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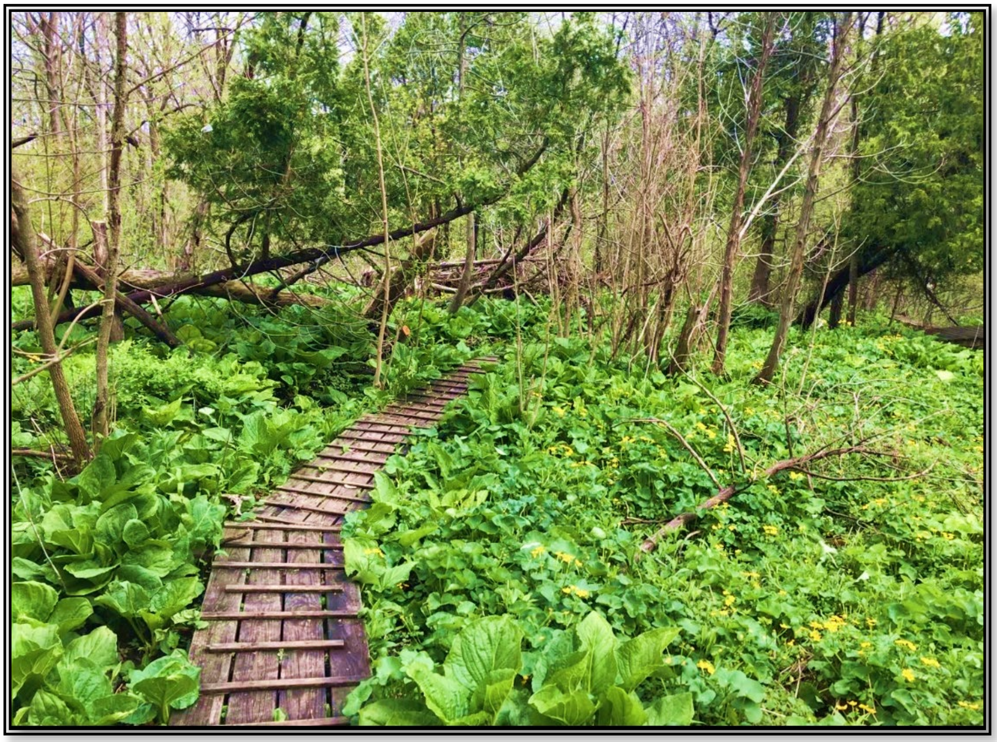
Water Quality and Levels in Trout Park Nature Preserve Before and After Reconstruction of the Jane Addams Memorial Tollway (Interstate 90), Kane County, Illinois

Eric T. Plankell, Geoffrey E. Pociask, and Lindsey A. Schafer



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Submitted Under Grants ITHA RR-07-9918 and ITHA 2015-01230 MINER to:
Illinois State Toll Highway Authority
2700 Ogden Avenue
Downers Grove, Illinois 60515

January 15, 2020

ILLINOIS
Illinois State Geological Survey
PRAIRIE RESEARCH INSTITUTE

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EXECUTIVE SUMMARY

In 2014, the Illinois State Toll Highway Authority began reconstruction of the Jane Addams Memorial Tollway along Interstate 90, a segment of which is adjacent to Trout Park Nature Preserve in Elgin, Illinois. The preserve contains rare and sensitive fen habitat, several threatened or endangered species, and a remnant stand of northern white cedar. This fen habitat, the associated northern white cedar, and a perennial stream within the preserve rely on persistent groundwater discharge to the land surface. Before reconstruction, several impacts to the hydrology and water quality in the preserve were identified, including decreased groundwater levels due to underground drainage infrastructure and elevated levels of pollutants related to roadway runoff from Interstate 90 and Illinois Route 25, as well as leaky storm sewers within and adjacent to the preserve. To mitigate for these impacts, several changes were made to the drainage network and a concrete barrier wall was installed during reconstruction. Under contract with the Illinois State Toll Highway Authority, the Illinois State Geological Survey monitored surface and groundwater levels and water quality at Trout Park Nature Preserve before, during, and after reconstruction to evaluate the response of groundwater levels and water quality due to the reconfiguration of the storm drainage infrastructure.

Results of monitoring show that the reconfiguration of the drainage network immediately resulted in increased groundwater levels along the north margin of the preserve. Although this water level recovery generally persisted after decommissioning of the former sewer lines, over the longer term a localized decrease in groundwater levels was observed at one monitoring location and likely reflects a reduction in surface-water runoff from Interstate 90 to the preserve due to the installation of the barrier wall.

Before and after reconstruction, groundwater and surface water at the preserve had elevated levels of dissolved solids, mainly due to high concentrations of sodium and chloride resulting from decades of deicing activities along Interstate 90 and Illinois Route 25. After reconstruction, increased levels of dissolved solids, owing mainly to increased sodium and chloride in groundwater, were observed in two of three ISGS monitoring wells. These increases were likely due in part to rewetting and dissolution of residual legacy road salt along the Tollway apron as local groundwater levels increased. Reduced dissolved solids in the third well likely reflects reduced runoff from Interstate 90 following installation of the barrier wall, but is also attributed to a decrease in water level and no rewetting and dissolution of residual legacy road salt at this location. Decreased levels of dissolved solids were observed at all surface-water monitoring locations after reconstruction and likely reflect the combined effects of a period of increased precipitation after reconstruction and reduced influence from the reconfigured drainage network. The occurrence of metals commonly associated with roadways and observed in water samples from Trout Park Nature Preserve generally decreased after reconstruction, although detections of chromium, manganese, and nickel increased slightly after reconstruction.

LIST OF ABBREVIATIONS AND SYMBOLS

ASTM	American Society for Testing and Materials
Al	aluminum
As	arsenic
B	boron
Ba	barium
Be	beryllium
°C	degrees centigrade
Ca	calcium
$CaCO_3$	calcium carbonate/limestone
$CaMg(CO_3)_2$	dolomite
Cd	cadmium
Cl	chloride
cm	centimeter(s)
Co	cobalt
Cr	chromium
Cu	copper
Esri	Environmental Systems Research Institute
F	fluoride
Fe	iron
FRFFNP	Fox River Forested Fen Nature Preserve
ft	feet
GCA	groundwater contribution area
GPS	global positioning system
gal	gallon(s)
HNO_3	nitric acid
H_3PO_4	phosphoric acid
H_2SO_4	sulfuric acid
I-90	Interstate 90/Jane Addams Memorial Tollway
ICP-MS	Inductively Coupled Plasma Spectroscopy / Mass Spectrometry
IL	Illinois
IL 25	Illinois Route 25
in.	inch(es)
ISGS	Illinois State Geological Survey
ISTHA	Illinois State Toll Highway Authority
ISWS	Illinois State Water Survey
K	potassium
L	liter(s)
LDO	luminescent dissolved oxygen
Li	lithium
liDAR	Light Detection and Ranging (topographic survey method)
m	meter(s)
MDL	minimum detection limit
Mg	magnesium
mg/L	milligram(s) per liter
mi.	mile(s)
Mn	manganese
Mo	molybdenum

MRCC	Midwestern Regional Climate Center
Na	sodium
NAVD88	North American Vertical Datum of 1988
NCEI	National Centers for Environmental Information
NH_3-N	ammonia-nitrogen
Ni	nickel
NIST	National Institute of Standards and Technology
NO_3	nitrate
NVOC	non-volatile organic carbon
NWS	National Weather Service
o-PO_4	ortho-phosphate
ORP	oxidation-reduction potential
P	phosporous
Pb	lead
PVC	poly-vinyl chloride
QA/QC	quality assurance/quality control
RMSE	root mean square error
S	sulfur
Sb	antimony
Se	selenium
Si	silicon
SM	standard method
Sn	tin
SO_4	sulfate
SpC	specific conductivity
Sr	strontium
TDS	total dissolved solids
Ti	titanium
Tl	thallium
TPNP	Trout Park Nature Preserve
TSS	total suspended solids
μS/cm	micro Siemens per centimeter
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
USDA	United States Department of Agriculture
V	vanadium
Zn	zinc

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INTRODUCTION

Trout Park Nature Preserve, located in Elgin, Illinois, was dedicated by the Illinois Nature Preserve Commission in 1972 and is currently owned by the City of Elgin. The preserve is located within a larger city park with the same name, and is in Section 1, of Township 41 North, Range 8 East in Kane County, Illinois (Figure 1). The preserve consists of three units encompassing 26 acres of steep bluffs and ravines formed from converging seeps and springs (Illinois Department of Conservation 1991). This habitat is unique within Illinois, and it provides a refuge for northern white cedar (*Thuja occidentalis*), the key tree species found in both TPNP and nearby For River Forested Fen Nature Preserve, as well as several state-listed threatened and endangered species (Table 1). The fens at both preserves also sustain an aquatic macroinvertebrate community that is representative of more northern habitats (Douglass et al. 2017).

Table 1. State-listed threatened and endangered plant species at Trout Park and Fox River Forested Fen Nature Preserves (Illinois Department of Natural Resources, 2019).

Scientific Name	Common Name	Status	Location
Triglochin maritima	Common Bog Arrow Grass	State-threatened	FRFFNP
Ulmus thomasii	Rock Elm	State-endangered	TPNP
Aster furcatus	Forked Aster	State-threatened	TPNP
Rubus pubescens	Dwarf Raspberry	State-threatened	TPNP
Rubus odoratus	Purple-flowering Raspberry	State-threatened	TPNP
Cimicifuga racemosa	False Bugbane	State-endangered	TPNP

In 2014, the Illinois State Toll Highway Authority began reconstruction of the Jane Addams Memorial Tollway along Interstate 90 adjacent to TPNP. Prior to reconstruction, roadway runoff and storm-water drainage facilities related to I-90 and Illinois Route 25 were suspected of adversely affecting the habitat within the preserve. The impacts included decreased groundwater levels in peat deposits in the preserve due to underground drainage infrastructure and elevated levels of pollutants related to leaky storm sewers and roadway runoff from I-90 and IL 25. The ISTHA implemented several changes to the I-90 and IL 25 drainage networks during the I-90 reconstruction project, with the aim of reducing these impacts.

Under contract with the ISTHA, the Illinois State Geological Survey began monitoring surface and groundwater levels and water quality at TPNP in October 2012, prior to the start of reconstruction. The initial phase of monitoring was conducted to establish baseline pre-construction water-level and water-quality conditions. Monitoring continued during and after reconstruction (2014-2019) to assess the effects of the reconstruction. The purpose of this study is to determine the degree of recovery of groundwater levels and the response of water quality at TPNP due to reconfiguration of storm drainage infrastructure within TPNP and along I-90 and IL 25.

