New Jersey Geological & Water Survey Open File Report 24-2

Water Table Fluctuations, Plainfield and South Plainfield, New Jersey, 2022-2023

New Jersey Department of Environmental Protection—Water Resource Management

STATE OF NEW JERSEY
Governor, Mikie Sherrill
Lt. Governor Dr. Dale G. Caldwell

Department of Environmental Protection
Acting Commissioner, Ed Potosnak

Water Resource Management
Assistant Commissioner, Patricia Gardner

Division of Water Supply and Geoscience
Director, Patricia Ingelido

Geological & Water Survey
State Geologist, Steven Domber

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

New Jersey Department of Environmental Protection (NJDEP)'s core mission is and will continue to be the protection of the air, waters, land and natural and historic resources of the State to ensure continued public benefit. The Department's mission is advanced through effective and balanced implementation and enforcement of environmental laws to protect these resources and the health and safety of our residents.

At the same time, it is critical to understand how actions of this agency can impact the State's economic growth, to recognize the interconnection of the health of New Jersey's environment and its economy, and to appreciate that environmental stewardship and positive economic growth are not mutually exclusive goals: we will continue to protect the environment while playing a key role in positively impacting the economic growth of the State.

NEW JERSEY GEOLOGICAL & WATER SURVEY

The mission of the New Jersey Geological & Water Survey (NJGWS) is to map, research, interpret and provide scientific information regarding the State's geology and groundwater resources. This information supports the regulatory and planning functions of NJDEP and other governmental agencies and provides the business community and public with information necessary to address environmental concerns and economic decisions.

For more information contact:
New Jersey Geological and Water Survey
P.O. Box 420, Mail Stop 29-01
Trenton, NJ 08625-0420
(609) 202-1185
www.dep.nj.gov/njgws/

Cover: Backyard ponding due to rise in shallow groundwater levels, in and next to Cedar Brook Park, Plainfield, New Jersey, April 2022.

Conversion Factors

Multiply inch/pound (U.S. customary) units	by	to obtain metric (SI) units	Multiply inch/pound (U.S. customary) units	by	to obtain metric (SI) units
VOLUME			**FLOW RATE**		
cubic inches (in^3)	16.39	cubic centimeters (cm^3)	million gallons/day (mgd)	0.04381	cubic meters/second (m^3/s)
cubic feet (ft^3)	0.02832	cubic meters (m^3)	cubic feet per second (cfs)	2,447	cubic meters/day (m^3/d)
gallons (gal)	3.785	liters (L)	million gallons/year (mgy)	3,785	cubic meters/year(m^3/y)
gallons (gal)	$3.785X10^{-3}$	cubic meters (m^3)	gallons/minute (gpm)	.06309	liters/second (L/s)

Note: In this report 1 billion = 1,000 million; 1 trillion = 1,000 billion

New Jersey Geological & Water Survey Reports (ISSN 0741-7357) are published by the New Jersey Geological & Water Survey, PO Box 427, Trenton, NJ 08625-0427.

This report, and information on additional NJGWS reports, is available at: www.dep.nj.gov/njgws/.

Figures used in this report were developed using New Jersey Department of Environmental Protection Geographic Information System digital data. References available upon request.

Note: Any use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the New Jersey state government.

Epigram

The water table is an environmental pulse to use
It's a part of the water cycle on which to cruise
Always moving up or down
Here and there under ground
It is the pivotal item to make the news.

from 'The Water Table' by Harry E. LeGrand, Sr. (2009)

NEW JERSEY GEOLOGICAL & WATER SURVEY

Open-File Report 24-2

Water Table Fluctuations, Plainfield and South Plainfield, New Jersey, 2022-2023

by

Jeffrey L. Hoffman[(retired)], Mark French, Bart Cerami, and Brian Buttari
New Jersey Geological & Water Survey

New Jersey Department of Environmental Protection
Water Resource Management
New Jersey Geological & Water Survey
PO Box 420, Mail Code 29-01
Trenton, NJ 08625-0420

2024

TABLE OF CONTENTS

ILLUSTRATIONS

TABLES

Water Table Fluctuations, Plainfield and South Plainfield, New Jersey, 2022-2023

Abstract

The Middlesex Water Company (MWC) has withdrawn groundwater from its Park Avenue well field in South Plainfield, Middlesex County for over a century. The well field is situated along Cedar Brook, south of Cedar Brook Park, Plainfield, Union County. Withdrawals began in the late 1890s, increasing to about one million gallons a day (mgd) by the early 1900s, approaching 9.0 mgd by 1922. In 2020 withdrawals for public supply were between 8.0 and 9.0 mgd at peak demand times. Water is withdrawn from both the Plainfield glacial outwash and the bedrock Brunswick aquifers.

In 2019 and 2020, the State of New Jersey adopted new maximum contaminant level (MCL) regulations for PFAS (per- and polyfluoroalkyl substances) for drinking water systems. PFAS substances are a long-lasting and widely-used family of chemicals common in industrial and commercial applications for over 70 years and which are linked to harmful health effects in humans and animals. The MCL for PFNA (perfluorononanoic acid) is 13 parts per trillion (ppt) and quarterly monitoring was required starting on January 1, 2020. The MCL for PFOS (perfluorooctanesulfonic acid) is 13 ppt and the MCL for PFOA (perfluorooctanoic acid) is 14 ppt. Quarterly sampling for both PFNA and PFOS was required starting on January 1, 2021. MCL compliance is based on a running average of quarterly samples taken over the course of one year for each contaminant.

MWC's groundwater compliance sampling showed PFOA concentrations approaching and then exceeding the new limits in 2021. Following customer notification and as an interim measure to reduce customer exposure, MWC ceased withdrawals from its Park Avenue well field. By June 2022, MWC began successfully treating groundwater for PFAS compounds with completion of its Phase 1 advanced treatment facility. The entire project was completed by June of 2023 and the Park Avenue well field pumping returned to normal rates.

In early 2022 and after the Park Avenue well field ceased pumping, nearby residents bordering Cedar Brook Park began reporting standing water in backyards and extraordinary amounts of water in basements to local and, ultimately, state authorities. The New Jersey Geological and Water Survey (NJGWS) began an investigation of the hydrogeology of the area in April 2022. NJGWS installed four shallow wellpoints to monitor water levels. NJGWS also installed an automatic data recorder in a glacial overburden observation well in MWC's Park Avenue well field.

In response to this water-table rise, and with urging from the New Jersey Department of Environmental Protection (NJDEP), MWC modified its plans and completed Phase 1 construction of the water treatment plant at the site, and resumed partial pumping of the Park Avenue wellfield on June 6, 2022 with production rates ranging between 4.0 and 5.0 mgd. On June 21, 2022 MWC began discharging an additional 1.0 mgd of groundwater to nearby Cedar Brook in order to create additional drawdown as part of an aquifer test designed to provide information on how precipitation, pumping, and seasonal changes affect groundwater levels in the area. These withdrawals lowered the water table, reducing inflows to basements, and eliminating surface water ponding. The warm, dry summer of 2022 also had an impact on water-table levels by decreasing recharge and increasing evapotranspiration. However, in late 2022 MWC noticed increasing PFOA concentrations in the treated water coming out of the Phase 1

plant. In order to prevent breakthrough concentrations greater than allowable limits and to protect public health, MWC reduced waterflow to the temporary treatment plant to approximately 2.0 mgd while still pumping 1.0 mgd of untreated groundwater to Cedar Brook. This reduction allowed groundwater levels to rise again producing a resumption of some surface water ponding and an increase in inflows to nearby, impacted basements. The new permanent water treatment plant began to come online in May 2023. Production capacity increased in stages until reaching its full capacity of 12.0 mgd in June 2023. Pumping untreated water to Cedar Brook stopped at the end of May 2023. As the pumping increased groundwater levels dropped, surface water ponding was eliminated and basement flooding was reduced.

Pumping at the Park Avenue well field since the late 1890's created a cone of depression that dewatered nearby areas. This allowed later development on the newly dry land near the well field. When withdrawals at the well field stopped in late 2021 water levels in the water table began to rise, re-activating historic wetlands impacting backyards and basements. MWC's renewed pumping in June 2022 reversed this water-table rise. Continual pumping at pre-shutdown rates will return the water table to pre-shutdown levels.

Rises in groundwater levels after a major pumping source is removed, with impacts on new development, have been noted elsewhere in New Jersey and the world. It is likely any major pumping center in a water-table aquifer has created a cone of depression. Cessation of this pumping will result in a rising water table, impacts on the built environment, and potential re-establishment of any preexisting conditions, such as wetlands.

Introduction

Plainfield is in southern Union County and borders South Plainfield in northern Middlesex County, New Jersey (fig. 1). The water-table rise in Plainfield and South Plainfield, near Middlesex Water Company's Park Avenue well field, in early -2022, occurred shortly after groundwater withdrawals at the well field stopped in late -2021. When withdrawals, via a temporary treatment plant, partially resumed in mid--2022 nearby groundwater levels declined. A decrease in withdrawals in late -2022 resulted in a resumption of nearby groundwater rises. Completion of the permanent water treatment plant in June 2023, and resumption of normal withdrawals, produced a significant drawdown in water levels.

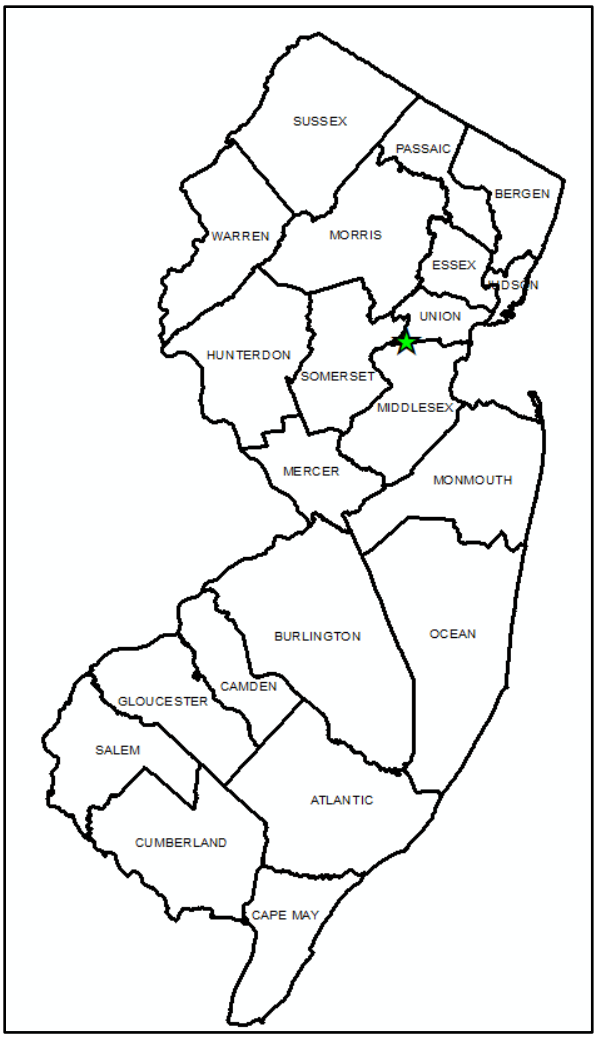

Figure 1. Location of Plainfield and South Plainfield, New Jersey

The increase in groundwater levels produced ponding of water in Cedar Brook Park, several backyards, and increased water infiltration into several basements. These conditions led impacted residents to request assistance from local municipal and county officials, and the State of New Jersey. The New Jersey Geological and Water Survey (NJGWS) began a study of how reductions in withdrawals, along with precipitation, impacted the water table.

The NJGWS and NJDEP would like to acknowlege the assistance of the Middlesex Water Company (MWC) in this investigation for allowing access to their onsite observation well, the installation of a temporary treatment plant, and restarting groundwater withdrawals in mid-2022.

