N/A	61	0.1
271212-- 92-7	11/14/1989	40.93899	-74.5699	N/A	N/A	43	20	1.4	74	27	279	N/A	N/A	25	0.1
271199-- 41-10	11/15/1989	40.93732	-74.5682	N/A	N/A	22	4	0.4	6	14	118	N/A	N/A	4	0.1
271200-- 41-11	11/15/1989	40.93732	-74.5682	N/A	N/A	28	3.7	0.4	5.4	18	96	N/A	N/A	10	0.2
271207-- 41-15	11/16/1989	40.93871	-74.566	N/A	N/A	40	19	2.2	65	30	309	N/A	N/A	47	0.1
271206-- 41-14	11/16/1989	40.93871	-74.566	N/A	N/A	29	14	1.4	16	35	191	N/A	N/A	17	0.1
271204-- 41-12	11/17/1989	40.93843	-74.5665	N/A	N/A	47	20	1.4	78	27	324	N/A	N/A	45	0.1
270243-- Caf 2	11/20/1989	40.93982	-74.5699	6.8	550	3	0.75	0.5	39	24	213	N/A	N/A	74	1
271214-- Caf-7	11/20/1989	40.93982	-74.5699	N/A	N/A	27	4.8	2.8	46	16	221	N/A	N/A	33	0.1
271215-- 9-G	11/21/1989	40.94093	-74.571	N/A	N/A	21	3.7	1.7	88	20	228	N/A	N/A	54	0.1
270094-- Obs 9B	11/21/1989	40.94093	-74.571	6.5	816	56	8.4	4.5	120	32	405	N/A	N/A	100	0.4
271220-- 13-1	11/27/1989	40.94204	-74.5718	N/A	N/A	32	16	1.4	69	23	265	N/A	N/A	39	0.1
271217-- 92-10	11/28/1989	40.93982	-74.571	N/A	N/A	19	5.1	1.5	50	11	140	N/A	N/A	19	<.1
271218-- 92-11	11/28/1989	40.93982	-74.571	N/A	N/A	34	15	1.1	50	25	235	N/A	N/A	27	0.1
271219-- 92-12	11/28/1989	40.93982	-74.571	N/A	N/A	28	8.5	0.8	21	23	140	N/A	N/A	5.1	0.1
271221-- 13-2	11/28/1989	40.94204	-74.5718	N/A	N/A	21	7.5	2.7	170	21	353	N/A	N/A	87	0.1
271216-- 9-H	11/28/1989	40.94093	-74.571	N/A	N/A	1.1	0.14	0.4	33	17	221	N/A	N/A	76	0.9
270937-- 41-1	11/29/1989	40.93732	-74.5674	6	295	17	7	1.1	54	17	169	N/A	N/A	34	0.1
270938-- 41-2	11/29/1989	40.93732	-74.5674	6.1	330	19	8.1	1.1	53	17	184	N/A	N/A	34	0.1
270942-- 41-8	11/29/1989	40.9376	-74.5677	6.7	418	27	12	1.1	54	18	221	N/A	N/A	34	0.1
270327-- 24-1	11/30/1989	40.94232	-74.5702	5.9	487	29	4.6	1.4	42	18	191	N/A	N/A	25	0.1
271222-- 24-5	11/30/1989	40.94232	-74.5702	N/A	N/A	19	8	1.3	150	34	890	N/A	N/A	97	0.1
270951-- 112-8	11/30/1989	40.93871	-74.5688	5.7	610	13	2.7	2.6	160	14	324	N/A	N/A	100	0.1
270949-- 112-6	11/30/1989	40.93871	-74.5688	7.3	N/A	35	18	1.6	86	43	338	N/A	N/A	62	0.1
270956-- 92-4	12/1/1989	40.93954	-74.5693	6.3	600	35	18	1.6	110	33	316	N/A	N/A	64	0.2

270957-- 92-5	12/1/1989	40.93954	-74.5693	6.1	395	2.8	0.73	0.9	50	29	206	N/A	N/A	74	0.2
270955-- 92-3	12/1/1989	40.93954	-74.5693	7.7	375	37	16	0.9	42	27	235	N/A	N/A	13	0.1
270960-- Caf-6	12/1/1989	40.93982	-74.5699	7.5	395	38	19	1.3	68	26	250	N/A	N/A	23	0.1
270940-- 41-4	12/5/1989	40.93677	-74.5685	8.2	158	22	1.5	0.3	6	13	118	N/A	n/A	11	0.2
270941-- 41-5	12/5/1989	40.93677	-74.5685	7.1	560	52	20	1.4	120	33	368	N/A	N/A	59	0.1
270962-- Obs 9E	12/5/1989	40.94065	-74.5713	6.4	720	16	2.2	2.5	100	27	397	N/A	N/A	120	0.8
270961-- Obs 9D	12/5/1989	40.94065	-74.5713	6.3	495	9.4	1.1	1.5	45	20	228	N/A	N/A	67	0.5
270961-- Obs 9D	12/5/1989	40.94065	-74.5713	6.3	495	9.5	1.1	1.5	45	20	221	N/A	N/A	67	0.6
270330-- 31-3A	12/5/1989	40.94093	-74.5707	6.1	403	6.4	0.67	0.8	32	20	184	N/A	N/A	55	0.5
270944-- 112-1	12/6/1989	40.93954	-74.5668	5.9	440	23	12	2.9	65	27	235	N/A	N/A	38	0.1
270945-- 112-2	12/6/1989	40.93954	-74.5668	5.6	210	21	4.6	1.5	63	10	162	N/A	N/A	26	0.1
270336-- 31-1	12/6/1989	40.94065	-74.5707	5.8	542	21	4.1	1.2	61	16	169	N/A	N/A	35	0.1
270953-- 112-10	12/7/1989	40.93815	-74.5696	5.4	440	25	4.2	2.6	98	19	257	N/A	N/A	49	<.1
270952-- 112-9	12/7/1989	40.93815	-74.5696	6.7	540	35	17	1	47	23	265	N/A	N/A	32	0.1
270950-- 112-7	12/7/1989	40.93871	-74.5688	6.4	N/A	37	12	0.8	39	39	228	N/A	N/A	21	0.1
270946-- 112-3	12/8/1989	40.93899	-74.5679	7.5	800	68	20	1.4	93	130	493	N/A	N/A	73	0.1
270948-- 112-5	12/8/1989	40.93899	-74.5679	6.1	235	15	6.5	2.4	9.5	18	103	N/A	N/A	8.3	0.1
270947-- 112-4	12/8/1989	40.93899	-74.5679	7.3	900	56	18	1.4	100	130	544	N/A	N/A	100	0.1
270093-- Obs 9A	12/8/1989	40.94149	-74.5704	6.1	660	34	6.5	4.1	110	25	331	N/A	N/A	75	0.1
270335-- 92-2	12/8/1989	40.9401	-74.5696	5.7	392	13	5.2	1	52	19	162	N/A	N/A	28	0.1
270239-- Obs I	12/11/1989	40.93732	-74.5696	7.4	770	53	18	1	100	31	331	N/A	N/A	73	N/A
270966-- 31-7	12/12/1989	40.94177	-74.5696	5.7	457	23	5	5.7	51	12	213	N/A	N/A	39	0.1
270963-- 31-2A	12/12/1989	40.94177	-74.5696	5.4	760	22	5.2	2.5	100	32	294	N/A	N/A	69	0.1
270332-- 112	12/12/1989	40.93899	-74.5674	6.8	553	34	19	2.9	25	29	221	N/A	N/A	15	0.1
270974-- 10-3	12/13/1989	40.94177	-74.5707	5.7	220	16	3	1.7	2.7	14	66	N/A	N/A	5.6	0.1
270326-- 10-2	12/13/1989	40.94177	-74.5707	5	512	7.1	2.4	1.9	64	24	169	N/A	N/A	50	<.1
270959-- 111-2	12/13/1989	40.94038	-74.5688	5.8	295	21	4.2	3	57	16	191	N/A	N/A	37	0.1
270958-- 111-1	12/13/1989	40.94038	-74.5688	5.6	480	18	6.3	3.4	81	21	235	N/A	N/A	56	0.1
270238-- MWh	12/14/1989	40.93871	-74.5704	5.8	390	22	8.6	1.5	66	29	199	N/A	N/A	38	0.1
270337-- 64-1	12/14/1989	40.94038	-74.5718	6	250	17	5.5	0.9	32	12	140	N/A	N/A	25	0.1
270239-- Obs I	12/14/1989	40.93732	-74.5696	7.3	770	48	21	1.4	130	43	434	N/A	N/A	27	0.1
270333-- 130-3	12/15/1989	40.9401	-74.569	N/A	625	6.2	1.9	2.4	67	30	118	N/A	N/A	64	0.1
270304-- Caf 5 Obs	12/15/1989	40.94149	-74.5688	6	683	31	11	2.9	150	17	419	N/A	N/A	87	0.1
270267-- 129-Ob	12/15/1989	40.94093	-74.5682	6.4	613	31	6.9	4.4	140	23	368	N/A	N/A	80	0.1