HYDROGEOLOGIC SETTING

TPNP lies within the Jelkes Creek-Fox River hydrologic unit (HUC #071200061206) (U.S. Department of Agriculture 2019). Bluff tops and slopes within TPNP are dry and wooded, while shallow depressions

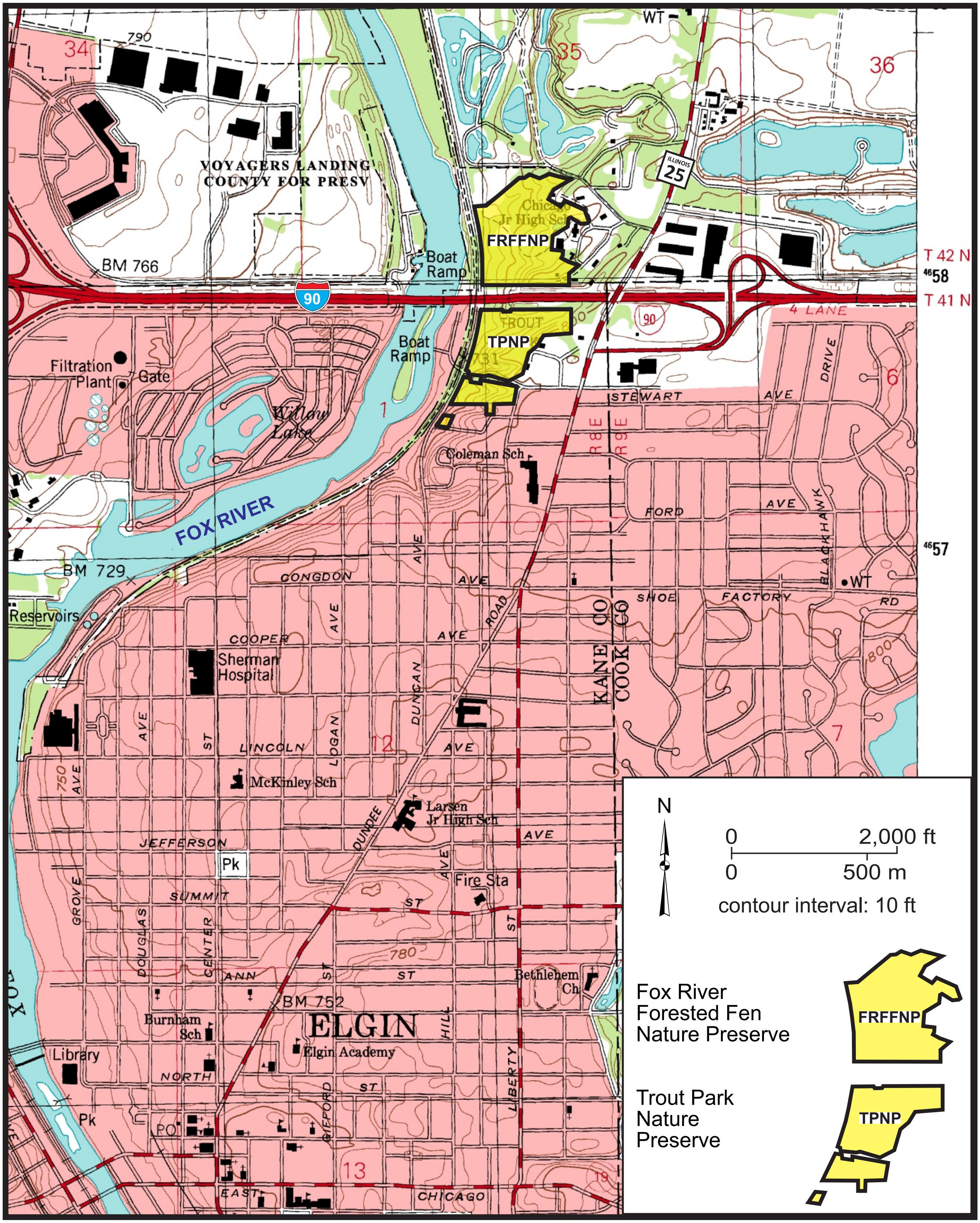

Figure 1. Map showing the location of Fox River Forested Fen and Trout Park Nature Preserves. Figure modified from the 1998 Elgin, IL 7.5-minute U.S. Geological Survey Topographic Quadrangle (Illinois State Geological Survey 2019).

at the base of the bluffs are moist and cool due to the discharge of calcareous groundwater at land surface. Peat (partially decomposed organic matter formed under saturated conditions) and tufa (calcium carbonate deposits precipitated from calcareous groundwater) are found in localized areas of persistent groundwater discharge within both TPNP and FRFFNP, and TPNP and FRFFNP contain the only forested-fen plant communities within the state of Illinois (Forest Preserve District of Kane County 2019). The primary stream channel in the preserve originates at a seep located at the base of the bluff approximately 102 meters (335 ft) west of the IL 25 centerline and 89 meters (292 ft) south of the I-90 centerline (Figure 2). From there the stream meanders westward through TPNP for approximately 0.6 km (0.37 mi.) before exiting the northwest corner of the preserve and flowing under I-90 toward its eventual discharge point at the Fox River. The streambed is composed of sand, gravel, and cobbles of the underlying glacially-derived materials. The stream is perennial and mostly fed by groundwater discharge through the highly-permeable substrate. The stream receives additional inputs from seeps and springs issuing from the base of the bluffs along the eastern edge of the northern unit, which then coalesce into small, shallow surface-water channels that eventually make their way down the slope until they join with the main stream. Streambed elevation within the preserve drops from approximately 236 m (774 ft) at the head of the stream to 221 m (725 ft) where it exits the northwest corner of the preserve (Figure 3). Land-surface elevations within the northern unit of TPNP range from a high of approximately 245 m (804 ft) at the top of the bluffs to a low of 221 m (725 ft) where the main stream exits the preserve (Figure 3). Regional groundwater flow in the vicinity of TPNP is to the west-southwest, towards the Fox River (Knight et al. 2010, Figure 4).

The uppermost bedrock unit underlying TPNP is mapped at an elevation between 650 and 700 ft above mean sea level (Herzog et al. 1994), and consists of undifferentiated dolomite of the Silurian System (Kolata 2005). In northeastern Illinois, the Silurian System is composed predominantly of reef (dolomite) and inter-reef deposits (cherty-silty to argillaceous dolomite) of the Niagaran and underlying Alexandrian series (Willman et al. 1975). Depth to bedrock under the preserve is mapped from 100 to 200 ft below the surface (Piskin and Bergstrom 1975), and the site is situated over the northwestern flank of an unnamed northeast-trending buried bedrock valley (Herzog et al. 1994). Unconsolidated sediments overlying bedrock at the preserve are mapped as proglacial outwash deposits of sand and gravel of the Henry Formation overlying till and debris flow deposits of diamicton of the Tiskilwa Formation (Figure 5, Curry 2007).

DRAINAGE FEATURES AND INFRASTRUCTURE

Prior to reconstruction of I-90, several artificial drainage features existed within or adjacent to TPNP, many of which were suspected of affecting water levels and water quality therein. The location and descriptions of many of these features are documented on plans and in a design report prepared by Stanley Consultants (2012a, 2012b) and on plans prepared by bV3 (2012). Approximate locations of these features are shown on Figure 6, and the feature names indicated on this figure will be referred to throughout this report.

The IL 25 culvert conveyed surface-water runoff from the I-90/IL 25 interchange into TPNP via the eroded IL 25 runoff channel. This channel extended to the northwest for approximately 100 m (328 ft) before intersecting the southwest-trending I-90 runoff channel. This second channel conveyed runoff from an undersized paved ditch along the eastbound shoulder of I-90 toward the main stream in the preserve. Also, the IL 25 storm sewer system along the east side of the preserve conveyed water from the IL 25 corridor northward to the I-90 storm sewer system.

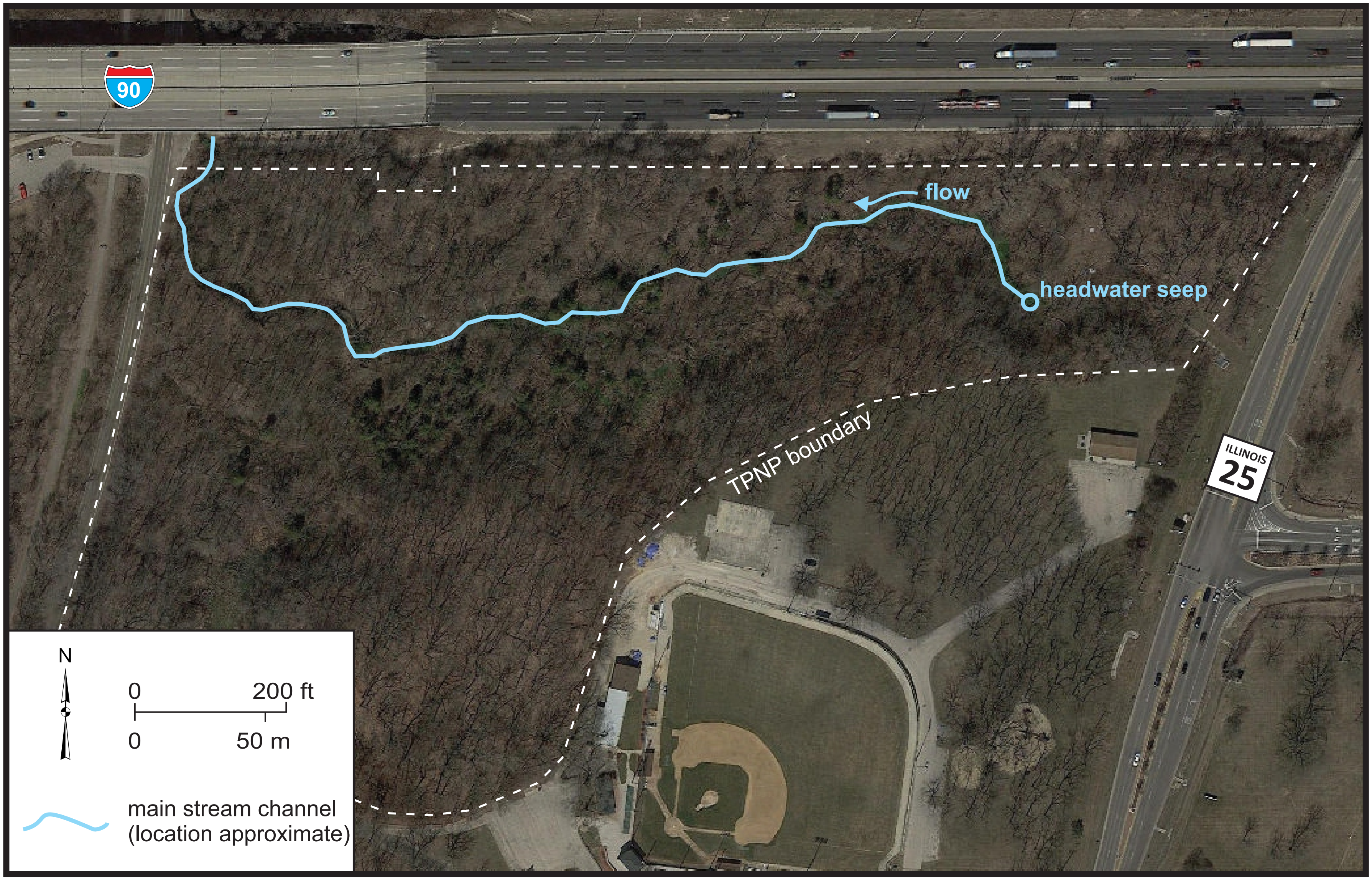

Figure 2. Location of primary stream in northernmost unit of Trout Park Nature Preserve. Pre-construction aerial imagery taken on April 02, 2014 and provided by Esri, 2019.