Middlesex Water Company began withdrawing water from its well field in South Plainfield in the late 1890's (fig. 2). By 1907, 12 wells were reportedly pumping and withdrawals from this well field reached just over a million gallons per day (mgd) (Lender, 1994). In 1916, several new wells were drilled and by 1922 the well field was capable of pumping over 9.0 mgd. By 2020 withdrawals were between 8.0 and 9.0 mgd on peak demand days.

Cessations of groundwater extraction, as at MWC's Park Avenue well field, have been repeated for myriad reasons around the world leading to water-table rise, or groundwater rebound. This has, in turn, impacted underground infrastructure, and caused surface flooding impacting surface infrastructure. Studies of this phenomenon have been published in scientific, engineering, and urban planning journals in every language. The following examples, one from western Long Island, New York, another from the plain east of Naples, Italy, and yet another in Sussex County, New Jersey are of particular interest. The

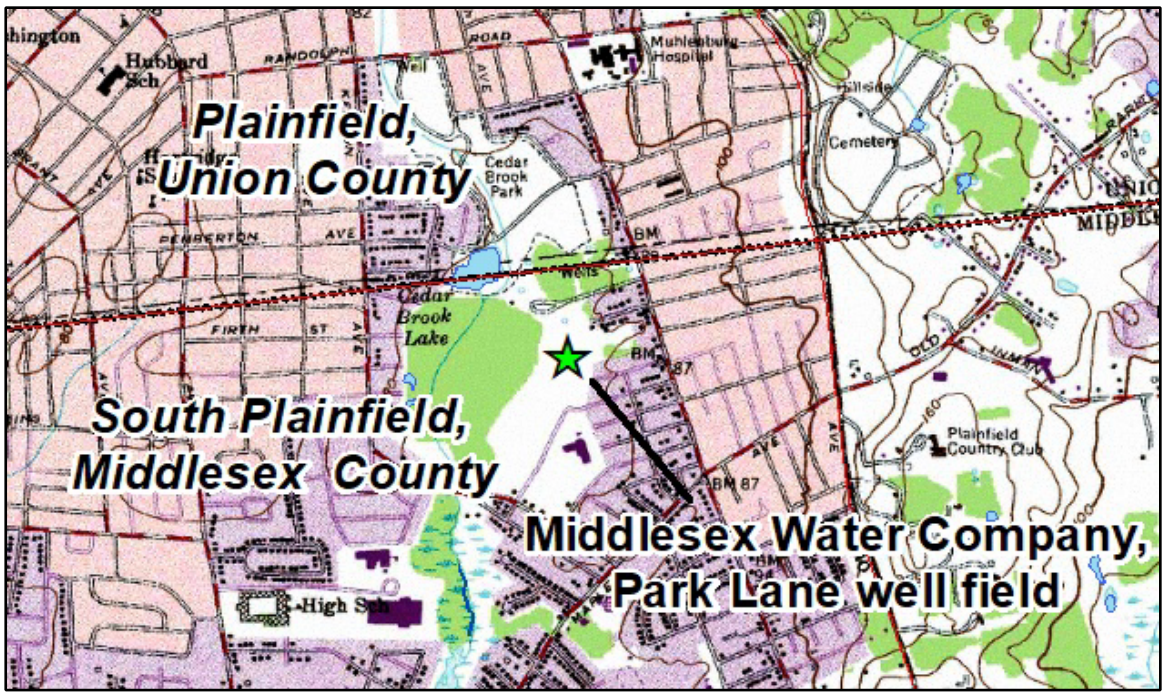

Figure 2. Location of Middlesex Water Company's Park Ave. well field, South Plainfield, NJ (background detail from USGS Plainfield NJ 1:24,000 quadrangle)

root cause for each is the shutdown of public supply and private wells with impacts to encroaching development as seen in the case of the Park Avenue Well field shutdown.

In western Long Island, beginning in 1903 and continuing over the next 50 -plus years, withdrawals of groundwater resources increased to unsustainable levels as groundwater recharge lessened due to urbanization, construction of impervious surfaces, and sanitary sewer and stormwater management systems redirecting runoff. These caused severe declines in the regional water table, disappearance of surface water features (streams, ponds, lakes, and wetlands) and induced increased saltwater intrusion into the aquifer. The increased urbanization also caused increased groundwater pollution reducing the groundwater quality. These combined factors led to the cessation of groundwater withdrawals, first in eastern Kings County in 1947, then in western Queens County in 1974. Since the cessation of the groundwater withdrawals the water table quickly recovered to pre-1906 levels resulting in impacts to underground infrastructure (deep basements and subway tunnels, for example) constructed in the preceding decades. Mitigation of the rising water table has required dedicated and ongoing dewatering operations. (Nemickas, and others, 1989)

Increased groundwater use from the aquifers east of Naples since 1950 led to a large decline in the water table. Expanding urbanization and population growth drove this increase in groundwater extraction. By 1989 the increased development had caused severe impacts to the output of the large well fields. The severe declines in the water table caused impacts to surface water and increased industrial and commercial development impacted the groundwater quality. These factors made groundwater withdrawals unsustainable, and in 1990, the well fields were shut down. The resulting rebound in groundwater levels has led to strong socio-economic impacts in the surrounding urban and agricultural areas. Impacts included groundwater flooding of agricultural and archeological areas;

flooding of basements, buildings, and underground infrastructure, including subway tunnels. The accompanying ground surface uplift has also caused structural damage. Mitigation required dewatering operations, reconstruction, modification, or abandonment of impacted structures, archeological sites, and agricultural features. (Coda, and others, 2019)

Nicholson (2016) reports on an instance of water-table rise in Sussex County following dewatering cessation at the Lime Crest marble quarry. When the dewatering ceased the rising water table supported re-establishment of historic wetlands which impacted new homes and infrastructure. When the quarry was reactivated, and dewatering resumed, the problems improved.

The impact and outcome near Cedar Brook Park is similar to those presented above. The aquifers in all these examples included unconsolidated sediments; sands, gravels, and, in one case, pyroclastics; of alluvial, glaciofluvial, lacustrine fan, and volcanic origin. They are highly conductive, productive, and conducive to easy exploitation. Urban industrial, commercial, and residential development spread to include areas adjacent to where the wells were operated. In the cases of Long Island and Naples, this expansion led to over-exploitation of the groundwater resource, the reduction of the groundwater quantity and quality, and the eventual cessation of groundwater production. A reduction in the water quality in the Park Avenue wells led to a temporary shutdown of production in South Plainfield.

The impacts were similar in all three cases, groundwater flooding of low-lying surface areas and flooding of underground infrastructure; in particular, basements of residential and non-residential structures. Mitigation efforts, in the cases of Long Island and Naples, focused on critical infrastructure and buildings in the form of localized dewatering or ditching operations to prevent the occurrence of serious physical and flooding damage. Remediation for private businesses, buildings and homes was usually left up to the owners. Basement pumping may be enough to keep the rising water and associated damage under control. However, the flooding in and around these buildings can be catastrophic and the only recourse in that case was outright abandonment and/or demolition.

In the case of the Cedar Brook Park area, the water utility is remediating the groundwater rise by restarting groundwater supply withdrawal operations and addressing the groundwater quality issue by installing permanent treatment. The water table was lowered to prior levels, reducing the impact in the Cedar Brook Park area. However, while this well field has been operating for upwards of 100 years, that is no guarantee that it will continue to operate for another century. And when it is finally shut down, impact from groundwater rebound will likely return with limited chances of remediation unless remedial pumping is instituted by state, county or local entities.

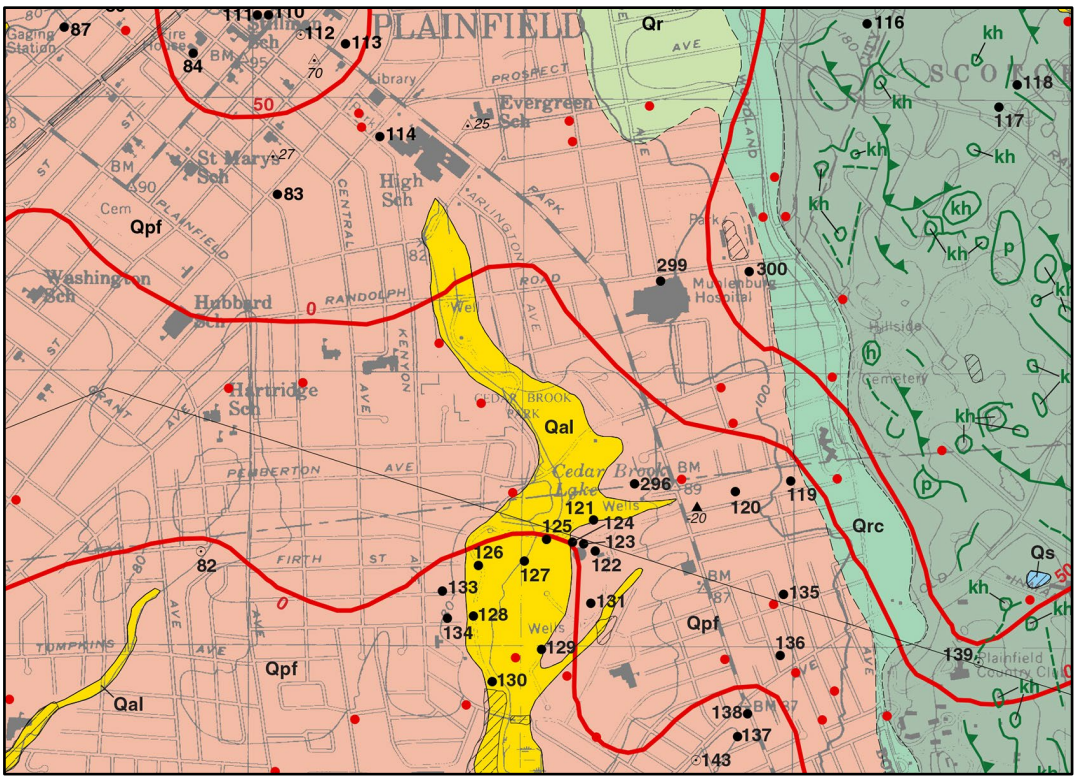

Figure 3. Surficial geology, Plainfield and S. Plainfield near Cedar Brook Park and MWC Park Ave. well field. Qpf-Plainfield deposit; Qr-Rahway Till; Qrc-Rahway Till colluvium; Qtmr-Till of the Terminal Moraine (Rahway Till); (detail from Stanford, 2009)

Geologic Setting

The Park Avenue well field in South Plainfield and Cedar Brook Park in Plainfield were established within the Cedar Brook Creek stream valley. Stanford (2009) reports the stream valley is filled with recent alluvium (Qal), fluvial sediments associated with surface water features containing sand, silt, clay, pebble gravel with varied amounts of organic matter (fig. 3). The alluvium was deposited as sand and gravel stream channels and associated silt, sand, and clay floodplain deposits. It can be as much as 15 feet thick. It cuts into the underlying Pleistocene Plainfield deposit (Qpf) of late Wisconsinan age (25,000 to 18,000 years ago).