270967-- 34-2	12/18/1989	40.94093	-74.5693	5.6	395	20	3.7	3.5	78	13	221	N/A	N/A	51	<.1
270331-- 34-1	12/18/1989	40.94065	-74.5693	5.6	409	17	4.6	3	51	20	191	N/A	N/A	35	0.1
270097-- Obs 11	1/24/1990	40.93649	-74.5763	6.1	452	16	5.4	2	73	23	213	N/A	N/A	44	0.1
270269-- 12D	1/25/1990	40.93538	-74.5752	7.7	785	53	20	1.7	110	26	N/A	N/A	N/A	51	0.2
270098-- 12A	1/25/1990	40.93593	-74.5752	6.5	1280	43	14	3.3	170	70	500	N/A	N/A	110	0.4
270242-- Caf 1 Obs	1/30/1990	40.93982	-74.5699	7.3	226	20	8.6	2.4	2.1	8	118	N/A	N/A	3.1	0.2
270245-- Caf 4 Obs	1/30/1990	40.93982	-74.5699	8.2	220	29	13	0.7	2.9	12	140	N/A	N/A	2.4	<.1
270244-- Caf 3	1/31/1990	40.93982	-74.5699	8.2	206	20	10	0.5	6.1	14	118	N/A	N/A	2.9	<.1
270095-- 9C Obs	3/6/1990	40.94121	-74.5713	6.1	638	54	6.6	5.8	110	37	368	N/A	N/A	61	0.8
270942-- 41-8	3/13/1990	40.9376	-74.5677	6.5	418	27	12	1.1	53	18	228	N/A	N/A	33	0.1
270951-- 112-8	3/13/1990	40.93871	-74.5688	5.6	610	13	3.7	3	230	15	412	N/A	N/A	130	<.1
270961-- Obs 9D	3/14/1990	40.94065	-74.5713	6.3	495	9.5	1.2	1.7	45	18	221	N/A	N/A	65	0.5
270961-- Obs 9D	3/14/1990	40.94065	-74.5713	N/A	495	9.9	1.2	1.9	45	19	221	N/A	N/A	66	0.6
270956-- 92-4	3/14/1990	40.93954	-74.5693	6.2	600	16	8.9	1.8	91	31	302	N/A	N/A	75	0.2
270957-- 92-5	3/14/1990	40.93954	-74.5693	6.5	395	3	0.8	1	53	27	228	N/A	N/A	79	0.3
270243-- Caf 2	3/15/1990	40.93982	-74.5699	6	550	5.4	1.3	0.7	63	16	221	N/A	N/A	75	0.7
270960-- Caf-6	3/15/1990	40.93982	-74.5699	7.3	395	39	19	1.5	73	24	302	N/A	N/A	26	<.1
270962-- Obs 9E	3/20/1990	40.94065	-74.5713	6.4	720	15	2.2	2.8	100	32	375	N/A	N/A	120	0.4
270094-- Obs 9B	3/20/1990	40.94093	-74.571	6.3	816	45	6.8	3.8	130	28	405	N/A	N/A	87	0.2
271274-- 80-3	3/22/1990	40.93343	-74.5727	N/A	N/A	87	27	5.6	140	91	640	N/A	N/A	72	N/A
271269-- C-1B	3/22/1990	40.92538	-74.5757	7.6	N/A	38	7.9	1	25	11	191	N/A	N/A	20	N/A
271267-- 1180-3	3/22/1990	40.9251	-74.5793	6.8	312	30	9.2	0.4	28	14	206	N/A	N/A	16	N/A
270949-- 112-6	3/23/1990	40.93871	-74.5688	7.2	N/A	36	19	1.8	93	44	368	N/A	N/A	69	0.1
270950-- 112-7	3/23/1990	40.93871	-74.5688	7.5	N/A	36	12	0.8	42	43	228	N/A	N/A	28	<.1
270955-- 92-3	3/23/1990	40.93954	-74.5693	7	375	37	17	1	49	31	243	N/A	N/A	28	0.2
271299-- 95-5	3/27/1990	40.93649	-74.5746	N/A	N/A	55	26	2.7	91	36	434	N/A	N/A	63	N/A
271300-- 95-6	3/27/1990	40.93649	-74.5746	N/A	N/A	40	19	4.4	98	32	338	N/A	N/A	57	N/A
271301-- 95-7	3/27/1990	40.93649	-74.5746	N/A	N/A	50	19	3.2	110	25	353	N/A	N/A	51	N/A
271207-- 41-15	4/9/1990	40.93871	-74.566	7.5	N/A	36	17	1.9	64	26	287	N/A	N/A	46	0.1
271206-- 41-14	4/9/1990	40.93871	-74.566	6.7	N/A	29	14	1.3	15	33	191	N/A	N/A	14	0.1
271205-- 41-13	4/9/1990	40.93843	-74.5665	6.1	318	15	7	1.1	47	18	177	N/A	N/A	29	0.1
271204-- 41-12	4/9/1990	40.93843	-74.5665	7.3	N/A	45	19	1.3	78	27	324	N/A	N/A	45	0.2
271203-- 41-18	4/10/1990	40.93732	-74.5693	8	N/A	22	3.1	0.3	6.4	15	118	N/A	N/A	4.5	0.1
271202-- 41-17	4/10/1990	40.93732	-74.5693	7.4	N/A	45	19	1.4	77	28	316	N/A	N/A	36	0.2