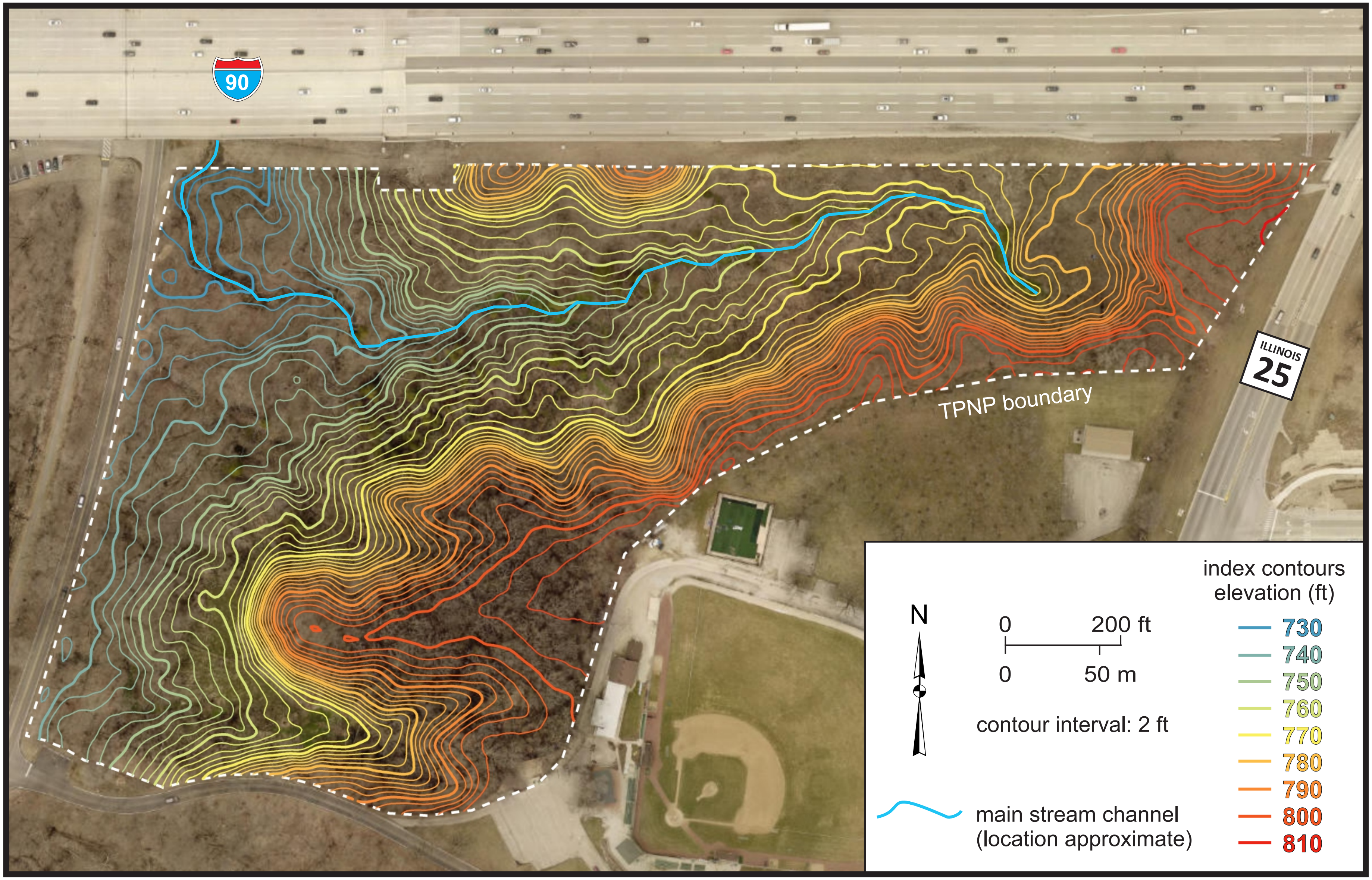

Figure 3. Topography of north unit of Trout Park Nature Preserve. Contours derived from 2008 LiDAR data for Kane County (Illinois State Geological Survey 2019) and base imagery provided by Esri, 2019.

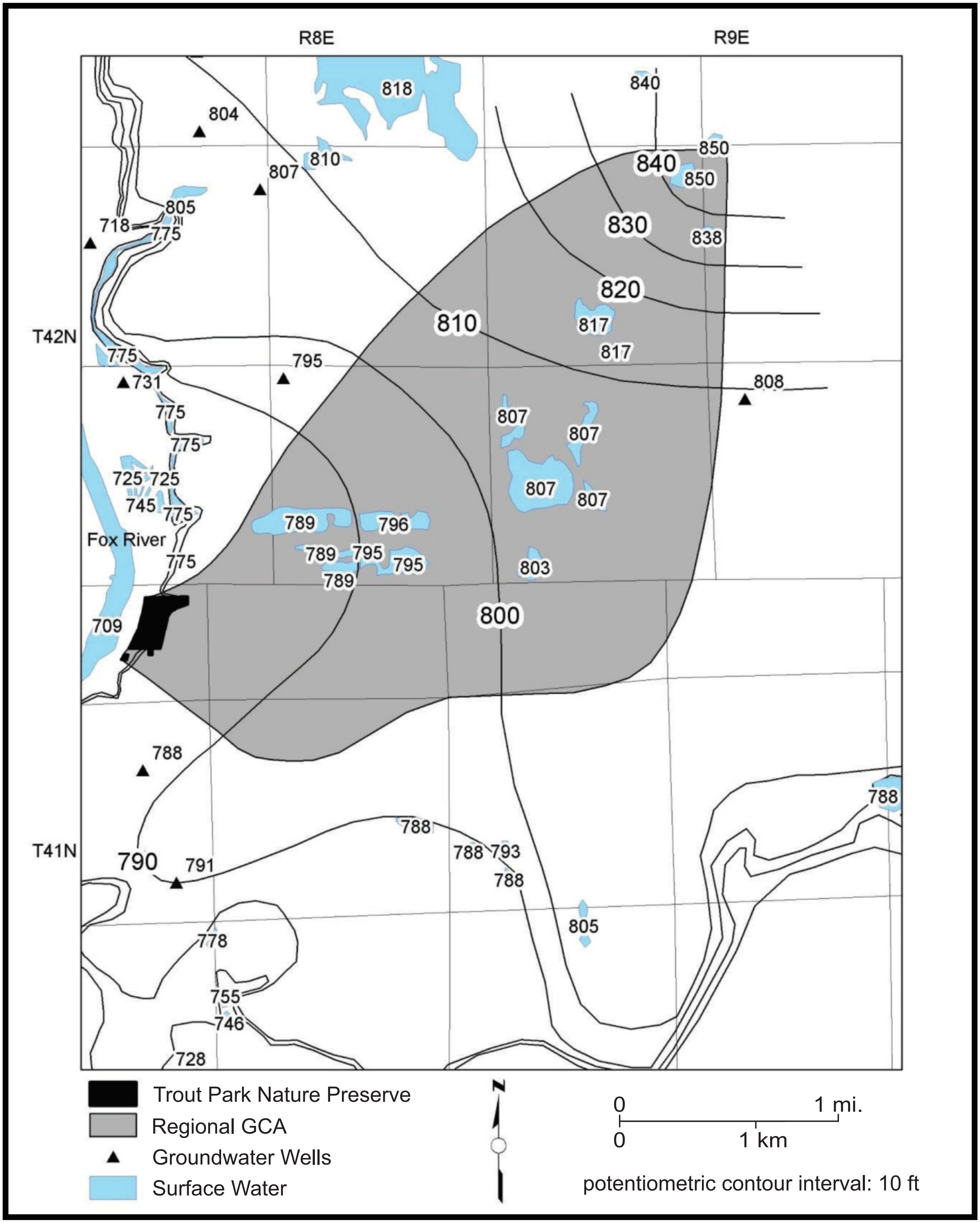

Figure 4. Potentiometric surface map and regional groundwater contribution area (GCA) for Trout Park Nature Preserve. Map modified from Figure 2 in Knight et al. (2010).