The Plainfield deposit is predominantely glaciofluvial braided-stream sediments with minor basal glaciolacustrine sediments. It contains reddish-brown, light reddish-brown, light gray, and gray, fine to medium sand, silt, pebbly sand, medium to coarse sand, pebble to cobble gravel, and minor clay. It is up to 90 feet thick. It thins east from the contact with the Rahway Till of the Terminal Moraine (Qtmr) to the west and southwest. It was deposited by glacial meltwater as the glacier stood at the terminal moraine, forming a sandy plain. The glacial deposits sit unconformably on the much older, fractured bedrock of the early (Lower) Jurassic, late (Upper) Triassic Passaic Formation. (fig. 4, Stanford, 2009)

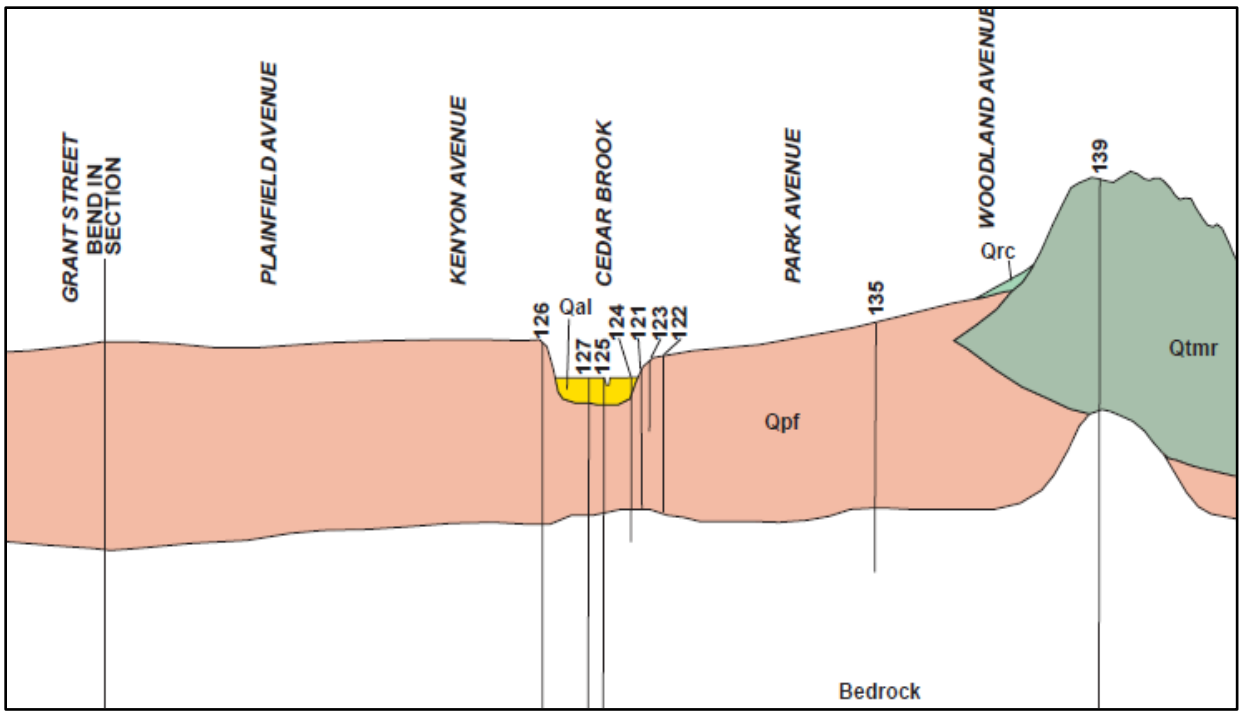

Figure 4. Geologic cross-section through the Cedar Brook floodplain and MWC Park Ave. well field. Qpf—Plainfield deposit; Qrc-Rahway Till colluvium; Qtmr-Till of the Terminal Moraine (Rahway Till); Qal-Alluvial deposits. The numbered vertical lines represent wells. (detail from Stanford, 2009)

The Passaic Formation was deposited during the late or Upper Triassic (237 million years ago (Ma.) to 201 Ma.) through the early or Lower Jurassic (201 Ma. to 183 Ma.). The northwest-dipping formation is made up of interbedded reddish-brown, less commonly maroon, or purple, fine- to coarse-grained sandstone, siltstone, shaly siltstone, silty-mudstone, and mudstone. Interbedded, gray-bed sequences occur in the southeastern section of the quadrangle. It is up to 11,480 feet thick. (Volkert, and others, 2013)

Hydrogeology

The glaciofluvial sand and gravel Plainfield deposit (Qpf) yields water to several public supply wells e.g., MWC Park Ave. Well 23, Sprague Avenue wells, 1 and 2, in South Plainfield. These wells yield 1,420, 1,600 and 1,055 gallons per minute, respectively. They produce from a basal sand and gravel at depths between 50 and 100 feet below ground surface, which is overlain by finer-grained sand and clay. These wells, as well as MWC Park Avenue Wells 18, 19, 20, and 21, are completed in the buried, preglacial Raritan valley, which contains the thickest section of the sand and gravel Plainfield deposit in the region. Additional water may be available in this buried valley where sand and gravel is more than 50 feet thick, which generally occurs where the bedrock surface (Passaic Formation) is below the zero foot mean sea level elevation. Logs of several other, non-MWC wells in the buried valley west of South Plainfield record finer grained material overlying basal sand and gravel, similar to the sequence in the South Plainfield area, although none of these wells produces from the sand and gravel. East of the South Plainfield wells, the buried valley deposits are overlain by Till of the terminal moraine (Qtmr). Till is less permeable than sand and gravel, potentially limiting production in this part of the buried valley. (Stanford, 2009)

Where the Plainfield deposit (Qpf) and the Rahway Till (Qr, Qtmr) in the South Plainfield area are between 20 and 50 feet thick, they provide groundwater storage for, and recharge to a major part of the underlying fractured-bedrock Brunswick aquifer; i.e., the Passaic Formation (JTrp). Groundwater occurs in the secondary porosity of this aquifer including gently dipping, bedding fractures, and subvertical fractures. Flow is primarily along the bedding fractures. These are connected by the subvertical fractures providing pathways for groundwater to infiltrate and flow between the bedding fractures. While being generally less porous and permeable than the overlying glacial sand and gravel, the fractured-bedrock aquifers are a valuable groundwater resource in the South Plainfield area and in northern New Jersey in general. Public-supply wells completed in the bedrock along Green, Cedar, and Stony Brooks are recharged from this surficial reservoir and produce substantial supplies of drinking water (Stanford, 2009, Herman, 2010, Michalski, 2010).

History of Withdrawals

The original Middlesex Water Company (Middlesex) was founded on April 20, 1896, with the intention of supplying water to the northeastern section of Middlesex County (Lender, 1994). Middlesex began negotiations with customers to provide them with a water supply, however, due to difficulties in finding an adequate water source, it struggled to establish itself as a water supplier. On May 25, 1896, the Midland Water Company (Midland) was incorporated, with the intention to sell water to Union, Middlesex and Somerset Counties. Midland purchased a site in South Plainfield that had proven reserves of groundwater. The two companies shared some of the same directors. In June of 1897 talks began between the two companies to merge the two companies, and on July 20, 1897, a certificate of

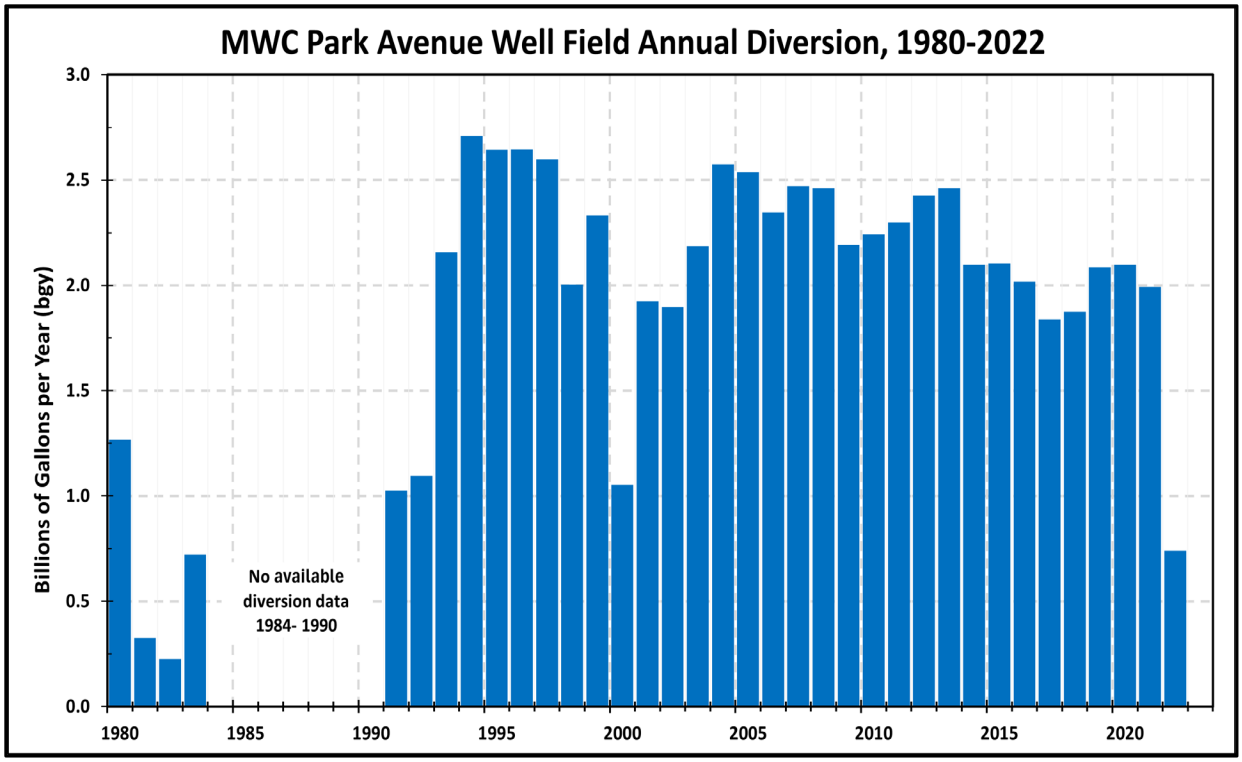

Figure 5. Annual MWC Park Ave. well field withdrawals, 1980-2022. (Cerami, B., written commun., 2023)

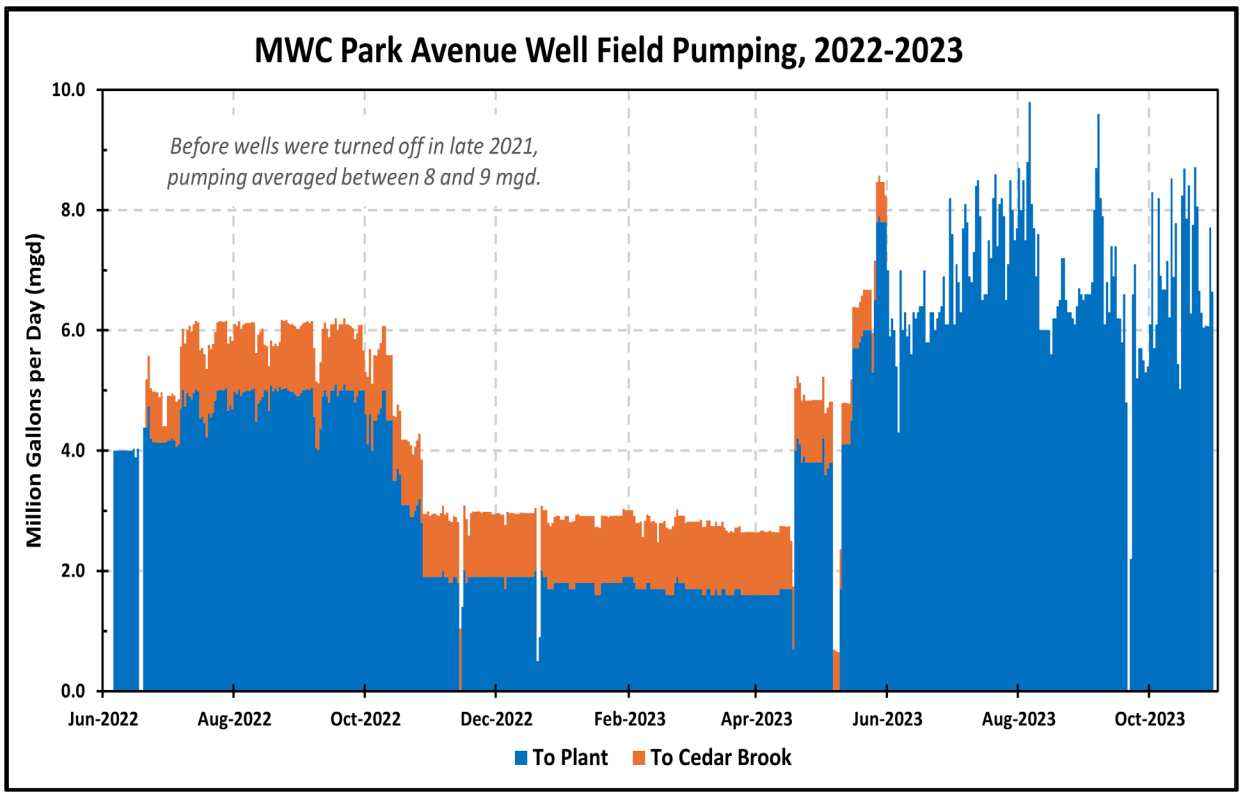

Figure 6. Daily withdrawals at MWC Park Ave. well field, 2022-2023. (MWC, written commun., 2023) Permanent treatment was completed in June of 2023.

incorporation was filed with the State of New Jersey to merge the two companies, which retained the name Middlesex Water Company (MWC) (Lender, 1994).