271201-- 41-16	4/10/1990	40.93732	-74.5693	7	N/A	49	22	1.1	120	35	427	N/A	N/A	61	0.1
271220-- 13-1	4/10/1990	40.94204	-74.5718	7.4	N/A	35	18	1.4	78	23	309	N/A	N/A	39	0.1
271221-- 13-2	4/10/1990	40.94204	-74.5718	5.1	N/A	15	5.3	2.1	150	25	353	N/A	N/A	80	0.1
271222-- 24-5	4/10/1990	40.94232	-74.5702	N/A	N/A	15	8	1.6	150	35	368	N/A	N/A	90	0.2
270333-- 130-3	4/10/1990	40.9401	-74.569	N/A	625	15	4.3	1.1	28	21	169	N/A	N/A	23	0.1
270327-- 24-1	4/10/1990	40.94232	-74.5702	N/A	487	23	4.5	1.1	28	21	154	N/A	N/A	25	0.1
271208-- 41-21	4/11/1990	40.93871	-74.5674	7.5	N/A	39	16	1.1	62	19	272	N/A	N/A	36	0.2
271215-- 9-G	4/11/1990	40.94093	-74.571	5.9	N/A	15	3.5	1.6	85	19	221	N/A	N/A	53	0.2
271216-- 9-H	4/11/1990	40.94093	-74.571	7.1	N/A	1.4	0.26	0.3	33	20	213	N/A	N/A	75	0.7
271216-- 9-H	4/11/1990	40.94093	-74.571	7.1	N/A	1.4	0.24	0.3	33	20	221	N/A	n/A	75	0.7
271213-- 92-9	4/12/1990	40.93899	-74.5699	5.6	N/A	56	17	2.8	260	36	581	N/A	N/A	100	<.1
271211-- 92-7	4/12/1990	40.93899	-74.5699	8.1	N/A	19	5.6	0.3	2.6	15	88	N/A	N/A	3.6	0.2
271212-- 92-8	4/12/1990	40.93899	-74.5699	7.4	N/A	57	28	1.7	120	36	397	N/A	N/A	33	0.1
270334-- 92-1	4/12/1990	40.93982	-74.5693	6.9	773	31	9.5	2.8	180	24	485	N/A	N/A	130	0.1
271218-- 92-11	4/13/1990	40.93982	-74.571	7.4	N/A	32	16	1.1	50	22	235	N/A	N/A	28	0.2
271217-- 92-10	4/13/1990	40.93982	-74.571	5.8	N/A	18	4.9	1.4	40	16	132	N/A	N/A	22	<.1
271219-- 92-12	4/13/1990	40.93982	-74.571	7.9	N/A	27	8.8	0.6	20	20	132	N/A	N/A	4.9	<.1
271214-- Caf-7	4/13/1990	40.93982	-74.5699	6.2	N/A	22	4.3	3.6	44	18	199	N/A	N/A	36	0.1
271199-- 41-10	4/16/1990	40.93732	-74.5682	7.9	N/A	25	4.5	0.4	11	18	110	N/A	N/A	3.9	<.1
271200-- 41-11	4/16/1990	40.93732	-74.5682	8.1	N/A	27	3.5	0.3	6.6	16	96	N/A	N/A	8.3	<.1
271210-- 41-23	4/17/1990	40.93871	-74.5674	6.8	N/A	31	17	2.6	33	31	235	N/A	N/A	23	<.1
271209-- 41-22	4/17/1990	40.93871	-74.5674	7.1	N/A	66	18	1	84	93	434	N/A	N/A	45	<.1
270084-- 430A	5/16/1990	40.94571	-74.5572	6.1	255	14	5.5	0.9	35	24	132	N/A	N/A	19	0.4
270081-- 129	5/16/1990	40.94093	-74.5682	7.7	422	42	15	1	40	23	243	N/A	N/A	22	0.2
270086-- 410	5/16/1990	40.94371	-74.5568	6.7	373	31	12	1	54	34	213	N/A	N/A	23	0.4
271265-- 1180-2A	5/31/1990	40.92454	-74.5807	8.5	205	18	4.2	0.6	3.1	11	118	N/A	N/A	19	N/A
271256-- 3548-3	5/31/1990	40.92371	-74.5796	6.9	366	39	9.5	1.2	19	18	191	N/A	N/A	15	N/A
271221-- 13-2	6/4/1990	40.94204	-74.5718	N/A	N/A	17	4.4	2	150	28	309	N/A	N/A	83	0.1
270961-- Obs 9D	6/6/1990	40.94065	-74.5713	N/A	495	8.7	1.1	1.3	42	18	184	N/A	N/A	62	0.4
270962-- Obs 9E	6/6/1990	40.94065	-74.5713	N/A	720	12	1.8	1.7	95	21	338	N/A	N/A	110	0.3
271253-- 1179D-1	7/10/1990	40.92315	-74.5821	6.7	313	33	11	1.1	23	7.3	199	N/A	N/A	12	N/A
271255-- 1179D-2	7/10/1990	40.92343	-74.5818	6.6	396	33	13	0.7	52	9.1	206	N/A	N/A	25	N/A
271268-- C-1A	8/7/1990	40.92538	-74.5757	9.9	279	12	4.4	1.1	8.2	22	169	N/A	N/A	46	N/A
271252-- 1179-4B	8/28/1990	40.92315	-74.5807	8.7	226	13	3.6	0.7	10	22	140	N/A	N/A	31	N/A