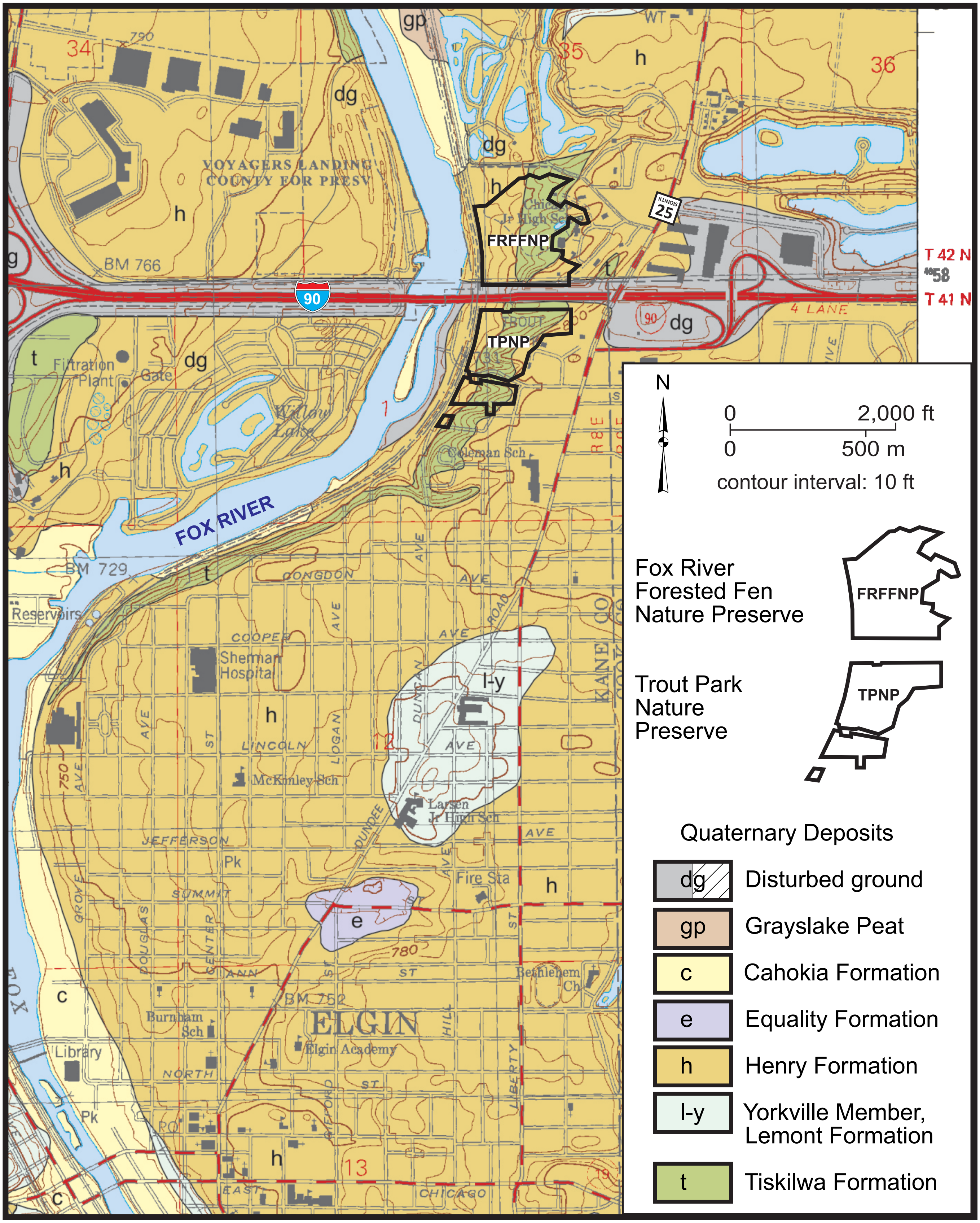

Figure 5. Unconsolidated sediments mapped in the vicinity of Trout Park and Fox River Forested Fen Nature Preserves. Figure modified from the Surficial Geology of Elgin Quadrangle (Curry 2007).

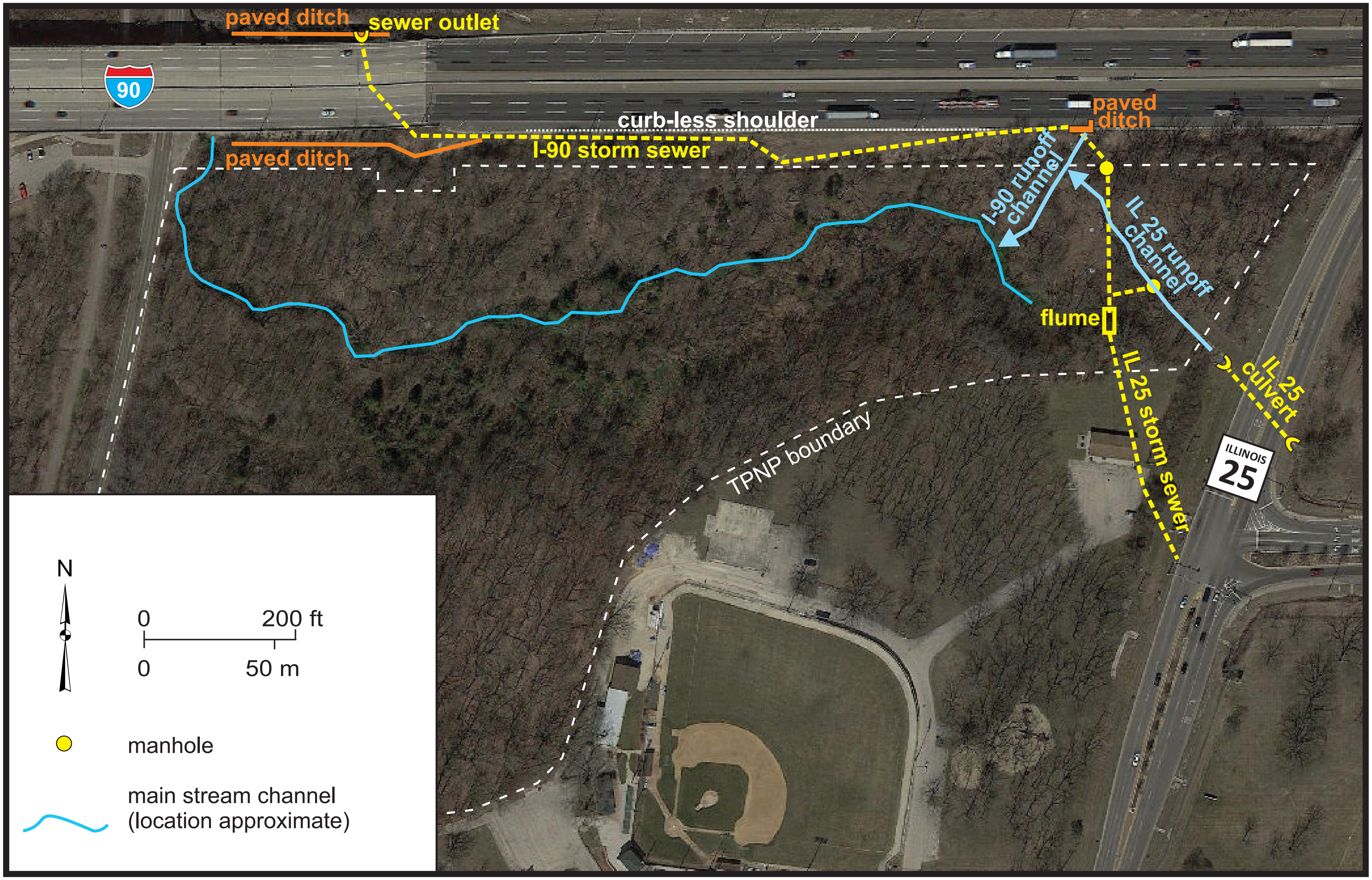

Figure 6. Drainage features at Trout Park Nature Preserve prior to reconstruction of I-90. Feature locations approximated based upon plans by bV3 (2012) and Stanley Consultants (2012a, 2012b). Pre-construction aerial imagery taken on April 02, 2014 and provided by Esri, 2019.

The I-90 storm sewer system drained westward toward the Fox River and ran roughly parallel to the eastbound shoulder of I-90 before it turned northwest, crossed under the roadway, and discharged onto a paved ditch on the north side of the interstate.

Other notable drainage features formerly within or adjacent to TPNP include: a curb-less section of shoulder along the eastbound lanes of I-90, which allowed runoff from the eastbound lanes of I-90 to flow directly into the preserve from the shoulder; a large concrete flume that directed storm-water flows from the IL 25 storm sewer at the top of the bluff down into another section of storm sewer at the base of the bluff; a damaged concrete manhole approximately 2 ft in diameter and 4 ft deep located within the IL 25 runoff channel and accessing a 12 to 18-in. diameter corrugated metal pipe extending to the west where it likely connected into the IL 25 storm sewer system; and a second manhole in the IL 25 storm sewer system and located north-northwest of the first manhole.

Most drainage features mentioned above were either abandoned, removed, or reconfigured during the reconstruction of I-90. Alterations made in an attempt to mitigate adverse effects to water levels and water quality in TPNP are listed in Table 2, while Table 3 provides a general timeline of some of these significant alterations to the I-90 drainage system and surrounding infrastructure.

Table 2. Alterations made to the drainage network and other infrastructure within and adjacent to Trout Park Nature Preserve, and the desired outcomes of those alterations.

Alteration made	Desired outcome
IL 25 culvert removed	-Stop runoff from I-90/IL 25 interchange from entering TPNP.
Manhole in IL 25 runoff channel removed, channel backfilled with native geologic materials and seeded with native vegetation	-Remove pathway (damaged manhole) for surface water to enter groundwater. -Restore landscape in northeastern corner of TPNP.
Original IL 25 storm sewer system abandoned. New system installed in southbound IL 25 right-of-way	-Eliminate potential for storm water to impact groundwater in TPNP. -Eliminate potential for discharge of TPNP groundwater via a leaky storm sewer system.
I-90 storm sewer system removed, abandoned, reconfigured, and lined	-Eliminate potential for storm water to interact with groundwater in TPNP. -Eliminate potential for drainage of TPNP groundwater through leaky storm sewer system.
Paved ditch at the head of the I-90 runoff channel removed	-Stop runoff from I-90 shoulder from entering TPNP.
Concrete barrier installed along eastbound shoulder of I-90 for the length of the preserve	-Stop runoff from I-90 shoulder from entering TPNP. -Reduce airfall of salt dust and spray from I-90 into TPNP.

Table 3. Timeline of alterations made to the drainage network and other infrastructure within and adjacent to Trout Park Nature Preserve.

Date	Modification to drainage network
9/4/2014	Construction begins - pumping for de-watering local construction sites in progress.*
10/3/2014	Work on I-90 storm sewer begins. IL 25 storm sewer disconnected from I-90 storm sewer.
10/13/2014	Pumping stopped.* ISGS observes manhole overflow event within TPNP following heavy rainfall.
10/17/2014	IL 25 storm sewer temporarily reconnected to new I-90 drainage system.
3/27/2015	Pumping in progress.*
4/8/2015	Pumping stopped.*
10/01/2015	Concrete barrier installed. Final grading of I-90 eastbound shoulder completed.
1/21/2016	Pumping in progress.*
02/01/2016	ISGS observes IL 25 culvert in process of abandonment.
03/19/2016	Manhole S-370 installed (station 57+46). Pumping stopped.*
03/23/2016	New IL 25 storm sewer along southbound IL 25 shoulder connected to new I-90 drainage system.
04/22/2016	I-90 lateral storm sewers connected.
05/16/2017	Additional portion of I-90 storm sewer and temporary IL 25 storm sewer connection abandoned. Approximately 5 in. of flowing water noted in I-90 storm sewer prior to abandonment.
05/17/2017	All storm sewers within TPNP abandoned. Construction ends.
04/23/2018	Back-filling of IL 25 runoff channel with native geologic materials begins.