In 1898, MWC drilled a well field in South Plainfield. By the early 1900s the field grew to twelve wells, with a total yield of nearly a million gallons of water per day (mgd). By July 1907 the company was pumping over 1.3 mgd (Lender, 1994).

In April 1916 MWC began drilling additional wells at Park Avenue, also in South Plainfield. It also began work on a new pump station at the Park Avenue location. The pump station came online quickly, and in late 1916 the combined capacity of its three pumps reached 8.5 mgd. By 1922, the Park Avenue well field had a total of 16 wells, with the pump station capable of pumping over 9.0 mgd (Lender, 1994).

Total annual withdrawals averaged between 2.0 and 2.5 billion gallons per year (bgy) in the period 1993 - 2021 (fig. 5). Withdrawals ceased in late 2021 due to detection of PFOA in groundwater greater than the new MCL standard that became effective January 1, 2021. Withdrawals to a temporary treatment plant, and discharge to nearby Cedar Brook, started in June 2022 as installation of the permanent treatment plant was accelerated (fig. 6). During late 2022 withdrawals were on the order of 6.0 mgd and then declined in late 2022 to prevent PFOA breakthroughs in the filer media. Withdrawals increased in May 2023 as the permanent treatment plant started to come online. With the completion of the new treatment plant in May 2023, the Park Avenue well field has a capacity to pump up to 12.0 mgd.

Land Use and Wetlands Changes

The withdrawals from MWC's Park Ave. well field began in the early 1900's. Before that time wetlands filled the area adjacent to the well field and along Cedar Brook and the region was much less developed. Figure 7 shows a detail of the USGS 1887 Plainfield topographic quadrangle for the area with 2012 mapped wetlands superimposed. In 1887, there was a significant wetlands area to the north of the Park Avenue well field bordering Cedar Brook that was much reduced in 2012. As the water table was drawn down by pumping of the well field, the wetlands were diminished, and development increased. In 1921, the Union County Park Commission was established, and the Olmsted Brothers landscape architecture firm was hired to design a county park system. In 1924, the preliminary plan for Cedar Brook Park was created and the park was completed in 1930. (Wikipedia, 2024) New residential streets and housing were constructed adjacent to the new park within the now dry wetlands. The area immediately adjacent to the Park Avenue well field has remained relatively unchanged, as the development was completed to the north and east. Figures 8 through 10 show aerial photos for 1930, 1951, and 2022, respectively, highlighting this development.

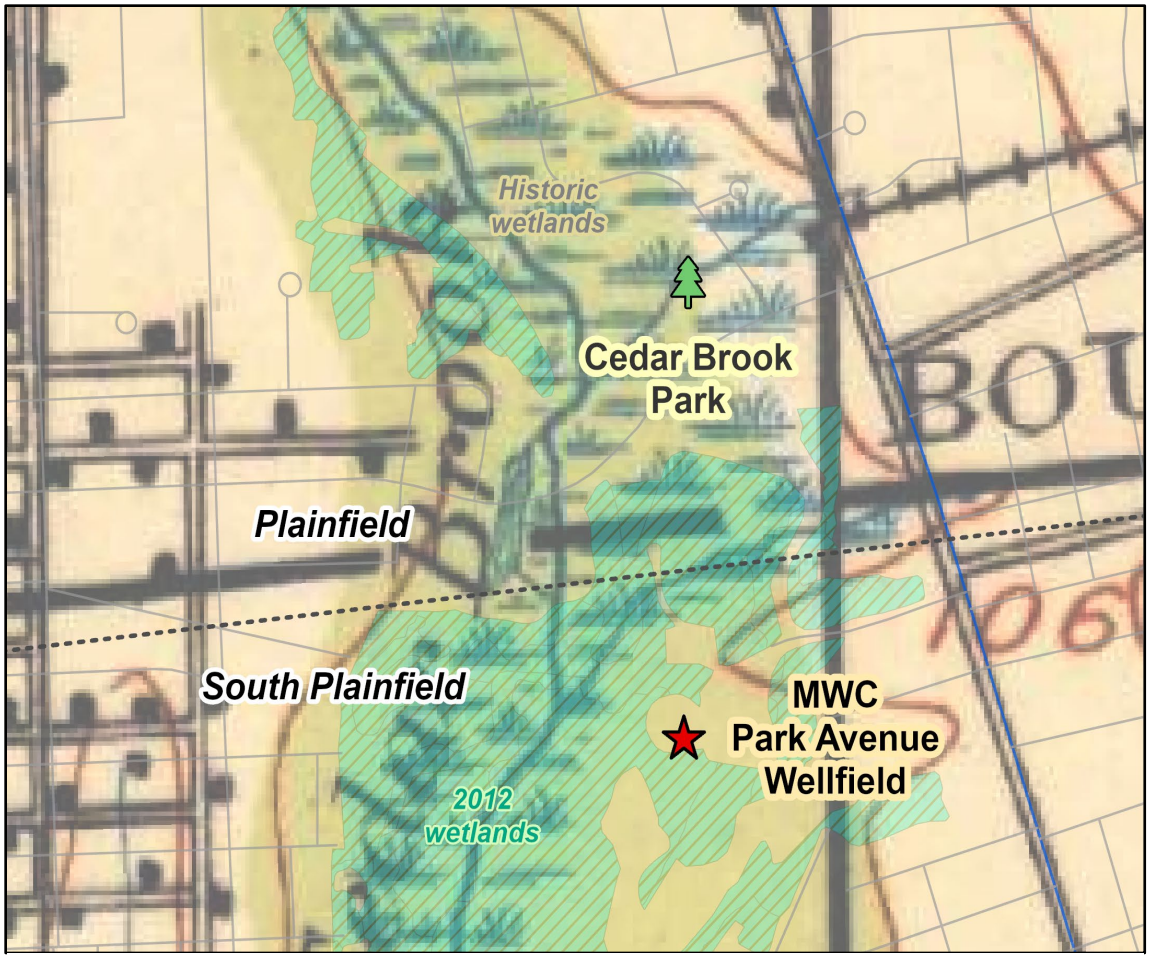

Figure 7. Detail from the 1887 (1921 ed.) USGS 1:62,500 quadrangle showing historic wetlands (sage-green areas with wetlands symbols) prior to development with an overlay of 2012 wetlands (green hatched teal areas) in the Cedar Brook Park and MWC Park Ave. wellfield area. The thin gray lines are the modern road network.

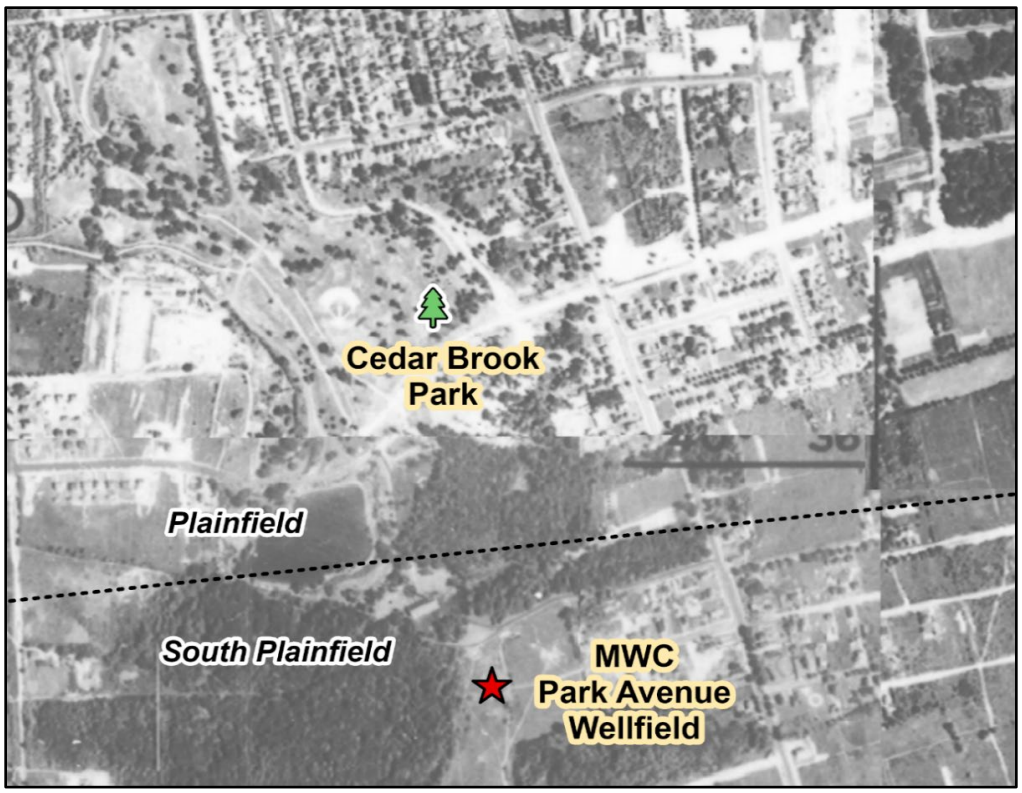

Figure 8. 1930 aerial photograph showing Cedar Brook Park and the location of the MWC Park Ave. well field.