271193-- Jockey Hollow Camp 1673	9/4/1990	40.76232	-74.551	6.1	169	12	5.9	0.5	10	14	110	50	41	6.2	<.1
271194-- Irr	9/5/1990	40.77455	-74.5746	7.2	276	32	7.5	1	6.9	42	154	104	85	10	0.3
270159-- Shongum	9/12/1990	40.82816	-74.5013	6.4	331	31	9.3	1.9	41	26	221	50	41	17	0.4
271196-- Dom	9/18/1990	40.98843	-74.4471	7.8	167	14	7.4	0.6	2.8	11	118	87	71	5.1	<.1
271305-- TW Whitehead Rd	9/19/1990	40.79204	-74.5293	7.3	590	80	17	1.1	65	27	456	218	179	14	0.2
271306-- TW Washington V Rd	9/24/1990	40.80454	-74.5218	7.7	233	26	10	0.7	7.2	26	140	99	81	7.7	0.1
271318-- Tw 14 Tingley Rd	9/26/1990	40.7901	-74.5513	6.5	311	36	11	0.8	36	15	206	104	85	8	<.1
271307-- TW Sussex Turnpike	9/27/1990	40.81288	-74.5124	8.1	303	23	5.2	0.7	20	38	191	94	77	32	2.3
270949-- 112-6	7/17/1994	40.93871	-74.5688	N/A	N/A	34	16	1.4	130	21	382	N/A	N/A	84	<.1
270949-- 112-6	7/19/1994	40.93871	-74.5688	N/A	N/A	64	11	6.2	410	24	228	N/A	N/A	190	<.1
270950-- 112-7	7/19/1994	40.93871	-74.5688	N/A	N/A	38	11	1	44	35	897	N/A	N/A	28	0.1
270955-- 92-3	7/21/1994	40.93954	-74.5693	N/A	375	37	16	0.8	47	24	213	N/A	n/A	11	<.1
270957-- 92-5	7/21/1994	40.93954	-74.5693	N/A	395	7.9	2.3	1.1	54	20	162	N/A	N/A	41	<.1
350085-- Harrisons Brook MW-5	8/19/1994	40.65649	-74.576	7.3	478	62	21	1.8	7.7	14	331	315	258	26	0.1
270956-- 92-4	9/20/1994	40.93954	-74.5693	N/A	600	38	16	1.5	65	32	294	N/A	N/A	37	<.1
270109-- PW 2	8/10/1995	40.91465	-74.4483	6.4	187	16	4.6	1.3	23	13	110	37	30	10	<.1
270300-- Obs S9	8/24/1995	40.89038	-74.5677	7.2	183	44	16	2.4	69	18	N/A	164	134	34	<.1
271852-- SUS 0402 Dom	8/26/1997	40.95511	-74.4962	6.4	791	68.4	15.6	1.39	156	35.2	544	N/A	N/A	48.9	<.1
271853-- SUS 0258 Dom	9/2/1997	41.01747	-74.4771	8.5	189	23.2	5.27	0.59	1.2	4.87	118	N/A	N/A	6.15	0.22
271850-- SUS 0777 Dom	9/3/1997	40.78831	-74.5671	6.7	508	42	26.3	1.74	49.5	27.7	324	N/A	N/A	27.7	0.11
271856-- SUS 0238 Dom	9/22/1997	41.02164	-74.5249	6.5	92	9.75	4.07	0.47	3.86	11.2	51	N/A	N/A	3.06	0.19
271854-- SUS 0498 Dom	9/23/1997	40.93169	-74.5875	8.1	98	11.8	6.13	0.46	6.62	13.4	74	N/A	N/A	1.83	<.1
270153-- Lidgerwood 5	10/1/1997	40.78538	-74.4771	7.2	421	42.6	22.5	1.22	37.2	23.2	250	N/A	N/A	10.3	<.1
350001-- Bernards Tw 1	10/1/1997	40.7276	-74.5446	7.8	521	42.1	23.4	0.84	49.4	33.7	287	N/A	N/A	24	0.31
270155-- Littleton 2	10/15/1997	40.83835	-74.4622	6.9	777	75	26.4	1.67	131	23.7	199	N/A	N/A	26.6	<.1
271858-- SUS 0355 Dom	10/15/1997	40.97594	-74.349	7.2	346	49.9	6.87	1.31	13.7	20.7	279	N/A	N/A	4.97	0.14
270130--PW A	10/15/1997	40.75343	-74.4004	7.9	N/A	54.9	18.2	0.87	33.2	40.9	N/A	N/A	N/A	11	<.1
271859-- SUS 0454 Dom	10/19/1997	40.94814	-74.4083	6.7	125	13	4.75	0.58	1.88	13.7	103	N/A	N/A	4.28	<.1
271862-- SUS 0649 Dom	10/19/1997	40.85083	-74.5797	6.5	280	18	12.6	2.22	43.6	14	169	N/A	N/A	10.2	0.15
271863-- SUS 0488 Dom	10/20/1997	40.9325	-74.469	6.2	671	74.5	22.5	2.6	151	16.6	427	N/A	N/A	16.4	<.1
270147-- PW 2	10/27/1997	40.81566	-74.3899	7.7	582	71	27.3	1.29	62.2	68.6	397	N/A	N/A	29.2	<.1
271861-- SUS 0824 Dom	10/29/1997	40.77408	-74.5622	6.6	222	18.6	7.64	1.58	38.2	2.99	154	N/A	N/A	6.82	<.1
270080-- PW 7	10/29/1997	40.91343	-74.5002	7.3	424	53.2	23.5	1.77	77.3	23.6	324	N/A	N/A	24.6	<.1

271865-- SUS 0526 Dom	11/9/1997	40.93406	-74.4033	6.9	196	19.5	7.25	1.11	12.4	15.2	132	N/A	N/A	6.27	0.11
270182-- PW 13	12/16/1997	40.85316	-74.3857	8.2	374	44.1	15.7	0.92	24.9	21.6	213	N/A	N/A	7.7	<.1
350107-- Dom	7/16/1998	40.65942	-74.4571	6.6	212	25.4	8.37	0.18	4.64	20.9	162	97	0	6.26	<.1
130063-- Cwc K2	8/16/1999	40.74399	-74.351	8	345	53	13.7	0.7	27.6	37.5	257	N/A	N/A	13.1	N/A
130009-- Cwc 51	8/16/1999	40.74193	-74.3718	8	520	71	19.5	0.97	42.1	63.8	346	N/A	N/A	18.3	N/A
270155-- Littleton 2	9/16/1999	40.83835	-74.4622	7.3	777	73.8	26.3	1.39	113	22.9	390	N/A	N/A	21.9	<.1
270147-- PW 2	9/20/1999	40.81566	-74.3899	7.9	582	68	26.5	1.34	64.5	59.4	324	N/A	N/A	29.8	<.1
270080-- PW 7	9/20/1999	40.91343	-74.5002	7.8	424	52.8	23.7	1.82	78.5	23.8	397	N/A	N/A	25.2	<.1
270182-- PW 13	9/21/1999	40.85316	-74.3857	8.1	374	44.3	15.9	0.89	27.6	20.6	221	N/A	N/A	8.06	<.1
130070-- Cwc 48	7/25/2000	40.74232	-74.351	8	507	61.6	14.2	0.84	32.1	56.7	279	N/A	N/A	20	N/A
350001-- Bernards Tw 1	9/11/2000	40.7276	-74.5446	7.8	521	38.8	21.2	5.43	51.5	39.9	309	N/A	N/A	37.6	N/A
271850-- SUS 0777 Dom	8/28/2001	40.78831	-74.5671	6.6	508	43.2	28.6	1.85	65.9	29.6	324	N/A	N/A	29.7	E.1
271188-- Institutional 1	10/16/2001	40.91232	-74.6096	6.8	570	70.3	28.6	2.15	121	23.5	507	N/A	N/A	65.1	E.08
271665-- Dom	4/17/2002	40.91038	-74.6143	8.2	187	19.8	8.81	0.43	2.74	11.2	125	N/A	N/A	3.19	0.15
270601-- Dom 1	4/17/2002	40.91954	-74.4468	7.9	436	40.9	14.1	2	44.5	12.1	228	N/A	N/A	20.3	0.13
270550-- Dom 78Ft	5/6/2002	40.90482	-74.3768	7.8	758	85.4	23	1.37	105	25.5	390	N/A	N/A	20.3	<.1
270516-- Dom 1	5/6/2002	40.90454	-74.376	7.1	672	64.8	20.2	1.14	76.4	29	368	N/A	N/A	32.3	<.1
272062-- MW79	10/29/2002	40.82899	-74.3896	7.8	624	80.8	31	1.27	2.87	36.7	368	328	N/A	12.2	0.25
272061-- MW131	11/13/2002	40.88593	-74.531	6.3	1540	79.1	29.1	3.12	390	9.69	824	151	N/A	165	<.17
130070-- Cwc 48	11/15/2002	40.74232	-74.351	7.7	507	63.1	14.2	0.91	42.3	55.2	294	N/A	N/A	20.4	N/A
350001-- Bernards Tw 1	11/20/2002	40.7276	-74.5446	7.9	521	47.4	25.1	0.88	58.5	26.2	287	N/A	N/A	18.9	N/A
130009-- Cwc 51	12/11/2002	40.74193	-74.3718	8	520	81.2	21.9	0.99	53	64.3	375	N/A	N/A	20	N/A
130063-- Cwc K2	1/28/2003	40.74399	-74.351	8	345	62.9	15.7	0.71	33.9	38.7	279	N/A	N/A	14.4	N/A
130063-- Cwc K2	1/28/2003	40.74399	-74.351	8	345	63.7	15.9	0.68	33.6	38.3	279	N/A	N/A	15.6	N/A
272070-- Wick Farm	8/26/2003	40.76536	-74.5448	6.2	149	13.2	4.17	0.92	8.25	12.8	103	N/A	N/A	7.68	<.85
272078-- Soldier Hut Trail 1	8/28/2003	40.77372	-74.5382	6.3	122	11.9	4.25	0.82	3.96	10.2	96	N/A	N/A	5.6	<.17
272068-- MW83	9/11/2003	40.92686	-74.604	8.1	146	18.7	6.27	0.43	4.07	8.44	103	75	N/A	2.49	<.17
272071-- Quarters 62 (Log House)	10/9/2003	40.7665	-74.5342	7	249	27.7	11.5	1.02	2.79	20.7	169	N/A	N/A	4.83	<.17
272069-- MW138	10/9/2003	40.85781	-74.3872	7.1	1380	117	34.7	2.22	342	39.1	794	N/A	N/A	103	<.17
272078-- Soldier Hut Trail 1	12/16/2003	40.77372	-74.5382	6.7	122	10.3	3.94	0.61	3.6	9.48	81	N/A	N/A	4.45	<.17
272072-- Trail 2 (G5)	12/16/2003	40.76756	-74.5328	6.3	142	16.9	7.02	0.33	2.51	16.8	118	N/A	N/A	4.02	<.17
272076-- Hand Pump/Soldiers Hut Parking Lot	12/17/2003	40.77494	-74.5409	6.7	180	19	6.69	1.69	3.32	15.9	125	N/A	N/A	5.25	<.17
272070-- Wick Farm	12/17/2003	40.76536	-74.5448	6.1	149	12.5	3.31	0.84	6.58	13.1	59	N/A	N/A	7.11	<.17