*as determined from a drop in groundwater levels recorded in TPNP monitoring wells

METHODS

MONITORING STATIONS

Surface-Water Stations

Six surface-water monitoring stations were installed by the ISGS for this project (Figure 7). Each station was outfitted with a non-vented In-Situ, Inc. Aqua TROLL 200 data logger, capable of measuring water level, water temperature, and specific conductivity. Aqua TROLLS were deployed vertically, either directly within square, galvanized Telespar tubing partially pounded into the ground, or within a one-inch diameter piece of slotted PVC well screen secured to the tubing. At times when water levels at a given station became too low to effectively cover the sensors on the data logger, the data logger was positioned horizontally on the stream bed, often within a section of slotted PVC well screen to keep sediment out of the conductivity cell, as conditions allowed. Station TP-A was positioned in the headwater seep of the primary stream in TPNP, upstream of the confluence with the roadway runoff channels in order to assess water quality in the stream prior to its interaction with surface-water inputs from I-90 and IL 25. TP-B was positioned at a seep within the I-90 runoff channel, immediately upstream of its confluence with the primary stream, and approximately 49 m (161 ft) downstream of TP-A.

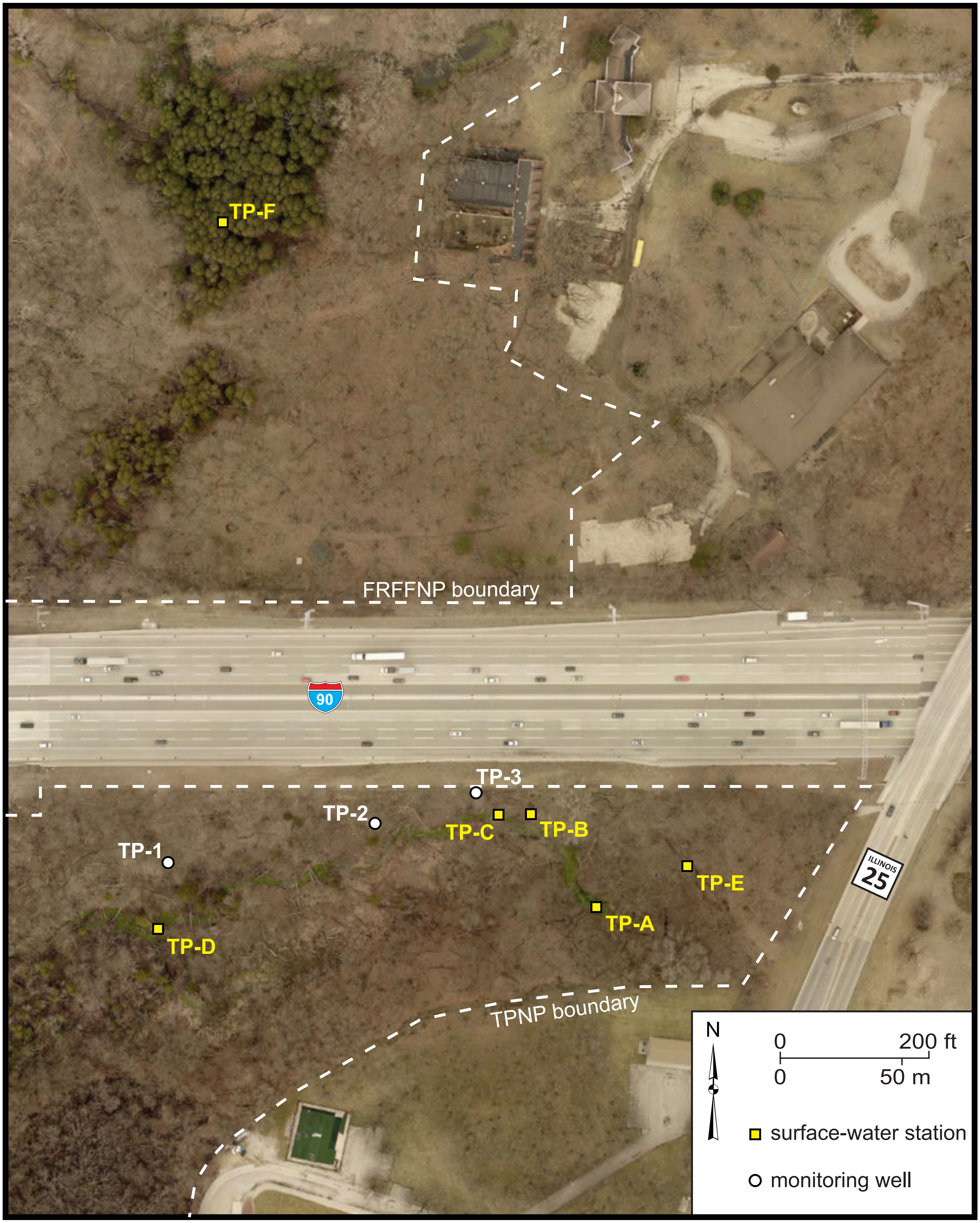

Figure 7. ISGS monitoring locations at Trout Park and Fox River Forested Fen Nature Preserves. TP-F location approximate. Base imagery provided by Esri, 2019.

TP-B was used to assess surface-water quality in the area of the preserve most likely to have been directly affected by roadway runoff from I-90 and IL 25. TP-C and TP-D were both located in the main stream channel, approximately 62 m (203 ft) and 225 m (738 ft) downstream of TP-A, respectively. TP-C was positioned just downstream of the I-90 runoff channel in order to assess changes to water quality in the primary stream due to roadway runoff inputs, while TP-D was positioned further downstream to assess the downstream evolution of water quality with greater distance from roadway runoff sources. TP-E was located in the IL 25 runoff channel, approximately 41 m (135 ft) east-northeast of TP-A and was positioned to document water quality entering TPNP from the I-90/IL 25 interchange. TP-F was located in a shallow surface-water channel in FRFFNP, north of I-90. TP-F was positioned up gradient of I-90, with respect to regional groundwater flow (see Figure 4) to provide a reference condition of water quality unaffected by Tollway facilities and operations along I-90. Installation dates, coordinates, and land-surface elevations of all surface-water monitoring stations are provided in Appendix A.

Groundwater Stations

Three groundwater monitoring wells were installed by the ISGS for this project. Boreholes were advanced by hand using an open-faced soil auger. Wells were constructed of 2-in. diameter PVC risers attached to 2-in. diameter factory-slotted PVC screens. Boreholes were backfilled with filter sand to fully surround the well screen, and then bentonite was added up to land surface to seal the annulus surrounding the well casing. Each monitoring well was outfitted with a vented In-Situ, Inc. Aqua TROLL 200 data logger suspended on a vented communication cable. Wells TP-1, TP-2, and TP-3 are located in an ENE-WSW transect north of the main stream channel and south of I-90 (Figure 7). These monitoring wells were positioned in areas where dried peat, muck (decayed peat), and tufa (calcium-carbonate precipitate) deposits were observed by ISGS personnel during initial scouting visits to the preserve. Installation dates, coordinates, and land surface elevations of all groundwater monitoring wells are provided in Appendix A, while well logs are provided in Appendix B.

HYDROLOGY

Precipitation and Snowfall Data

Daily and monthly precipitation and snowfall totals recorded at the Elgin, Illinois, weather station (NWS Coop #112736) for the duration of this study were obtained from the Midwestern Regional Climate Center at the Illinois State Water Survey (MRCC 2019). The weather station is located approximately 1.6 km (1.0 mi) west-southwest of TPNP at the City of Elgin's Riverside Water Treatment Plant (Figure 1). Monthly precipitation normals for this station, calculated by the National Centers for Environmental Information (NCEI) for the 30-year period from 1981-2010, were also downloaded from the MRCC. These data were used primarily to identify seasonal patterns observed in the analytical results for the monthly grab samples, and to assess the more rapid changes in water-quality parameters recorded by the data loggers deployed in the preserve.

Water-Level Data

Groundwater levels in the monitoring wells were measured manually to the nearest millimeter on a monthly basis using a Solinst 101 water-level meter. Water levels were also measured by the pressure transducers on the Aqua TROLL 200 data loggers, with accuracies ranging from +/- 2-6 mm depending on the factory-specified pressure range of the specific data logger deployed. Measured groundwater levels were then converted to water-level elevations using well top elevations measured by the ISGS using a Leica 1200 survey-grade GPS with a listed vertical accuracy of 2cm + 1ppm (part per million) (Leica Geosystems AG 2008). The data loggers were programmed to record water-level measurements every 15 minutes at surface-water stations and every four hours in the monitoring wells. The manual water-level measurements were used as a quality-control check on the water levels recorded by the data loggers.

Water-Quality Data

Water Samples

Grab samples for water-quality analysis were collected monthly from four surface-water stations (TP-A, TP-B, TP-C, and TP-D) beginning October 2012, from the three groundwater monitoring wells (TP-1 through TP-3) beginning December 2012, and from TP-F beginning October 2013. No grab samples were collected from TP-E during this project due to lack of water during each sampling campaign. The final round of grab samples was collected from all active monitoring stations on April 23, 2018. Detailed information regarding grab sample collection and preservation procedures is documented in Appendix C.

Water-Quality Parameters

Continuously recorded water-level and water-quality parameters (temperature and specific conductivity) were collected from surface-water stations TP-A through TP-D beginning October 2012, from monitoring wells TP-1 through TP-3 and from surface-water station TP-E beginning December 2012, and from TP-F beginning October 2013. At present, the data loggers are still recording data at TPNP and FRFFNP, however only data through August 15, 2019 are included in this analysis.

In-Situ Aqua TROLL 200 data loggers were used to measure water-level and water-quality parameters every 15 minutes at surface-water stations and every 4 hours in groundwater monitoring wells. Instrument accuracies were ±0.5% of reading +1 μS/cm when the reading was less than 80,000 μS/cm for specific conductivity, ±0.002 m for water level, and ±0.1° C for water temperature (In-Situ, Inc. 2016). Aqua TROLLs were cleaned and checked for accuracy every month at surface-water stations and quarterly at groundwater monitoring wells, and calibrated according to the In-Situ Aqua TROLL 200 manual (In-Situ, Inc. 2016). Standard conductivity solutions used to calibrate sensors were purchased from the device manufacturers or other suppliers, and were generally NIST traceable.

The Aqua TROLL 200 data loggers deployed for this project operated continuously, including during periods when little or no water was in contact with the sensors, the water touching the sensors was frozen, or, as was sometimes the case in regards to the conductivity cell, the sensor became clogged with sediment. As a result, raw data collected by the data loggers sometimes did not reflect accurate water depth, water temperature, or specific conductivity. Also, erroneous data was sometimes recorded as instruments aged and became unstable due to battery or sensor degradation. All data recorded by Aqua TROLLs were graphed and visually inspected and known or suspected errors were removed from the dataset before analysis. Also, data were removed during periods when the data logger was out of the water for downloading and calibration.