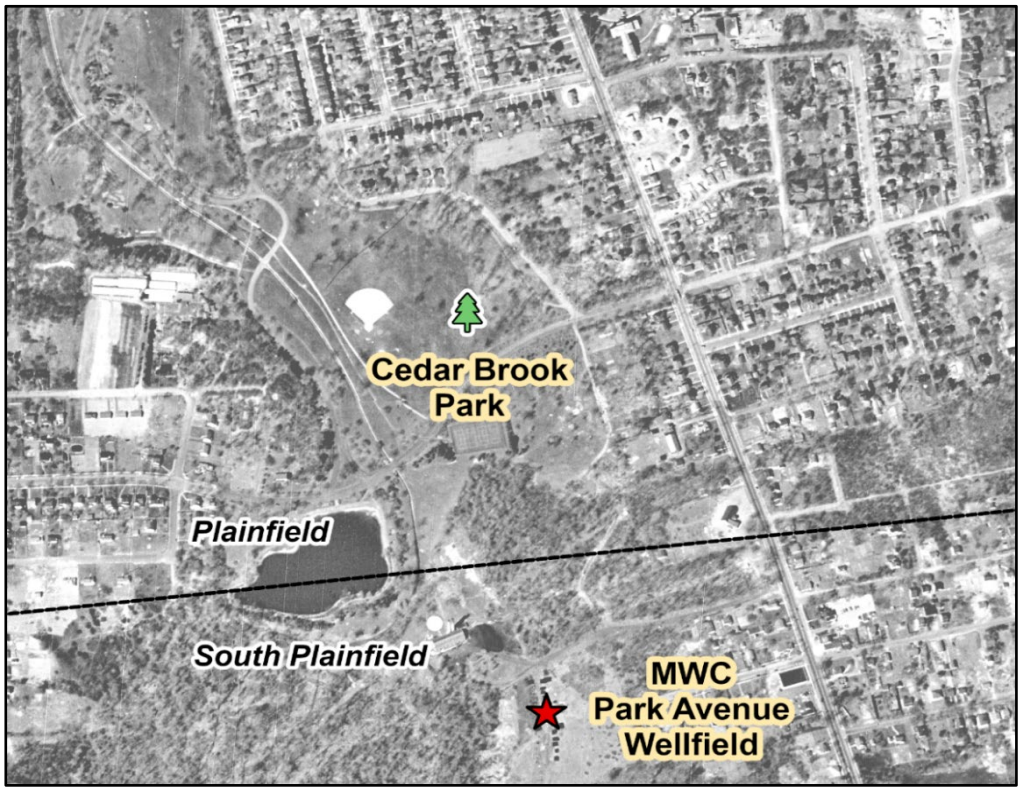

Figure 9. 1951 aerial photograph showing Cedar Brook Park and the location of the MWC Park Ave. well field.

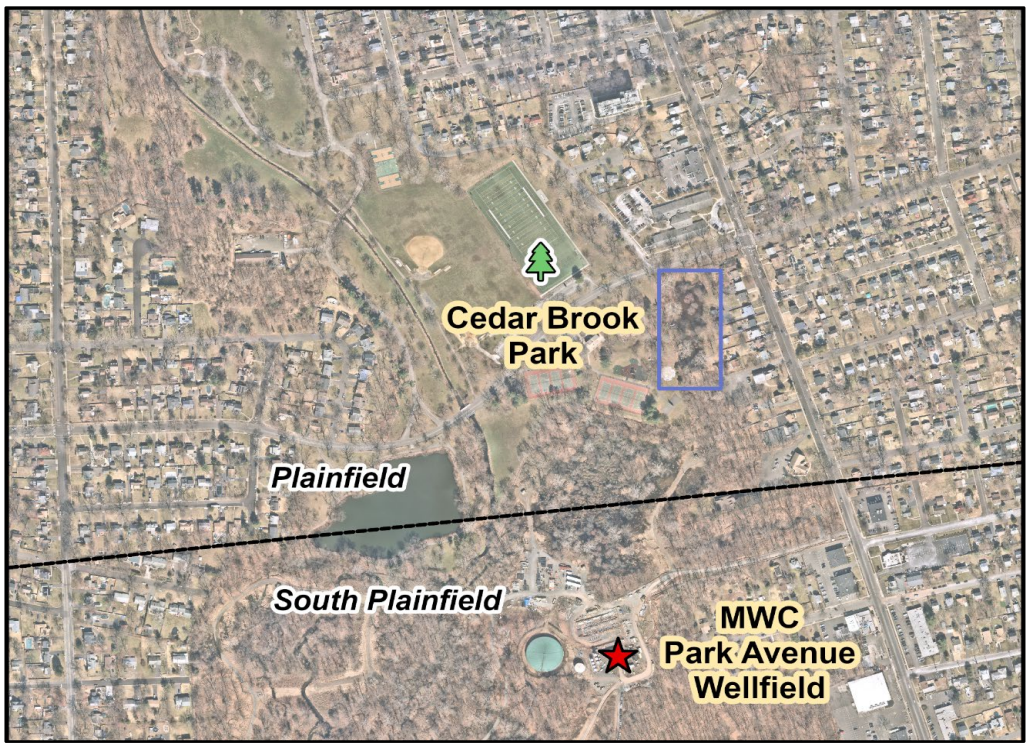

Figure 10. 2022 aerial photograph showing Cedar Brook Park and the location of the MWC Park Ave. well field. Backyard flooding can be seen inside blue box.

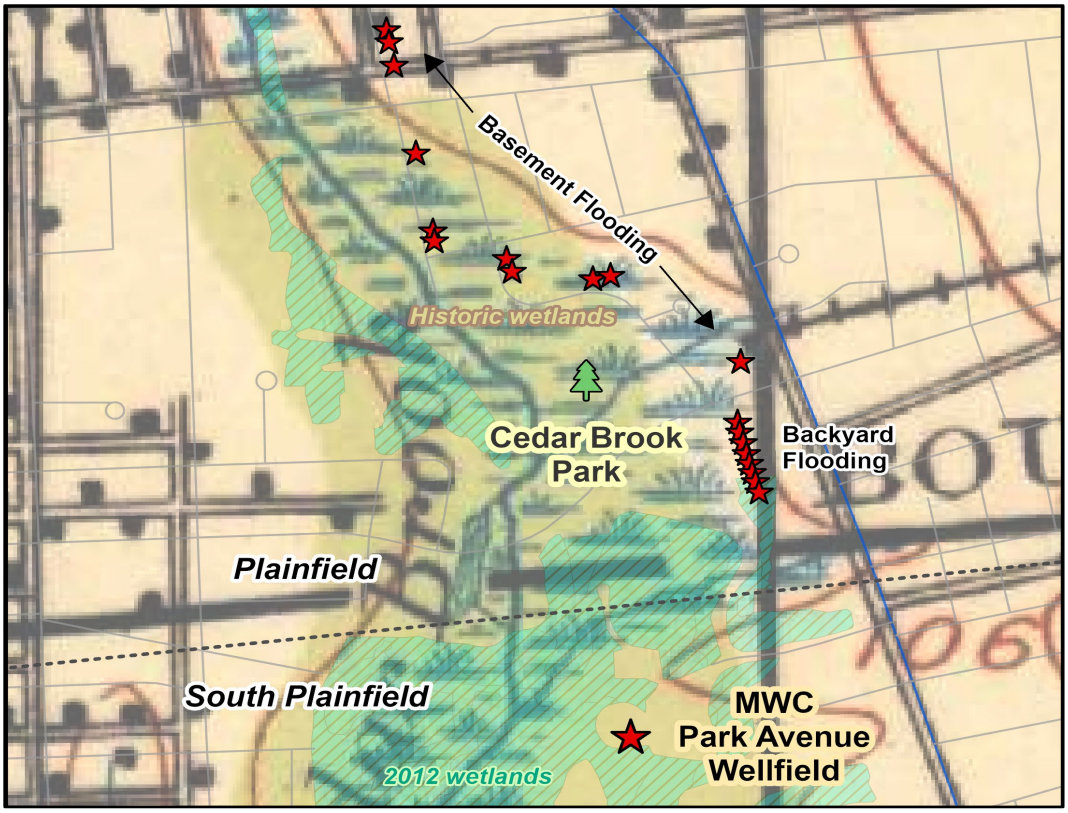

Figure 11. Basement and backyard flooding complaints overlain on the 1887 USGS quadrangle with modern and historic wetlands from figure 7.

Observed Groundwater Rise Problems

In early 2022 some residents north and east of the Park Avenue well field reported water intrusion into previously dry basements. Additionally, just west of Park Avenue water began ponding at the surface, as seen in figure 10. Figure 11 shows the reported locations of wet basements along with the current road network and mapped wetlands on a basemap of the 1887 USGS topographic quadrangle. These reports led to an investigation of the causes of this rise in the water table.

Wellpoints and Observation Well

In response to reports of a rising water table, the New Jersey Geological and Water Survey (NJGWS) initiated a study of groundwater levels. On April 21, 2022, NJGWS staff met with a representative of the Middlesex Water Co. to select sites to monitor groundwater levels in and around Cedar Brook Park in Plainfield NJ. Five locations were chosen to install a shallow (<10 feet) wellpoint to observe the groundwater level before and after pumping conditions of the MWC. Of the five, four sites were identified as suitable for installation of the wellpoints. These are identified as WP1, WP2, WP3, and WP4 (fig. 12). All wellpoints were installed on April 28, 2022 by NJGWS staff.

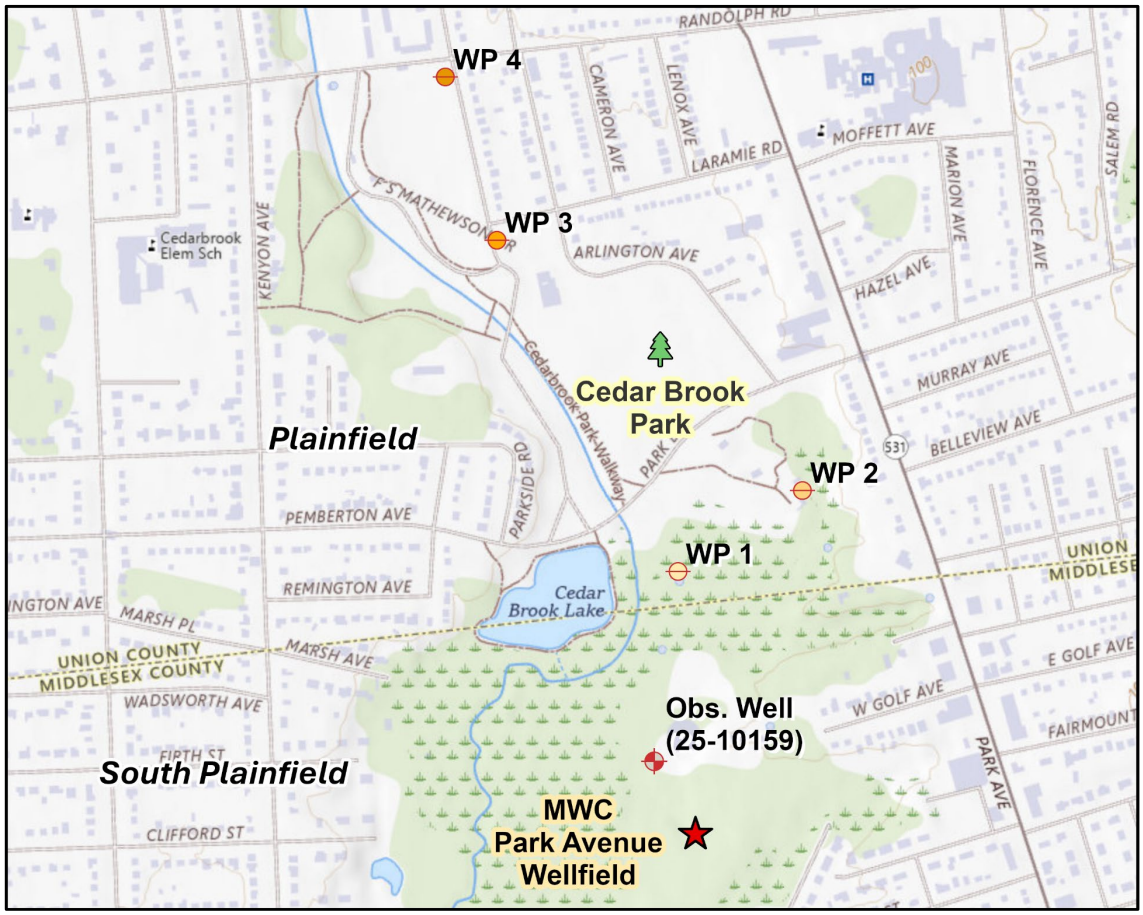

Figure 12. Location of wellpoints and Middlesex Water Company well field (background detail from USGS Plainfield NJ 1:24,000 quadrangle).