272107-- MW125	3/30/2004	40.78444	-74.4703	7.5	3570	183	67.2	5.95	960	113	2067	341	N/A	463	<.17
272061-- MW131	4/30/2007	40.88593	-74.531	6.1	1540	73.8	24.5	4.74	645	40.6	1302	66	N/A	310	E.06
272062-- MW79	7/25/2007	40.82899	-74.3896	7.5	624	71.5	27.5	1.15	2.01	22	331	327	N/A	9.54	0.25
272107-- MW125	7/21/2008	40.78444	-74.4703	7.3	3570	133	47.9	4.44	833	93.7	1927	335	N/A	424	<.12
272069-- MW138	7/28/2008	40.85781	-74.3872	6.5	1380	115	37.8	1.86	354	36.1	963	187	N/A	111	E0.08
272068-- MW83	8/12/2008	40.92686	-74.604	8.5	146	16.5	6.12	0.37	5.29	7.62	96	81	N/A	2.89	E0.09
Passaic River near Bernardsville NJ	9/22/2008	40.73361	-74.54	7.1	391	34.3	17.7	1.32	26.1	28.7	N/A	N/A	N/A	13.4	0.13

Appendix 2. Well data for the Upper Passaic River Basin, samples measured by USGS.

Site Name	Latitude	Longitude	Field Measurement Date	Land Surface Elevation Above NGVD29 (ft)	Well Depth Below Land Surface (ft)	Water Depth Below Land Surface (ft)	Hydraulic Head (ft)
390308-- Ind 10	40.7234	-74.378762	3/19/1958	230	719	109	121
270541-- Dom 1	40.9534	-74.415431	6/15/1959	510	44	29	481
130040-- Standby	40.764	-74.30376	4/27/1961	460	819	0	460
270550-- Dom 78Ft	40.9048	-74.376818	7/3/1961	250	78	37	213
350001-- Bernards Tw 1	40.7276	-74.544601	12/29/1961	270	1,450	36	234
390180-- Ind 1	40.6923	-74.409318	1/4/1962	230	200	20	210
390181-- Ind 1	40.6965	-74.400985	7/11/1962	230	310	30	200
270357-- PW4	40.8859	-74.540991	7/22/1962	555	138	5.5	549.5
270913-- White Rock 2	41.0352	-74.517908	9/7/1962	790	250	1	789
350045-- Ind	40.657	-74.575991	7/2/1963	230	106.5	3.5	226.5
271193-- Jockey Hollow Camp 1673	40.7623	-74.55099	12/10/1963	480	96	18	462
130052-- TW11/Ltwd 7	40.7995	-74.359762	5/21/1965	180	301	6	174
130093-- PW 4	40.8712	-74.312927	9/20/1965	170	101	20	150
390008-- Ac 4	40.6873	-74.434875	12/18/1965	210	303	65	145
270021-- Interpce Oep 1	40.8679	-74.439598	4/11/1966	318	213	32	286
270182-- PW 13	40.8532	-74.385707	4/30/1966	180	47	0	180
271746-- PW 1	40.8162	-74.388763	5/13/1966	178	110	10	168
270159-- Shongum	40.8282	-74.501267	10/6/1966	410	155	0	410
270686-- 339	40.8857	-74.517934	10/15/1966	560	148	6	554
270016-- Morris Treat 2	40.8062	-74.456265	1/16/1967	260	85	5	255
270007-- Homestead	40.8337	-74.357929	1/18/1967	190	72	1	189
270077-- Black Brook 1	40.7987	-74.404041	5/8/1967	200	121	5.17	194.83
270062-- PW 6	40.9134	-74.500156	8/10/1967	520	163	20	500
130090-- Hollywood 6	40.8876	-74.29376	8/27/1969	170	200	24	146
270080-- PW 7	40.9134	-74.500156	11/24/1969	520	150	21.5	498.5
270290-- Tw 5	40.8882	-74.56738	8/11/1971	589.58	68	13.03	576.55