ANALYSIS

Laboratory Analysis

All samples were analyzed by the Illinois State Water Survey Public Service Laboratory for the following geochemical parameters: metals, anions, total dissolved solids (TDS), phosphate, pH, alkalinity, ammonia-nitrogen, and total and dissolved non-volatile organic carbon. Surface-water samples were also analyzed for total metals and total suspended solids (TSS). Appendix D provides a complete list of constituents measured and the methodologies used by the lab.

Unfiltered samples for analysis of total recoverable metals were collected from all surface-water stations throughout the course of the study. These samples were acidified in the lab (to liberate any metals adsorbed to sediment) and then analyzed using USEPA Method 200.7 (Appendix D), with results representing the sum of all metals present in the sample. Details regarding quality assurance and quality control (QA/QC) procedures are provided in Appendix E.

Regression Models for Estimating Chloride

A model for predicting chloride concentration from specific conductivity was developed using data collected from all groundwater and surface-water stations at TPNP and FRFFNP in a similar manner to previous ISGS studies (Campbell et al. 2011, Miner et al. 2013, Plankell and Miner 2014). Each data point used in constructing the model consisted of the chloride concentration (the dependent variable, Y) reported by the ISWS for the grab sample paired with the stabilized specific conductivity (the explanatory variable, X) measured by the ISGS as a field parameter immediately prior to the collection of the sample. Data points were excluded from the analysis if either of the following were true: the percent error of the charge balance analysis for a given sample was greater than +/-5%, or any one of the following field parameters - temperature, specific conductivity, or pH – had not stabilized prior to collection of the grab sample. Field parameters were measured and recorded every two minutes, and were considered stable if three consecutive measurements were made with the following criteria: temperature (+/- 3% of the lowest of the three measurements); specific conductivity (+/- 3% of the lowest of the three measurements); pH (+/- 0.1 unit). These criteria are based upon United States Environmental Protection Agency standards for low-flow groundwater sampling (USEPA 1996). Six data points were excluded from the analysis for not meeting the charge balance criteria, and an additional 197 data points were excluded for not meeting the field parameter stabilization criteria. In total 324 of 527 (61%) of available data points were used to create the model.

Data was separated into a predictor group and a validator group. The model was constructed using the predictors, while the validators were used to assess the accuracy of the model. For this study, 20% of the data (65 data pairs) were randomly selected as validators. The remaining 80% (259 data pairs) were used to develop the linear regression model to predict chloride concentration.

RESULTS

ANNUAL PRECIPITATION AND WINTER SNOWFALL TOTALS

Total annual precipitation recorded at the Elgin, Illinois, weather station was much less during the pre-construction period (8/16/2012 – 9/3/2014; total = 80.5 in.) as compared to the post-construction period (5/18/2017 – 8/15/2019; total = 112.1 in.; Table 4, Figure 8). Conversely, total snowfall recorded during pre-construction winters 2012-2013 and 2013-2014 (total = 95.9 in.) was considerably more than that recorded during post-construction winters 2017-2018 and 2018-2019 (total = 70.9 in.; Table 4, Figure 9).

DEICING AGENT LOADS APPLIED TO TOLLWAY MAINTENANCE UNIT 6

Deicing and anti-slip agents applied to Tollway Maintenance Unit M-6 during the course of this study include salt (sodium chloride), calcium chloride applied as a liquid, and “abrasives” (Table 5; Tollway 2019, unpublished data). Salt application was 8% higher during the pre-construction period (55.8 tons/lane mile applied) as compared to the post-construction period (51.2 tons/lane mile applied) and corresponds to a greater number of snow events reported by the Tollway for the pre-construction period (60 events) versus the post-construction period (42 events; Table 5). Calcium chloride applied during post-construction period (10,704 gallons) was more than three times the amount applied during the pre-construction period (2,915 gallons). Only a slightly greater amount of abrasives was applied during the pre-construction period (1,673 tons) versus the post-construction period (1,629 tons).

Table 4. Annual precipitation and snowfall recorded at the Elgin, Illinois, weather station (MRCC 2019) and comparison to NCEI annual normal calculated for 1981-2010.

Tollway Year	Total Precipitation (in.)	Total Precipitation (% Normal)	Total Snowfall (in.)
2012-2013	37.7	100	30.7
2013-2014	40.8	108	65.2
2014-2015	38.6	102	35.6
2015-2016	42.2	112	23.0
2016-2017	47.2	125	20.0
2017-2018	46.5	123	31.7
2018-2019	48.6	129	39.2
Pre-construction total (8/16/12-9/3/14)	80.5		95.9
Post-construction total (5/18/17-8/15/19)	112.1		70.9

Table 5. Annual number of snow events and total amounts of deicing agents applied to Tollway Maintenance Unit M-6 (Tollway 2019, unpublished data) during the course of this study.

Construction period	Winter period	Tollway snow events	Salt (tons)	Salt (tons/lane mile)	Calcium chloride liquid (gallons)	Abrasives (tons)
Pre-construction	2012-2013	21	4,210	23.2	640	270
	2013-2014	39	5,926	32.6	2,275	1,403
Construction	2014-2015	24	2,468	13.6	2,360	431
	2015-2016	16	3,125	17.2	1,720	240
	2016-2017	12	2,640	14.5	1,650	285
Post-construction	2017-2018	21	3,852	21.2	5,254	1,090
	2018-2019	21	5,454	30.0	5,450	539
Pre-construction total		60	10,136	55.8	2,915	1,673
Post-construction total		42	9,306	51.2	10,704	1,629

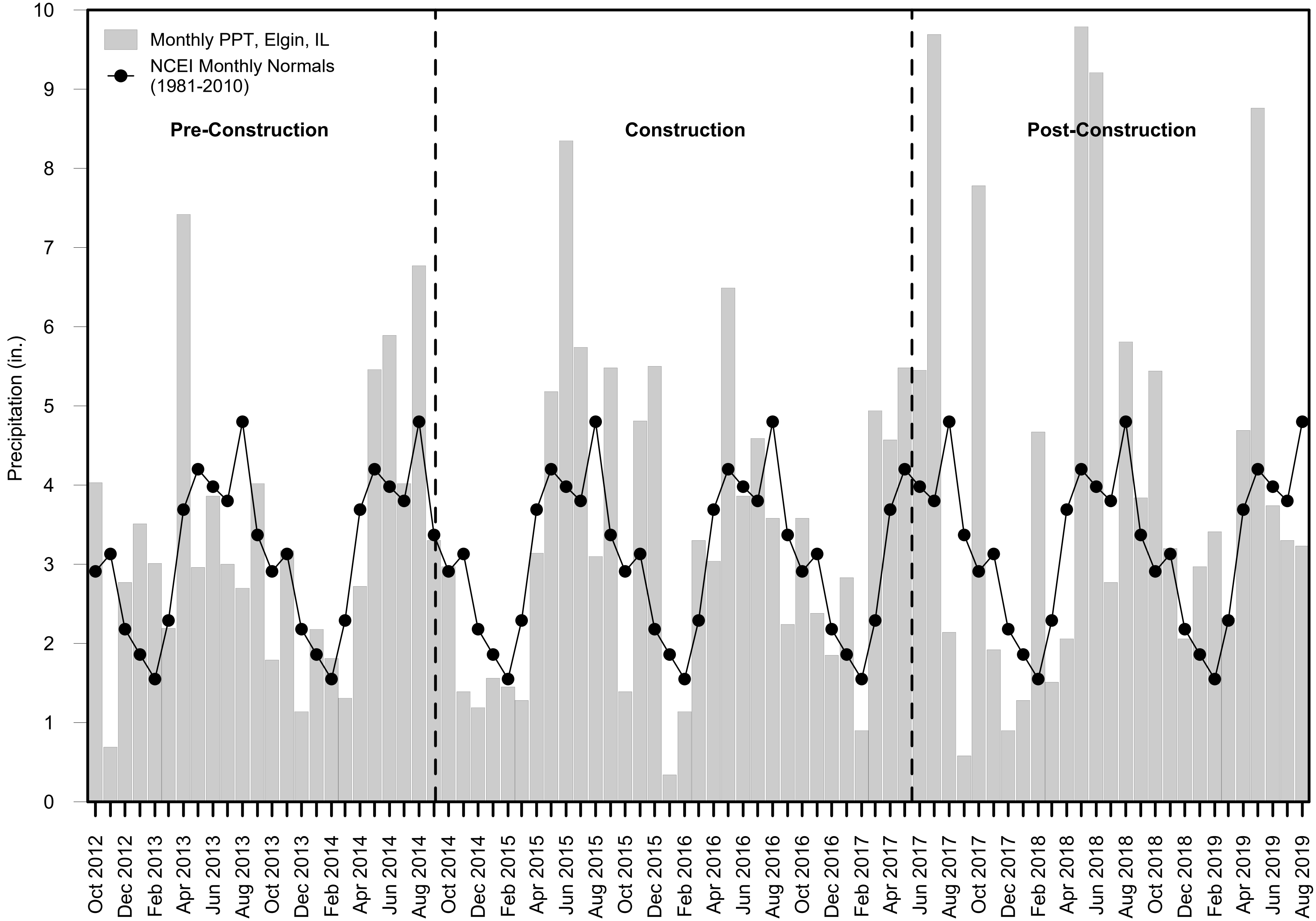

Figure 8. Monthly precipitation recorded at the Elgin, Illinois, weather station compared to NCEI monthly normals.