WP1 is located next to the MWC production well 21 at the north end of their well field. This site was chosen due to its proximity to Well 21 in order to monitor drawdown when Well 21 is pumping. The wellpoint consists of a 1.25 inch diameter by 3-foot length drive-tipped galvanized well screen, driven into the ground using a fence post hammer. The screen advanced to a finished depth of 9.65 feet below ground surface. The wellpoint was left with 2.7 feet of 1.25 inch casing above ground surface for an overall length of 12.35 feet from the marking point above grade to the finished depth. The screened interval was finished from 6.65 to 9.65 feet below ground surface. The initial static water level taken after installation was 0.79 feet below ground surface.

WP2 is located between the tennis courts and a water splash playground which are located in the southeast portion of Cedar Brook Park near the rear property line of the residential properties along Park Avenue. This is close to the area that became flooded when pumping stopped, and as such was prioritized for water level monitoring. The wellpoint installed was a 1.25 inch diameter by 4-feet length drive-tipped galvanized well screen. The use of the fence post hammer to install the wellpoint was initially attempted, however it was soon apparent it was not suitable. The well screen was then advanced using an electric jack hammer. The screen was advanced to a finished depth of 9.12 feet below ground surface. The wellpoint was left with 3.15 feet of 1.25 inch diameter casing above ground surface for an overall length of 12.27 feet from the marking point to the finished depth. The screened interval was finished from 5.12 to 9.12 feet below ground surface. The static water level taken after installation was 2.28 feet below ground surface.

WP3 is located east of Park Drive and south of Laramie Road. This location was chosen due to its proximity to properties which had sump pumps discharging to the street. The wellpoint is constructed of 1.25 inch diameter by 2-foot drive-tipped galvanized well screen, and was driven into the ground using an electric jack hammer. The screen was advanced to a finished depth of 9.74 feet below ground surface. The wellpoint was left with 2.46 feet of casing above grade for an overall length of 12.2 feet from the marking point to the finished depth. The screened interval was finished from 7.74 to 9.74 feet below ground surface. The initial static water level taken after installation was 3.31 feet below ground surface.

WP4 is located in the southwest corner of the intersection of Randolph Road and Rose Street. This location was chosen due to the proximity to residential properties exhibiting possible flooding based on sump pumps discharging to the street. The installation begun by using a 1.25 inch diameter by 4-feet drive-tipped galvanized well screen, which was driven into the ground using an electric jack hammer and advanced to a finished depth of 9.4 feet below ground surface. The wellpoint is 12.3 feet from the marking point (2.9 feet of casing above ground surface) to the finished depth. The screened interval was finished from 5.40 to 9.40 feet below ground surface, and the initial static water level is 4.05 feet below ground surface.

The Middlesex Water Company provided access to an observation well in their well field (see fig. 12). The well was drilled in 1961, was assigned well permit 25-10159, and is 66 feet, 4 inch deep. The well driller reported the geology as:

Table 1. Geologic Log of MWC overburden observation well

Depth (feet)	Formation	Depth (feet)	Formation
0-1	Brown topsoil	52-59	Medium coarse sand
1-4	Red soil	59-65	Coarse sand and gravel
4-29	Red clay and sand	65-67	Grayish blue clay
29–52	Red sandy hardpan		

Observed Groundwater Levels

Water levels in the four wellpoints were first measured on April 28, 2022. The observed depth to water observations are in figure 13. Depth to water measurements were made twice weekly from April 2022 to May 2023, then weekly thereafter. The wellpoints were removed on Oct 26, 2023.

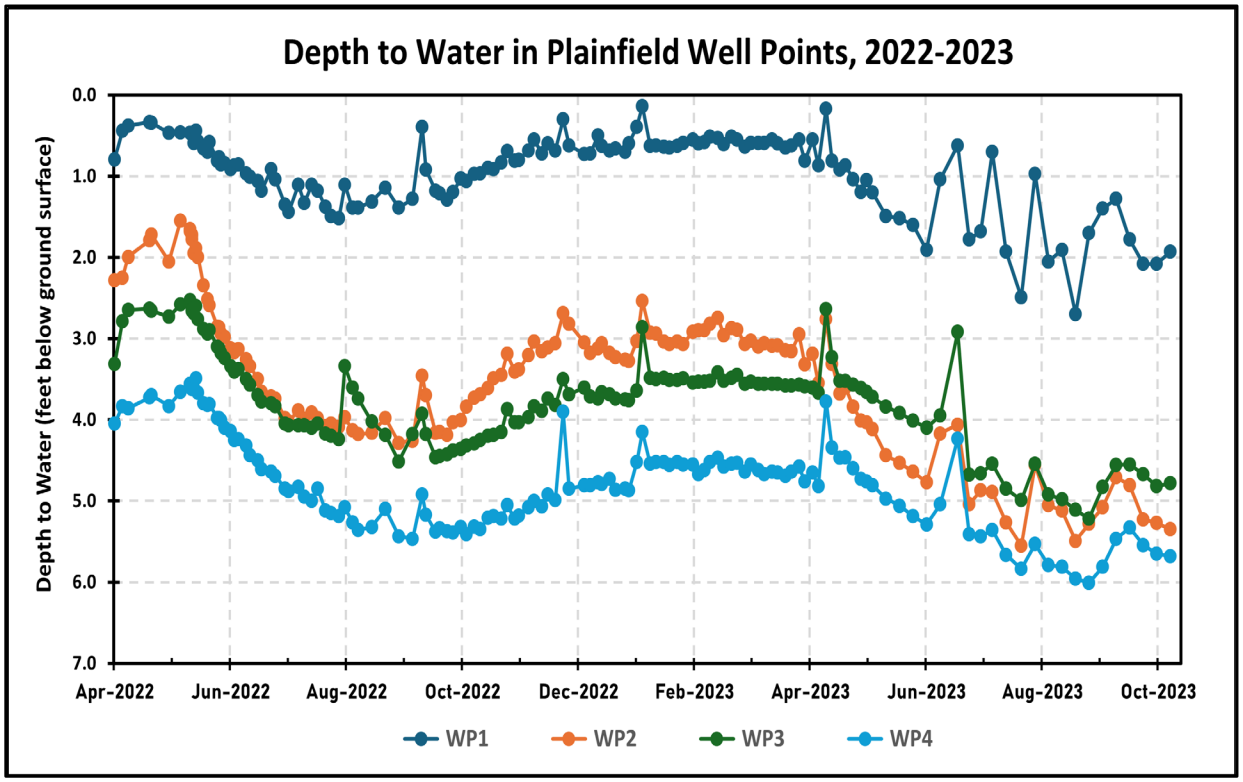

Figure 13. Observed depth to water in wellpoints, June 2022 to Oct. 2023.

An automatic data logger was installed in MWC's overburden observation well on April 28, 2022. It was removed on September 28, 2023. During that time water level readings were recorded at 2-hour intervals as shown in figure 14.

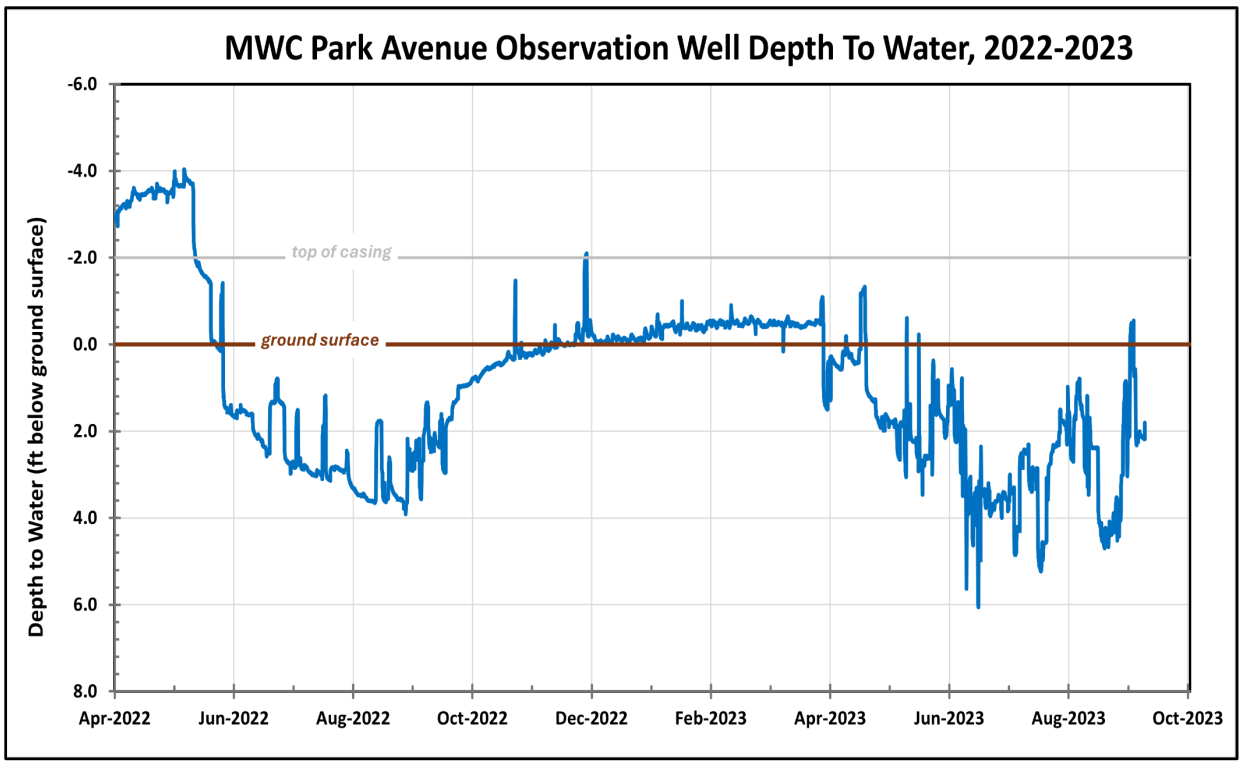

Figure 14. Observed water levels in MWC Observation Well, June 2022 to Oct. 2023

The observed water levels show a decline in groundwater levels during mid-2022. Field observations at that time showed a decrease in surface water ponding and lessening of water pumped to the street by sump pumps. When MWC reduced withdrawals in November 2022 the surface water ponding returned along with increased sump pump activity. The increase in withdrawals in May 2023, associated with the final treatment plant coming online, created a decline in groundwater levels, cessation of the surface water ponding, and a lessening of sump pump activity. Fluctuations in observed water levels from May 2023 are a function of production wells going on and off in the Park Avenue well field.

Water-level elevation graphs in figure 15 illustrate the relationship between the backyard ground surface and basement-floor elevations. Using GIS parcels data the flooding complaint locations were located and mapped. GIS analysis of LIDAR elevation data allowed for the interpolation of the ground surface and basement-floor elevations. The basement average floor depth of eight feet below ground surface was deduced using online resources. Water level elevations were calculated by subtracting the water level depths from the interpolated ground surface elevation for each wellpoint. These values were then plotted against the backyard and basement-floor elevations.