270291-- PW5	40.8882	-74.56738	9/29/1971	590.06	64	14	576.06
270008-- Greenhouse	40.7562	-74.384874	11/6/1974	167	73	11.2	155.8
270601-- Dom 1	40.9195	-74.446821	6/6/1975	530	106	21	509
270045-- PW 17	40.8712	-74.427653	12/8/1975	310	136.31	19.31	290.69
270010-- Braidburn Club	40.7693	-74.37904	3/10/1980	176.4	115	37.5	138.9
270255-- 130-Ob	40.9401	-74.569047	4/7/1980	701.72	125	9.67	692.05
271187-- Dom	40.912	-74.61016	1/1/1981	710	188	60	650
271139-- Mendham Test4-Franklin	40.7726	-74.589047	2/4/1981	520	560	20	500
350046-- Dom 1	40.6576	-74.457098	9/16/1981	400	222	3	397
390387-- MW2	40.6854	-74.397651	12/15/1981	460	52.2	30.4	429.6
270239-- Obs I	40.9373	-74.569603	12/30/1981	693.31	29	9.5	683.81
270246-- 65-1	40.939	-74.571547	12/22/1982	700.26	287	11.5	688.76
270657-- Dom	40.9329	-74.4771	4/8/1983	530	42	16	514
270275-- Pressure Relief	40.884	-74.521823	5/13/1983	550	134	82	468
270238-- MWh	40.9387	-74.570436	8/1/1983	699.48	32	10.08	689.4
271194-- Irr	40.7745	-74.574602	9/8/1983	535	400	30	505
270269-- 12D	40.9354	-74.575159	1/21/1984	693.98	30	4	689.98
270278-- 176-Sh	40.9432	-74.560436	3/5/1984	689.31	60	-2.5	691.81
270296-- Obs S5	40.8904	-74.567658	5/10/1984	588.82	28.9	10.07	578.75
270300-- Obs S9	40.8904	-74.567658	5/14/1984	586.53	27.4	8.16	578.37
270298-- Obs S7	40.8893	-74.569325	5/15/1984	585.95	18.6	7.65	578.3
270302-- S11	40.887	-74.566825	5/16/1984	583.14	28	6.98	576.16
270299-- Obs S8	40.8893	-74.569603	5/16/1984	584.14	18.8	5.79	578.35
270097-- Obs 11	40.9365	-74.57627	7/13/1984	696.1	20.3	4	692.1
270305-- D1 Obs	40.8879	-74.567658	8/14/1984	581.78	59.5	6.21	575.57
270306-- D6 Obs	40.8879	-74.569603	8/18/1984	591.45	60.5	12.96	578.49
270099-- 12B	40.9359	-74.575436	9/11/1984	693.62	19.3	4.2	689.42
270100-- 12C	40.9359	-74.575714	9/11/1984	694	13.4	4.2	689.8
270098-- 12A	40.9359	-74.575159	9/11/1984	694.28	18.2	4.9	689.38
270243-- Caf 2	40.9398	-74.569881	9/11/1984	702.74	36	11.2	691.54
270270-- 12E	40.9326	-74.574603	9/11/1984	690.05	20	3.4	686.65
270307-- Dh-3	40.9354	-74.577381	10/12/1984	690.47	51	1.89	688.58

270280-- H-2(D)	40.9387	-74.570436	11/28/1984	699.23	223	10.33	688.9
270281-- H-3(M)	40.9387	-74.570436	11/28/1984	699.16	125	9.61	689.55
270282-- H-1(S)	40.9387	-74.570436	11/28/1984	698.98	25	9.7	689.28
270911-- Dom	40.9304	-74.596548	2/22/1985	700	102	5	695
270268-- 151	40.9418	-74.56627	3/7/1985	694.36	30	4.63	689.73
270093-- Obs 9A	40.9415	-74.570436	3/19/1985	701.8	24	8.3	693.5
270267-- 129-Ob	40.9409	-74.568214	3/20/1985	703.38	23.2	13.3	690.08
270339-- 12I	40.9351	-74.575714	5/29/1985	691.02	13.2	1.5	689.52
270341-- 12F	40.9354	-74.575159	5/29/1985	692.03	14	2.4	689.63
270342-- 12G	40.9357	-74.574881	5/29/1985	695.19	18.5	4.9	690.29
270340-- 12H	40.9357	-74.575992	5/29/1985	693.22	14	3.1	690.12
270332-- 112	40.939	-74.567381	8/1/1985	700	18.2	0.9	699.1
270336-- 31-1	40.9407	-74.570714	8/1/1985	700	24	1.5	698.5
270333-- 130-3	40.9401	-74.569047	8/2/1985	700	28	11.2	688.8
270337-- 64-1	40.9404	-74.571825	8/2/1985	700	22	9.2	690.8
270331-- 34-1	40.9407	-74.569325	8/2/1985	700	24	12.6	687.4
270330-- 31-3A	40.9409	-74.570714	8/2/1985	700	23	9.9	690.1
270326-- 10-2	40.9418	-74.570714	8/2/1985	700	25	9.5	690.5
270328-- 31-4	40.9423	-74.569603	8/2/1985	700	23	9.9	690.1
270327-- 24-1	40.9423	-74.570159	8/2/1985	700	23	7.9	692.1
270334-- 92-1	40.9398	-74.569325	8/6/1985	700	23	7.5	692.5
270335-- 92-2	40.9401	-74.569603	8/6/1985	700	28	11.5	688.5
270329-- 31-2	40.9418	-74.569603	8/6/1985	700	27	5.9	694.1
270087-- 305A	40.9423	-74.565158	10/27/1987	695.81	90.8	5.6	690.21
270244-- Caf 3	40.9398	-74.569881	12/15/1987	702.8	128	11.8	691
270970-- 39-1	40.9343	-74.57127	12/17/1987	692.68	205.4	2.15	690.53
270971-- 39-2	40.9343	-74.57127	12/17/1987	692.39	101.5	2.5	689.89
270972-- 95-1	40.9357	-74.574881	12/17/1987	695.17	120	2.58	692.59
270973-- 95-2	40.9357	-74.574881	12/17/1987	695.17	200	3.96	691.21
270939-- 41-3	40.9365	-74.568214	12/17/1987	689.47	22.1	3.24	686.23
270940-- 41-4	40.9368	-74.568492	12/17/1987	688.61	33.1	1.05	687.56
270941-- 41-5	40.9368	-74.568492	12/17/1987	688.75	17.2	1.84	686.91

270937-- 41-1	40.9373	-74.567381	12/17/1987	692.59	44.6	1.75	690.84
270938-- 41-2	40.9373	-74.567381	12/17/1987	692.59	44.6	1.75	690.84
270954-- I-2	40.9373	-74.570159	12/17/1987	693.22	36.9	3.39	689.83
270942-- 41-8	40.9376	-74.567658	12/17/1987	690.55	35.8	0.52	690.03
270943-- 41-9	40.9376	-74.567658	12/17/1987	690.4	20.8	3.59	686.81
270952-- 112-9	40.9382	-74.569603	12/17/1987	694.33	36	3.74	690.59
270953-- 112-10	40.9382	-74.569603	12/17/1987	694.3	15.7	3.99	690.31
270949-- 112-6	40.9387	-74.56877	12/17/1987	695.59	41.1	4.75	690.84
270950-- 112-7	40.9387	-74.56877	12/17/1987	695.66	51.1	4.88	690.78
270951-- 112-8	40.9387	-74.56877	12/17/1987	695.62	20.9	4.91	690.71
270946-- 112-3	40.939	-74.567936	12/17/1987	698.18	51.1	7.27	690.91
270947-- 112-4	40.939	-74.567936	12/17/1987	698.26	42	7.52	690.74
270948-- 112-5	40.939	-74.567936	12/17/1987	698.16	20.9	7.25	690.91
270944-- 112-1	40.9395	-74.566825	12/17/1987	697.24	37	6.11	691.13
270945-- 112-2	40.9395	-74.566825	12/17/1987	696.87	20.9	5.76	691.11
270955-- 92-3	40.9395	-74.569325	12/17/1987	700.22	55.2	7.98	692.24
270956-- 92-4	40.9395	-74.569325	12/17/1987	699.95	43	7.73	692.22
270957-- 92-5	40.9395	-74.569325	12/17/1987	699.65	30.9	7.4	692.25
270960-- Caf-6	40.9398	-74.569881	12/17/1987	702.71	55.9	8.95	693.76
270958-- 111-1	40.9404	-74.56877	12/17/1987	702.49	41.1	9.39	693.1
270959-- 111-2	40.9404	-74.56877	12/17/1987	702.43	25.9	9.22	693.21
270961-- Obs 9D	40.9407	-74.57127	12/17/1987	702.16	31	6.2	695.96
270962-- Obs 9E	40.9407	-74.57127	12/17/1987	702.17	19.3	6.63	695.54
270967-- 34-2	40.9409	-74.569325	12/17/1987	703.3	18	9.89	693.41
270964-- 31-5	40.9415	-74.569325	12/17/1987	702.98	21	8.43	694.55
270963-- 31-2A	40.9418	-74.569603	12/17/1987	702.13	30.9	6.31	695.82
270966-- 31-7	40.9418	-74.569603	12/17/1987	702.24	20	7.21	695.03
270968-- 10-3A	40.9418	-74.570714	12/17/1987	701.88	264.5	2.4	699.48
270969-- 10-4	40.9418	-74.570714	12/17/1987	701.93	95.5	7.08	694.85
270974-- 10-3	40.9418	-74.570714	12/17/1987	702.03	15	5.64	696.39
271110-- Convent 2	40.7859	-74.428486	3/8/1988	200	588	21.69	178.31
271338-- Dm23-1	40.9198	-74.572659	3/11/1988	851	37	14.87	836.13