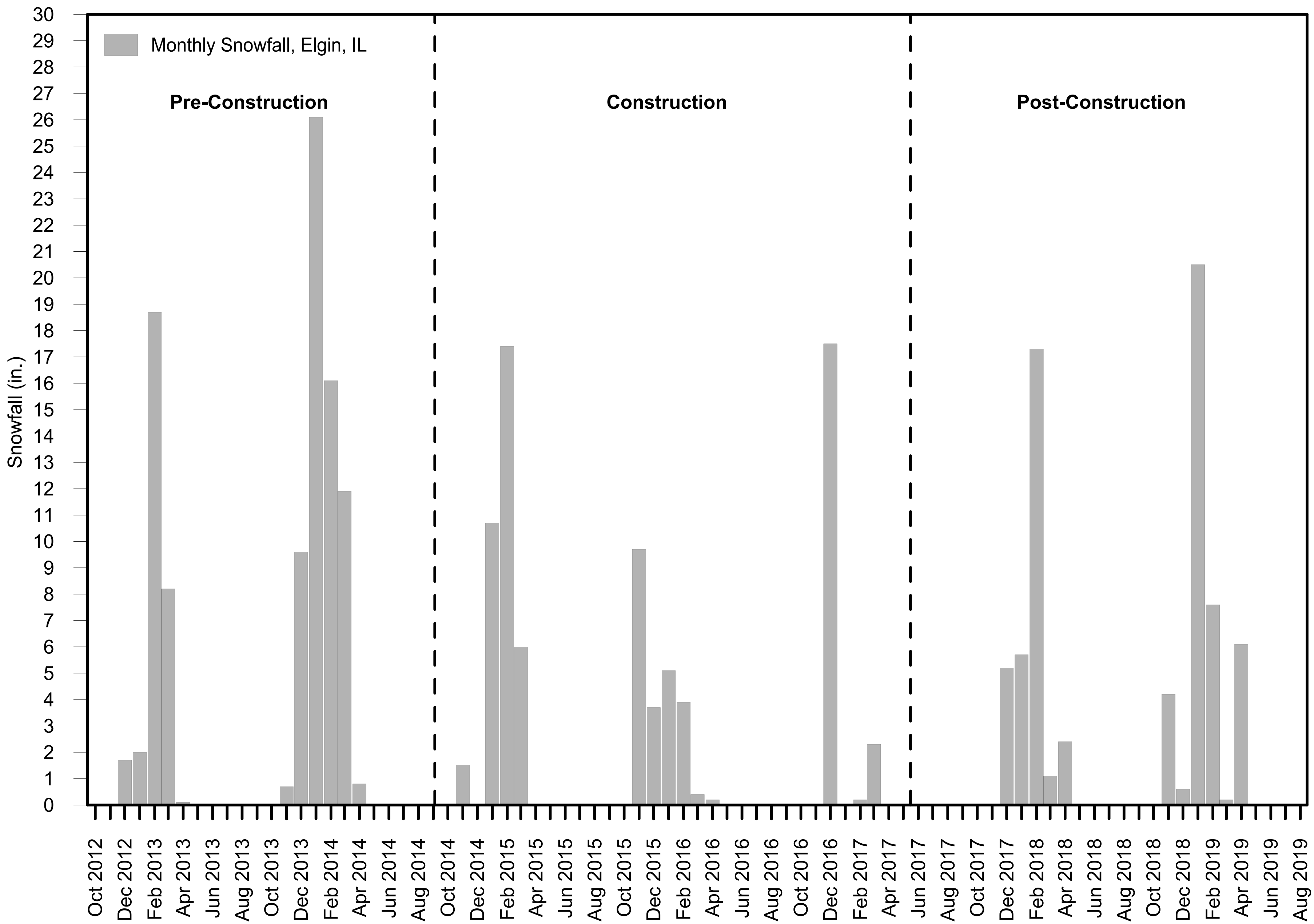

Figure 9. Monthly snowfall totals recorded at the Elgin, Illinois, weather station.

GROUNDWATER RESPONSES TO PRECIPITATION

Base groundwater levels before and after construction were generally stable with subtle seasonal variations (Figure 10). Base water levels were typically higher from late winter through spring, and lower from summer through early winter. Short-duration increases (1-2 days) frequently followed precipitation events. After these events, water levels quickly returned to pre-event base levels. Occasionally, longer-duration increases in base water levels, lasting from a few weeks to several months, followed extended periods of rainfall or winters with excessive snowfall. One such period was recorded in all three monitoring wells from March to May 2014, following the 2013-2014 winter, the winter with the highest total snowfall recorded during this study (Table 4).

Comparison of pre-construction and post-construction groundwater levels using box plots shows: an appreciable increase in water level and decreased variability in well TP-1, a slight increase in water level with no discernable change in variability in well TP-2, and a distinct decrease in water level with slightly increased variability in levels in well TP-3 (Figure 11). Mean water levels rose 27 cm (10.6 in.) in well TP-1, rose 12 cm (4.7 in.) in well TP-2, and dropped 14 cm (5.5 in.) in well TP-3 (Table 6).

Table 6. Mean water-level elevations measured by data loggers in the monitoring wells at Trout Park Nature Preserve.

Monitoring Well	Mean pre-construction water-level elevation (m)	Mean post-construction water-level elevation (m)	Change in mean water-level elevation (m)
TP-1	231.32	231.59	+0.27
TP-2	233.85	233.97	+0.12
TP-3	234.38	234.24	-0.14

During the pre-construction period, water levels in well TP-3 showed less variability relative to wells TP-1 and TP-2 (Figures 10 and 11), particularly with respect to the short-duration increases in water level in response to rainfall events. Well TP-1 initially exhibited strong responses in water levels following rainfall events, but this well was vandalized on June 1, 2013, and the replacement well at this location (installed on July 24, 2013) did not exhibit as pronounced an effect in water levels as were observed in the original well at this location. Also, water-level data from well TP-1 is missing from December 16, 2013 to May 27, 2014 due to a failed pressure transducer, so the well's response to rainfall during this period is unknown. Following construction, variability in water levels recorded at well TP-3 increased as base water level decreased. Conversely, variability in water levels in well TP-1 decreased as base water level increased. Well TP-2, which had a slight increase in base water level over the post-construction period, also had higher variability in levels.

The observed increase in mean groundwater level measured in well TP-1 appears to be strongly associated with the abandonment of the original I-90 storm sewer system. The immediate effect of abandonment of the I-90 storm sewer, initiated on October 3, 2014 (see Table 3), is illustrated by the response of groundwater levels following a 1.54-inch rain event that occurred during October 13-15, 2014. Prior to the start of the abandonment of the sewer, water levels in well TP-1 were artificially drawn down approximately 0.18 m (0.59 ft) by construction-related pumping which started on or around September 4, 2014 (Figure 10, Table 3).

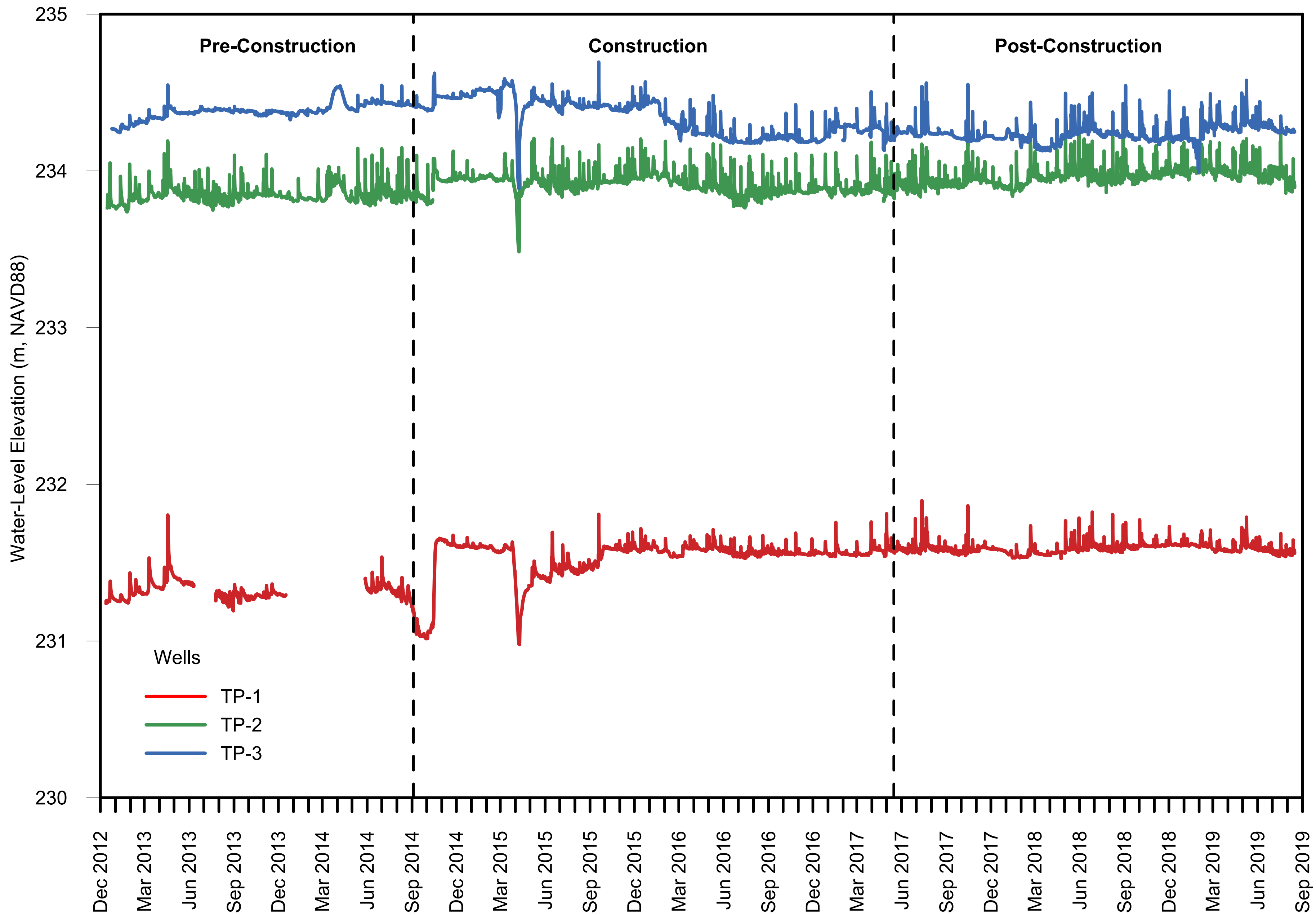

Figure 10. Water-level elevations in groundwater monitoring wells at Trout Park Nature Preserve.