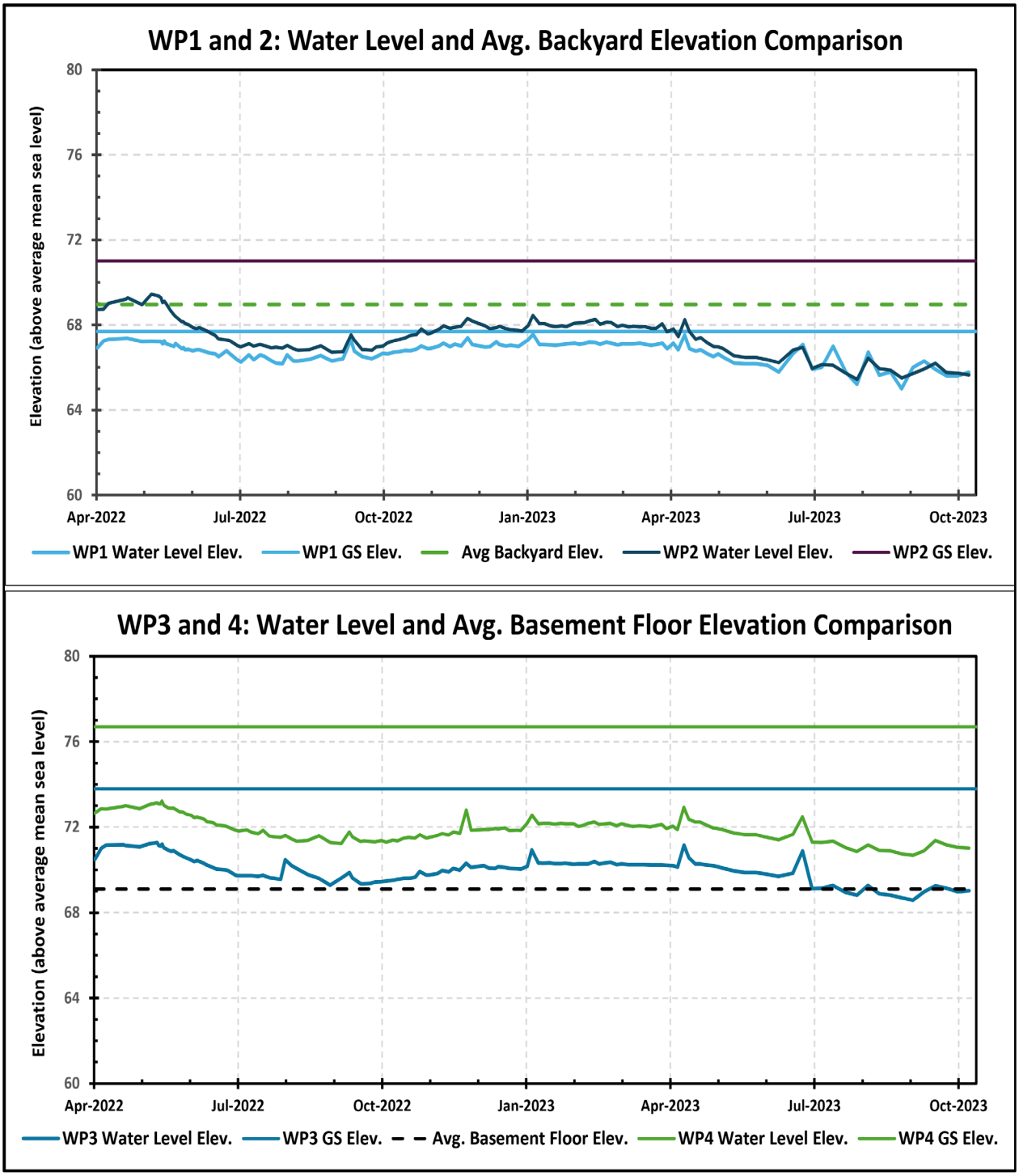

Figure 15. Water-level elevations in wellpoints in comparison to ground surface, average backyard (WP1 and 2), and basement-floor (WP3 and 4) elevations.

Average daily precipitation from the New Brunswick 3 SE, Newark Liberty Intl Airport, and Boonton1 SE. climatological stations, approximately 9 miles south, 14 miles ENE, and 20 miles north, respectively of the Park Avenue well field is presented in figure 16. The temporary rises in water levels observed in the well points in the summer of 2023 (see fig. 17) were correlated with precipitation events. But these precipitation-induced increases dissipate relatively quickly. The long-term trend in water levels is governed by the wellfield withdrawal pattern (see fig. 6). Note, some summer precipitation events observed in figure 16 are due to localized thunderstorms that may not have affected the Plainfield/South Plainfield areas. And some of the water level rises shown in figure 13 were caused by localized thunderstorms that did not significantly impact climatological stations.

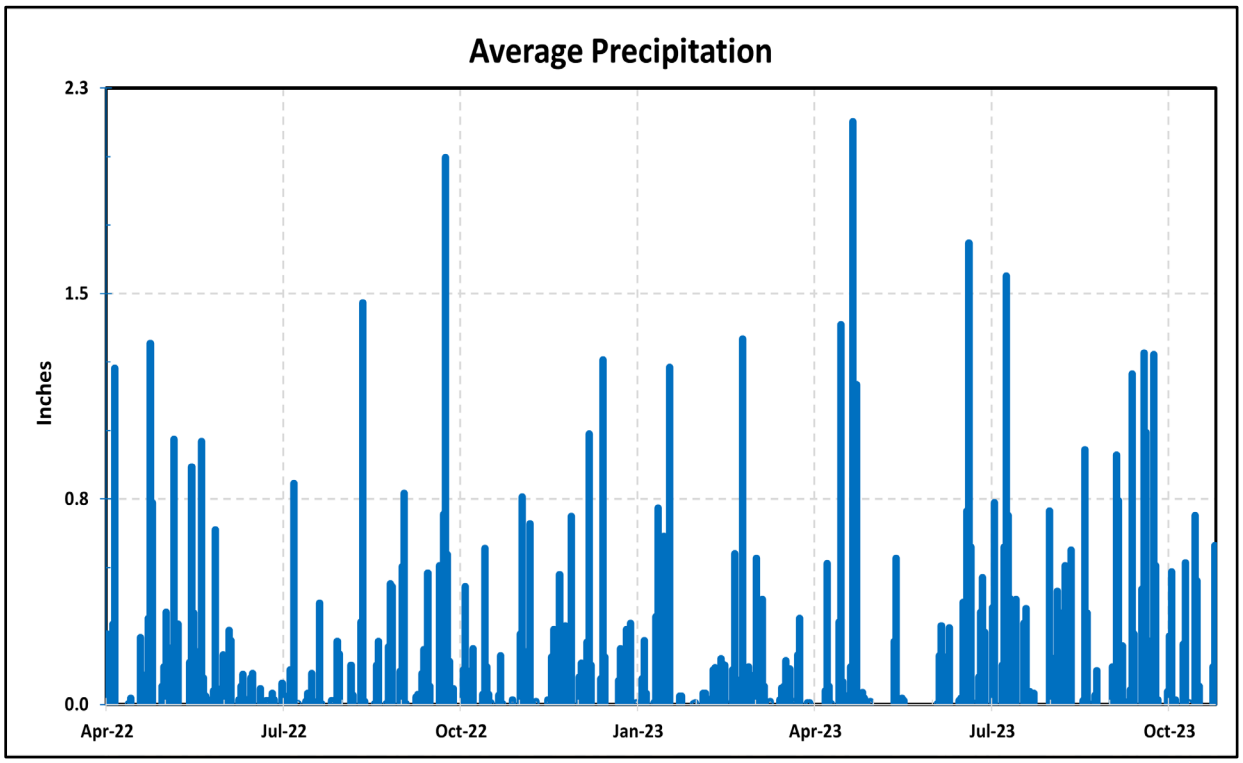

Figure 16. Average daily precipitation from N. Brunswick 3 SE, Newark Liberty Intl. Airport, and Boonton 1 SE climatological stations.

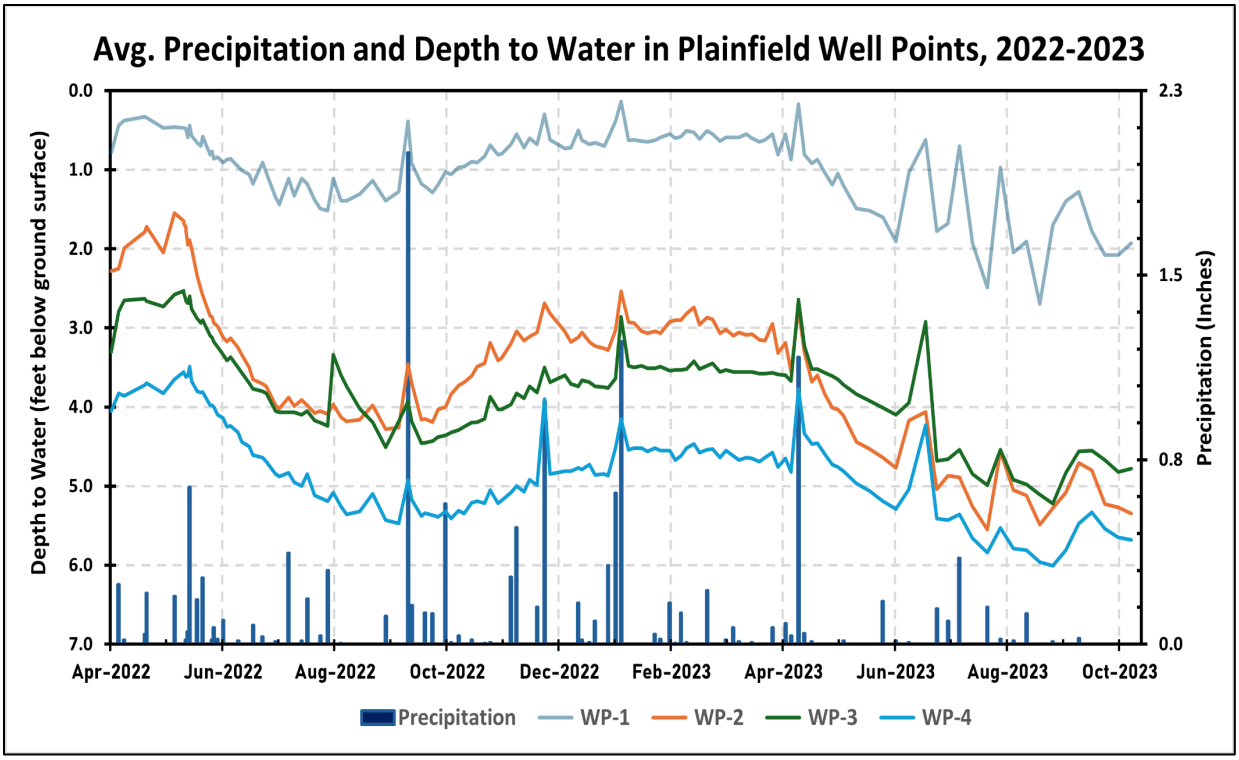

Figure 17. Comparison of average daily precipitation from 3 climatological stations (see fig. 16) to well point water levels.

Conclusions

Withdrawals from the Park Avenue well field, in what is now South Plainfield, Middlesex County, NJ, began in the late 1890's, with pumping rates reaching about 1.0 million gallons per day (mgd) in the early 1900's. In 1916, a pumping station was constructed at the well field along with several new wells. In 1922, there were 16 wells in operation. By 2022, withdrawal rates were typically between 8.0 and 9.0 mgd (2.0 to 2.5 bgy) during peak demand periods. Withdrawals are from both the Plainfield Formation, a glacial outwash, overburden, sand-and-gravel aquifer, and the bedrock Brunswick aquifer (Passaic Formation).

Middlesex Water Company (MWC) reduced withdrawals from its Park Avenue well field in South Plainfield, Middlesex County, NJ after PFOA in untreated groundwater exceeded the new maximum contaminant level (MCL) in September 2021. MWC ceased withdrawals from its Park Avenue well field in November 2021 as an interim preventative measure to reduce customer exposure to PFOA until a treatment option was installed. MWC began construction of its permanent granular activated carbon (GAC) treatment plant in January 2022.