271188-- Institutional 1	40.9123	-74.609604	9/20/1988	705	55	32.26	672.74
271185-- Dom 1	40.9087	-74.606826	9/21/1988	700	51	38.53	661.47
271665-- Dom	40.9104	-74.614327	4/4/1989	720	80	34.6	685.4
271263-- 1180-1	40.9245	-74.580714	4/21/1989	689.1	61.3	0.36	688.74
271264-- 1180-2	40.9245	-74.580714	4/24/1989	689.7	20.5	4.18	685.52
271261-- 1181-1	40.9243	-74.580159	4/26/1989	688.5	22	2.34	686.16
271276-- 70-1A	40.9334	-74.575992	5/16/1989	690.12	15.1	1.03	689.09
271306-- TW Washington V Rd	40.8045	-74.521823	6/5/1989	325	543	1	324
271280-- 70-2	40.9343	-74.575714	6/5/1989	691.3	39.6	2.33	688.97
271281-- 70-3	40.9343	-74.575714	6/5/1989	691.5	15	2.8	688.7
271282-- 70-4	40.9343	-74.575714	6/5/1989	691.97	26.3	3.17	688.8
271285-- Wg3-3	40.9348	-74.575436	6/5/1989	690.71	14.8	1.57	689.14
271283-- Wg3-1	40.9348	-74.575436	6/6/1989	690.75	36.8	1.69	689.06
271284-- Wg3-2	40.9348	-74.575436	6/6/1989	690.95	25.3	1.58	689.37
271286-- Wg9-1	40.9351	-74.574881	6/6/1989	691.4	31	0.21	691.19
271287-- Wg9-2	40.9351	-74.574881	6/6/1989	691.37	28.2	1.75	689.62
271288-- Wg9-3	40.9351	-74.574881	6/6/1989	691.35	14.5	1.74	689.61
271289-- 36-1	40.9354	-74.574048	6/6/1989	692.37	45.1	1.14	691.23
271290-- 36-2	40.9354	-74.574048	6/6/1989	692.26	24.6	2.38	689.88
271291-- 36-3	40.9354	-74.574048	6/6/1989	692.21	15.9	2.65	689.56
271292-- Wg11-1	40.9354	-74.574325	6/6/1989	691.89	25.1	3.12	688.77
271294-- Wg11-3	40.9354	-74.574325	6/6/1989	692.34	34.1	1.04	691.3
271293-- Wg11-2	40.9354	-74.574325	6/9/1989	692.47	14.8	2.34	690.13
271297-- 95-3	40.9362	-74.574881	6/9/1989	686.75	20.5	6	680.75
271298-- 95-4	40.9365	-74.574603	6/9/1989	697.08	20.3	6	691.08
271271-- B18-1	40.937	-74.575159	6/9/1989	697.61	20.6	5.8	691.81
271296-- MW12-L	40.9357	-74.575159	6/13/1989	694.11	23.6	24	670.11
271257-- 1181-2	40.9237	-74.580437	6/14/1989	688.2	22.9	1.97	686.23
271258-- 3548-2	40.924	-74.579325	6/14/1989	690.9	13.6	2.76	688.14
271243-- 1178-1	40.9207	-74.58377	6/15/1989	690.2	21.9	5.45	684.75
271244-- 1179-3	40.9223	-74.582381	6/15/1989	687.8	20.2	2.06	685.74
271248-- 1179-1	40.9226	-74.582381	6/15/1989	688	50.2	1.87	686.13

271249-- 1179-2	40.9226	-74.582381	6/15/1989	688.1	30.7	0.96	687.14
271260-- 3548-1	40.9243	-74.579603	6/16/1989	689.44	20.2	2.42	687.02
271246-- 1179-5	40.9226	-74.580159	6/19/1989	691.5	27.3	3.62	687.88
271254-- 1181-3	40.9234	-74.580159	6/19/1989	688.5	22.5	1.75	686.75
271245-- 1179-6	40.9226	-74.579603	6/20/1989	690.6	19.8	2.68	687.92
271250-- 1179-4	40.9232	-74.580714	6/20/1989	689.2	22.2	2.64	686.56
271277-- 82-1	40.9343	-74.572936	6/22/1989	690.03	17.8	1.71	688.32
271278-- 82-2	40.9343	-74.572936	6/22/1989	690.2	27.9	1.94	688.26
271279-- 82-3	40.9343	-74.572936	6/22/1989	690.87	42.8	1.93	688.94
271247-- 1179-7	40.9226	-74.580992	6/23/1989	689.8	18	3.06	686.74
271251-- 1179-4A	40.9232	-74.580714	6/23/1989	689.1	59.4	2.32	686.78
271259-- 1179A-1	40.924	-74.58127	6/28/1989	688.1	22.4	3.36	684.74
271262-- 1179A-2	40.9243	-74.58127	6/28/1989	688.1	19.5	3.24	684.86
271307-- TW Sussex Turnpike	40.8129	-74.512378	7/6/1989	330	293	2	328
271318-- Tw 14 Tingley Rd	40.7901	-74.551268	7/24/1989	360	247	4	356
271253-- 1179D-1	40.9232	-74.582103	8/9/1989	688	20.4	3.34	684.66
271255-- 1179D-2	40.9234	-74.581825	8/9/1989	687.8	20.6	21	666.8
271267-- 1180-3	40.9251	-74.579325	8/10/1989	688.8	17.6	2.09	686.71
271256-- 3548-3	40.9237	-74.579603	9/20/1989	690.1	22.2	2.27	687.83
271272-- 80-1	40.9334	-74.572659	9/25/1989	690.57	29.8	4.18	686.39
271273-- 80-2	40.9334	-74.572659	9/25/1989	690.63	14.4	4.7	685.93
271274-- 80-3	40.9334	-74.572659	9/25/1989	690.77	47.8	4.31	686.46
271299-- 95-5	40.9365	-74.574603	9/25/1989	695.33	21.2	4.5	690.83
271266-- 1179A-3	40.9245	-74.580992	9/26/1989	688.4	22.5	3.59	684.81
271300-- 95-6	40.9365	-74.574603	9/27/1989	694.58	15.1	3.44	691.14
271301-- 95-7	40.9365	-74.574603	9/27/1989	694.5	25.6	4.54	689.96
270325-- Valley Rd 3	40.9284	-74.437654	10/15/1989	501.71	147	6.6	495.11
271269-- C-1B	40.9254	-74.575714	10/27/1989	691.4	22.3	1.67	689.73
271305-- TW Whitehead Rd	40.792	-74.529323	11/14/1989	240	222	23	217
271859-- SUS 0454 Dom	40.9481	-74.408333	6/6/1990	610	173	38	572
270002-- W B Driver 1	40.794	-74.401263	9/19/1990	182	70	33.5	148.5
271132-- Sb3-1 Obs	40.9215	-74.587103	4/1/1991	699	360	24.6	674.4