By January 2022, nearby residents in South Plainfield and in Plainfield, Union County, began to report water entering previously-dry basements. In addition, water began ponding at the ground surface in Cedar Brook Park and some private property just east of the park. Local residents and officials reached out to the NJ Department of Environmental Protection (NJDEP) for assistance. The NJDEP's NJ Geological and Water Survey (NJGWS) began an investigation of what might be causing the groundwater rise.

MWC installed an interim treatment plant that came online in June 2022 initially pumping at about 5.0 mgd. As part of an investigation of the impacts of pumping on water levels, MWC also began pumping about 1.0 mgd to nearby Cedar Brook. The final treatment plant came online in stages, beginning in May 2023. Withdrawals in 2023 were typically in the range of 6.0 to 8.0 mgd with peaks of almost 10.0 mgd. The final treatment plant has a total capacity of 12.0 mgd.

The NJGWS installed four shallow wellpoints, one in the northern portion of the Park Avenue well field and three in Cedar Brook Park in April 2022. NJGWS staff monitored depth to water in the wellpoints biweekly from April 2022 to May 2023, then weekly thereafter. The wellpoints were removed in late October 2023. MWC made available an observation well in the Park Avenue well field. NJGWS installed a data logger in the observation well and monitored water levels every 2 hours. Water levels fluctuated both in response to local precipitation and withdrawals in the Park Avenue well field. In general, precipitation events caused short-term rises in water levels while the long-term trends of water level rises and falls correlated to changes in groundwater withdrawals.

The NJGWS also investigated land use changes in the area. Topographical atlas sheets and antique USGS quadrangles show a larger wetlands area bordering Cedar Brook in the late 1800s. Wetlands mapping in 2022 showed less wetlands bordering Cedar Brook north of the Park Avenue well field. Groundwater withdrawal at the well field has, over the 120 years since pumping began, lowered the water table and dried up wetlands in the area. Homes were then built on some of the newly-dried properties. When the groundwater withdrawals ceased in late 2021, the groundwater level quickly rose to pre-pumpage levels, impacting homes to the north of the Park Avenue well field. Resumption of groundwater withdrawals lowered the water table and mitigated the impacts. If withdrawals from the Park Avenue well field were to cease the water table would again rise causing a resumption of the problems.

The NJGWS conducted a literature review and found numerous reports of rising groundwater levels from around the world, and over several decades. After cessation of long-term pumping, the rising groundwater levels impacted both new and existing underground and surface infrastructure. Responses generally included deliberate dewatering to lower the water table.

References Cited

Coda, S., Tessitore, S., Di Martire, D., Di Vita, P., 2019, Environmental effects of the groundwater rebound in the eastern plain of Naples (Italy): *in* Rendiconti Online Societa Geologica Italiana ·July 2019, vol. 48, p. 35-40, 4 figs. (https://www.researchgate.net/publication/334585918_Environmental_effects_of_the_ground water_rebound_in_the_eastern_plain_of_Naples_Italy)

Herman, G.C., 2010, Hydrogeology and borehole geophysics of fractured-bedrock aquifers, Newark basin, New Jersey, *in* Herman, G.C. and Serfes, M.E., eds., Contributions to the geology and hydrogeology of the Newark basin, Chapter D: N.J. Geological Survey Bulletin 77, Trenton, N.J., p. F1-F45 (https://dep.nj.gov/wp-content/uploads/njgws/techincal-publications-and-reports/bulletins-and-reports/bulletins/bulletin77.pdf)

LaGrand Sr., H.E., cited Nov. 17, 2023, posted June 26, 2009, The Water Table [Internet], Harry Legrand's Hydrogeology Site poems and essays about ground water by a retired hydrogeologist with 60 years' experience. (https://legrandhydrogeology.blogspot.com/2009/06/water-table.html)

Lender, M.E., 1994, Middlesex Water Company, A Business History: The Uplands Press, Metuchen, N.J., 234 p. (https://search.worldcat.org/en/title/31695582)

Michalski, A., 2010, Hydrogeologic characterization of contaminated sites in the Newark basin: Selecting conceptual flow model and characterization tools, *in* Herman G.C. and Serfes, M.E., eds., Contributions to the geology and hydrogeology of the Newark basin, Chapter D: N.J. Geological Survey Bulletin 77, Trenton, N.J., p. D1-D12 (https://dep.nj.gov/wp-content/uploads/njgws/techincal-publications-and-reports/bulletins-and-reports/bulletins/bulletin77.pdf)

Nemickas, B., Mallard, G.E., Reilly, T.E., 1989, Availability and historical development of ground-water resources of Long Island, New York, an introduction: USGS, Water-Resources Investigations Report 88-4113, Syosset, NY 41 p. (p.26) (https://www.usgs.gov/publications/availability-and-historical-development-ground-water-resources-long-island-new-york)

Natl, Centers for Environ. Info. (NCEI), NOAA, 2025, Climate Data Online (CDO) Global Historical Climatology Network Daily (GHCND) precipitation data download from 2022-04-01 to 2023-11-30 for stations USC00286055 (New Brunswick 3 SE, NJ), USC00280907 (Boonton 1 SE, NJ), and USW00014734 (Newark Liberty Intl. Airport, NJ): requested 2025-07-16 via https://www.ncei.noaa.gov/cdo-web/

Nicholson, L.J., 2016, Hydrogeologic framework and computer simulation of groundwater flow in the valley-fill and fractured-rock aquifers of the Germany Flats Area of Sussex County, New Jersey; NJGWS Open-File Report OFR 16-1, 74 p., 31 illus., 2 plates, 6 tables. (https://dep.nj.gov/wp-content/uploads/njgws/reports/ofreport/ofr16-1.pdf)

Stanford, S.D., 2009, Surficial Geology of the Plainfield Quadrangle, Middlesex, Union, and Somerset Counties, New Jersey: NJGS Open-File Map OFM 77, scale 1 to 24,000, size 36x44 inches, 2 cross-sections, 17-page pamphlet. (https://dep.nj.gov/wp-content/uploads/njgws/maps/ofmap/ofm77.pdf)

Volkert, R.A., Monteverde, D.H., Silvestri, S.M., 2013, Bedrock Geologic Map of the Plainfield Quadrangle, Union, Middlesex, and Somerset Counties, New Jersey: NJGS, Geologic Map Series, GMS-13-5, prepared in cooperation with the USGS National Geologic Mapping Program, scale 1 to 24,000, size 50 by 30 inches, single map sheet. (https://dep.nj.gov/wp-content/uploads/njgws/maps/gmseries/gms13-5.pdf)

Wikipedia contributors, cited: July 9, 2024, last revision: August 29, 2023, 20:07 UTC, Cedar Brook Park [Internet], Wikipedia, The Free Encyclopedia, available: (https://en.wikipedia.org/w/index.php?title=Cedar_Brook_Park&oldid=1172862202)

Selected References for Groundwater Rise/Rebound

Adams, R., Younger, P.L., 2001, A strategy for modeling ground water rebound in abandoned deep my systems: Ground Water v. 30, no. 2 p. 249-261 (https://doi.org/10.1111/j.1745-6584.2001.tb02306.x)

Brassington, F.C., Rushton, K.R., 1987, A rising water table in central Liverpool: Quarterly Journal of Engineering Geology and Hydrogeology, v. 20, no. 2, p. 151-158 (https://doi.org/10.1144/GSL.QJEG.1987.020.02.05^)

Chih-Tung, Chen, et. al., 2007, Thirty-year land elevation change from subsidence to uplift following the termination of groundwater pumping and its geological implications in the Metropolitan Taipei Basin: Engineering Geology, v. 95, i. 1-2, p. 30-47 (https://doi.org/10.1016/j.enggeo.2007.09.001)

Coda, S., et. al., 2019, Uplift evidences related to the recession of groundwater abstraction in a pyroclastic-alluvial aquifer of Southern Italy (https://doi.org/10.3390/geosciences9050215): *in* Meisina, C., Boni, R., eds, geosciences, v. 9, i. 5, Special Issue Earth observations to support the management of groundwater level changes impacts, 15p. (https://www.mdpi.com/journal/geosciences/special_issues/earth_observations_support_management)

Gattinoni P., Scesi, L., 2017, The groundwater rise in the urban area of Milan (Italy) and its interactions with underground structures and infrastructures: Tunneling and Underground Space Technology, v. 62, p. 103-114, (https://doi.org/10.1016/j.tust.2016.12.001

Guang-ya, Wang, et. al., 2017, Land rebound after banning deep groundwater extraction in Changzhou, China: Engineering Geology, v. 229, p. 13-20 (https://doi.org/10.1016/j.enggeo.2017.09.006)

Greswell, R.B., Lloyd, J.W., Lerner, D.N., Knipe, C.V., 1994, Rising groundwater in the Birmingham area, (https://doi.org/10.1680/gpiua.19744.0024) *in* Wilkinson, W.B. (ed.), 1994 Groundwater problems in urban areas: Proceedings of the International Conference organized by the

Institution of Civil Engineers and held in London, 2–3 June 1993: Thomas Telford London, 448 p., (https://doi.org/10.1680/gpiua.19744)

Hernández, M.A., González, N., (1997) - Impact of rising piezometric levels on Greater Buenos Aires due to partial changing of water services infrastructure, *in* Groundwater in the Urban Environment: Problems, Processes and Management. Chilton, J. (Ed.)., AA Balkema, Rotterdam, p. 237-242. (http://sedici.unlp.edu.ar/handle/10915/26650)

Ishitsuka, Kazuya, et. al., 2014, Natural surface rebound of the Bangkok plain and aquifer characterization by persistent scatterer interferometry: Geochemistry, Geophysics, Geosystems, v. 15, i. 4, p. 265-274 (https://doi.org/10.1002/2013GC005154)

Johnson, D.W., Wilkinson, W.B., 1994, Keynote Paper: Rising groundwater levels: engineering and environmental implications, (https://doi.org/10.1680/gpiua.19744.0021), *in* Wilkinson, W.B. (ed.), 1994 Groundwater problems in urban areas: Proceedings of the International Conference organized by the Institution of Civil Engineers and held in London, 2–3 June 1993: Thomas Telford London, 448 p., (https://doi.org/10.1680/gpiua.19744)

Li, Z., Sheng, Y., Reddish, D.J., 2005, Rock strength reduction and its potential environmental consequences as a result of groundwater rebound, (https://www.imwa.info/docs/imwa_2005/IMWA2005_072_Li.pdf) *in* Loredo, J., Pendás, F.: Mine Water 2005 – Mine Closure, p. 513-519, Oviedo (University of Oviedo), (https://doi.org/10.1007/s10230-005-0080-4).

Rushton, K.R., Al-Othman, Wilkinson, W.B., 1994, Control of rising groundwater levels in Riyadh, Saudi Arabia, (https://doi.org/10.1680/gpiua.19744.0022), *in* Wilkinson, W.B. (ed.), 1994 Groundwater problems in urban areas: Proceedings of the International Conference organized by the Institution of Civil Engineers and held in London, 2–3 June 1993: Thomas Telford London, 448 p., (https://doi.org/10.1680/gpiua.19744)

Vázquez-Suñé, E., Sánchez-Villa, X., Carrera, J. 2004, Introductory review of specific factors influencing urban groundwater, an emerging branch of hydrogeology, with reference to Barcelona, Spain. Hydrogeology Journal, vol. 13, p. 522-533. (https://doi.org/10.1007/s10040-004-0360-2)

Zhao, J., Konietzky, H., 2021, An overview on flooding induced uplift for abandoned coal mines: International Journal of Rock Mechanics and Mining Sciences, Vol. 148 (https://doi.org/10.1016/j.ijrmms.2021.104955)