271131-- Sb2-2 Obs	40.9193	-74.585437	4/15/1991	688.4	35	3.6	684.8
271850-- SUS 0777 Dom	40.7883	-74.567056	4/18/1991	520	155	10	510
271133-- Sb2-3 Obs	40.9193	-74.585437	4/19/1991	688.8	253	13.2	675.6
271134-- Sb3-2 Obs	40.9215	-74.587103	4/19/1991	699.5	180	19.6	679.9
271130-- Sb2-1 Obs	40.9193	-74.585437	4/19/1991	688	168	12.6	675.4
271135-- Sb3-3 Obs	40.9215	-74.587103	4/20/1991	698.8	31	11.3	687.5
271127-- Sb1-1 Obs	40.9162	-74.581548	4/20/1991	690	93	0.9	689.1
271128-- Sb1-2 Obs	40.9162	-74.581548	4/21/1991	690	18	2.5	687.5
271129-- Sb1-3 Obs	40.9162	-74.581548	4/21/1991	690.2	34	2.6	687.6
271852-- SUS 0402 Dom	40.9551	-74.496222	9/27/1991	735	200	50	685
270250-- Lf 1 Obs	40.9193	-74.584048	11/17/1991	692.85	345	21.6	671.25
271854-- SUS 0498 Dom	40.9317	-74.587528	1/27/1992	740	205	15	725
270242-- Caf 1 Obs	40.9398	-74.569881	3/3/1993	702.72	268	14.3	688.42
270304-- Caf 5 Obs	40.9415	-74.56877	4/16/1993	703.24	29	9.3	693.94
270245-- Caf 4 Obs	40.9398	-74.569881	4/16/1993	702.91	173	12.7	690.21
270095-- 9C Obs	40.9412	-74.57127	4/16/1993	702.11	20.3	4.6	697.51
271861-- SUS 0824 Dom	40.7741	-74.562167	4/28/1993	510	248	35	475
271863-- SUS 0488 Dom	40.9325	-74.469	5/21/1993	580	250	20	560
271858-- SUS 0355 Dom	40.9759	-74.349	9/30/1993	760	200	60	700
271865-- SUS 0526 Dom	40.9341	-74.403306	3/10/1994	705	200	38	667
350085-- Harrisons Brook MW-5	40.6565	-74.575991	3/30/1994	225	25	20	205
271853-- SUS 0258 Dom	41.0175	-74.477111	6/28/1994	1,060	152	12	1048
271862-- SUS 0649 Dom	40.8508	-74.579667	12/27/1994	850	225	1	849
271856-- SUS 0238 Dom	41.0216	-74.524917	3/10/1995	845	200	38	807
272072-- Trail 2 (G5)	40.7676	-74.532778	3/14/1996	470	10.5	2	468
350107-- Dom	40.6594	-74.457083	4/23/1996	335	185	20	315
270015-- 2 Obs	40.7954	-74.422375	5/6/1997	180.6	62	2.9	177.7
270252-- Lf 3	40.9193	-74.584048	10/7/1997	693.08	157	16.9	676.18
270249-- 65-4	40.939	-74.571547	10/7/1997	700.23	35	9.5	690.73
270292-- Obs S1	40.8879	-74.567658	10/7/1997	581.23	17.7	6.8	574.43
270297-- Obs S6	40.8879	-74.569603	10/7/1997	591.36	28.4	15.5	575.86
270295-- Obs S4	40.8884	-74.568214	10/7/1997	588.64	28.6	15	573.64

270030-- PW 5	40.9154	-74.446376	10/7/1997	499.26	106	11.3	487.96
270109-- PW 2	40.9147	-74.448265	10/7/1997	502.86	45	11.8	491.06
270108-- PW 1	40.9155	-74.447904	10/7/1997	496	43	14.2	481.8
270248-- 65-3	40.939	-74.571547	10/7/1997	700.32	140	10	690.32
270977-- Evergreen Acres 1	40.9176	-74.607382	10/7/1997	705	208	17.4	687.6
270251-- Lf 2 Obs	40.9193	-74.584048	10/8/1997	693.29	65	9.3	683.99
270321-- Geonics 2	40.8957	-74.46071	10/8/1997	514.45	167	36.6	477.85
271184-- Com	40.9023	-74.609882	10/8/1997	720	50	14.1	705.9
270059-- PW 6	40.9037	-74.506823	10/8/1997	520	83	14.1	505.9
270827-- PW 2	40.9034	-74.590159	10/8/1997	650	32	10.4	639.6
270104-- MW16	40.9198	-74.584881	10/8/1997	692.63	20.4	9.8	682.83
270247-- 65-2	40.939	-74.571547	10/8/1997	700	206	11.4	688.6
270035-- PW 5	40.8987	-74.48385	10/9/1997	509.21	201	30	479.21
270189-- PW 4	40.9048	-74.459877	10/9/1997	503.89	64	11.1	492.79
270014-- Exxon Obs	40.7848	-74.414041	8/13/1999	176	120	23.1	152.9
270004-- Clemens Obs	40.8045	-74.399319	9/22/2011	174.91	110	8.82	166.09
272068-- MW83	40.9269	-74.604028	6/10/2013	700	55	34.48	665.52
272107-- MW125	40.7844	-74.470278	7/27/2016	347	38	27	320
270020-- Troy Meadows 1 Obs	40.8409	-74.389319	8/15/2017	192.07	89	10.84	181.23
270006-- Green Acres Obs	40.827	-74.366262	9/5/2017	181	104	9.43	171.57
270023-- Mt Freedom 2 Obs	40.8226	-74.565158	9/5/2017	800	218	2.53	797.47
270005-- Sandoz Obs	40.8073	-74.395985	9/5/2017	188.25	123	26.84	161.41
270003-- W B Driver 2 Obs	40.7968	-74.404874	9/5/2017	178.26	108	21.64	156.62
270001-- Recreation Fld Obs	40.7423	-74.380707	9/5/2017	218.8	150	67.93	150.87
270012-- Briarwood School Obs	40.7776	-74.382929	11/9/2017	198	110	39.87	158.13
270027-- Berkshire Valley 9 Obs	40.9254	-74.604882	12/4/2017	725.64	98	12.58	713.06
270083-- 302D	40.9423	-74.565992	1921	697.02	404	8	689.02
272070-- Wick Farm	40.7654	-74.54475	1964	570	150	41	529
130059-- Canoe Brook 6	40.7687	-74.319038	1977	230	172	68	162
270936-- Mussiker	40.8226	-74.563213	1986	810	111	43	767
270191-- PW 5	40.8829	-74.456904	1970	504.96	332	124	380.96