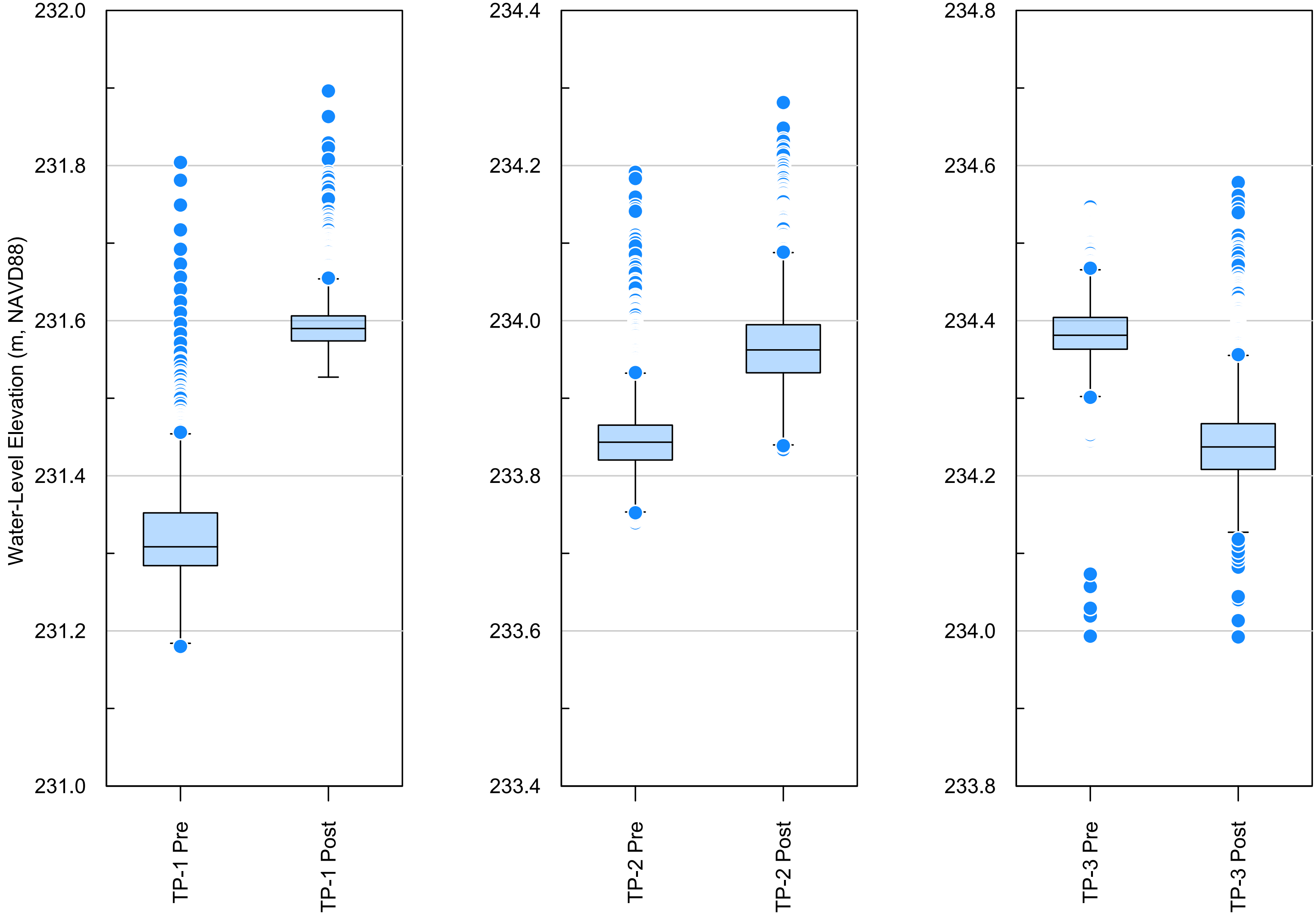

Figure 11. Boxplots of groundwater elevations before and after reconstruction of I-90. The pre-construction period as recorded in monitoring wells was from December 12, 2012 through September 3, 2014. The post-construction period was from May 18, 2017 through August 15, 2019.

The pump appears to have been shut off around the time of the rainfall event as water levels in Well TP-1 rose 0.56 m (1.84 ft) over the next 14 days and remained at an elevated base level for nearly six months. The increase in base water level in well TP-1 was largely sustained throughout the construction and post-construction periods, except for the sharp drawdown in level recorded in late March and early April 2015 (see Figure 10). This drawdown was also observed in water-level records from wells TP-2 and TP-3, and likely indicates another instance of dewatering of the local groundwater table by pumping during construction activities along I-90 (Table 3).

The sustained increase in base water levels in well TP-1 suggests that, prior to its removal, the I-90 storm sewer intercepted groundwater and artificially depressed the local groundwater table in the vicinity of well TP-1. This interpretation is supported by observations made by Stanley Consultants in 2012, that prior to the removal of the storm sewer, water flowed from the I-90 storm sewer outlet no matter the precipitation-related runoff conditions (Stanley Consultants 2012b). Figure 12 provides an interpretation of the influence of the I-90 storm sewer on the local groundwater table in the vicinity of well TP-1. This interpretation is also supported by evidence of lower mean water levels in well TP-1 prior to storm sewer removal, even as precipitation totals increased. Whereas, following removal of the sewer, mean water levels in well TP-1 increased in response to increased precipitation (Figure 13).

Prior to construction, the I-90 storm sewer reduced local groundwater levels near these wells, and likely created a shallow but localized groundwater gradient to the north, drawing groundwater away from the preserve, while at the same time it intercepted solute-rich groundwater along I-90 and carried it off westward to the Fox River (Figure 12a). After sewer removal, water levels around wells TP-1 and TP-2 rebounded, resulting in a more natural groundwater gradient to the south-southwest, toward the perennial stream running through TPNP (Figure 12b).

The pattern of water-level response in well TP-2 during and following the October 13-15, 2014 rainfall event was similar to but less pronounced than in well TP-1, and mean annual water levels in well TP-2 after construction have been consistently higher than prior to construction (Figure 10, Table 7). The initial increase in mean groundwater levels observed in well TP-2 following removal of the I-90 storm sewer suggests that the local groundwater table in the vicinity of well TP-2 may have also been artificially depressed by the storm sewer prior to its removal. However, the increase in mean water levels during the pre-construction period also corresponds to increasing precipitation during this time (Figure 13), so the influence on the water table in the vicinity of well TP-2 by the I-90 storm sewer is more difficult to discern. The mean water level recorded in well TP-2 decreased in 2015-2016 and again in 2016-2017 even though precipitation increased over that same period (Figure 13). This decrease may reflect a lesser volume of water available to recharge the local groundwater table as a result of the installation of the barrier wall along the eastbound shoulder of I-90 in late 2015, and removal of the IL 25 culvert in early 2016.

Similar to wells TP-1 and TP-2, groundwater levels in well TP-3 increased immediately following the abandonment of the I-90 storm sewer, but the initial increase at this well was much less pronounced (Figure 10). This temporary recovery of the local groundwater table took place despite a period of below average precipitation during Fall 2014. Unlike wells TP-1 and TP-2, after construction water levels in well TP-3 persisted below pre-construction levels (Figure 10, Table 7). Although the timing of the initial decrease in well TP-3 corresponds with construction-related pumping in January 2016, the subsequent removal of the IL 25 culvert and the addition of the barrier wall in October 2015 (see Table 3) both reduced the amount of water available for groundwater recharge, and are thus the most likely reasons for the overall decrease in water levels in well TP-3.

Recovery of the water table in the vicinity of wells TP-1 and TP-2 after reconstruction ultimately resulted in additional moisture in the root zone. This change in hydrology is considered a beneficial result for

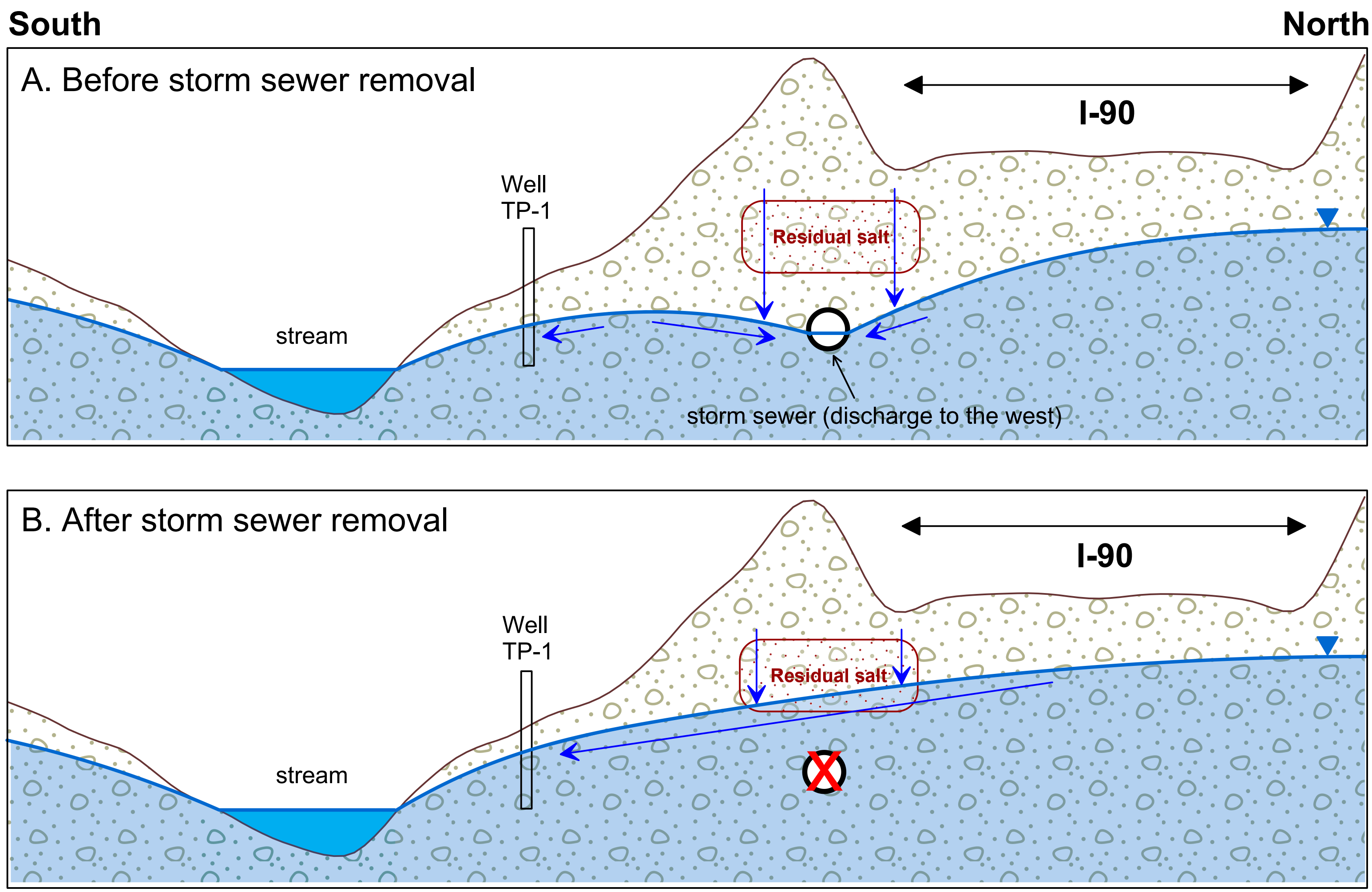

Figure 12. Conceptual cross-sections at Trout Park Nature Preserve near well TP-1 showing A) the likely influence of the storm sewer on groundwater levels before re-construction and B) water level recovery and presumed dissolved salt transport through groundwater after the storm sewer was decomissioned. Blue arrows indicate groundwater flow direction.

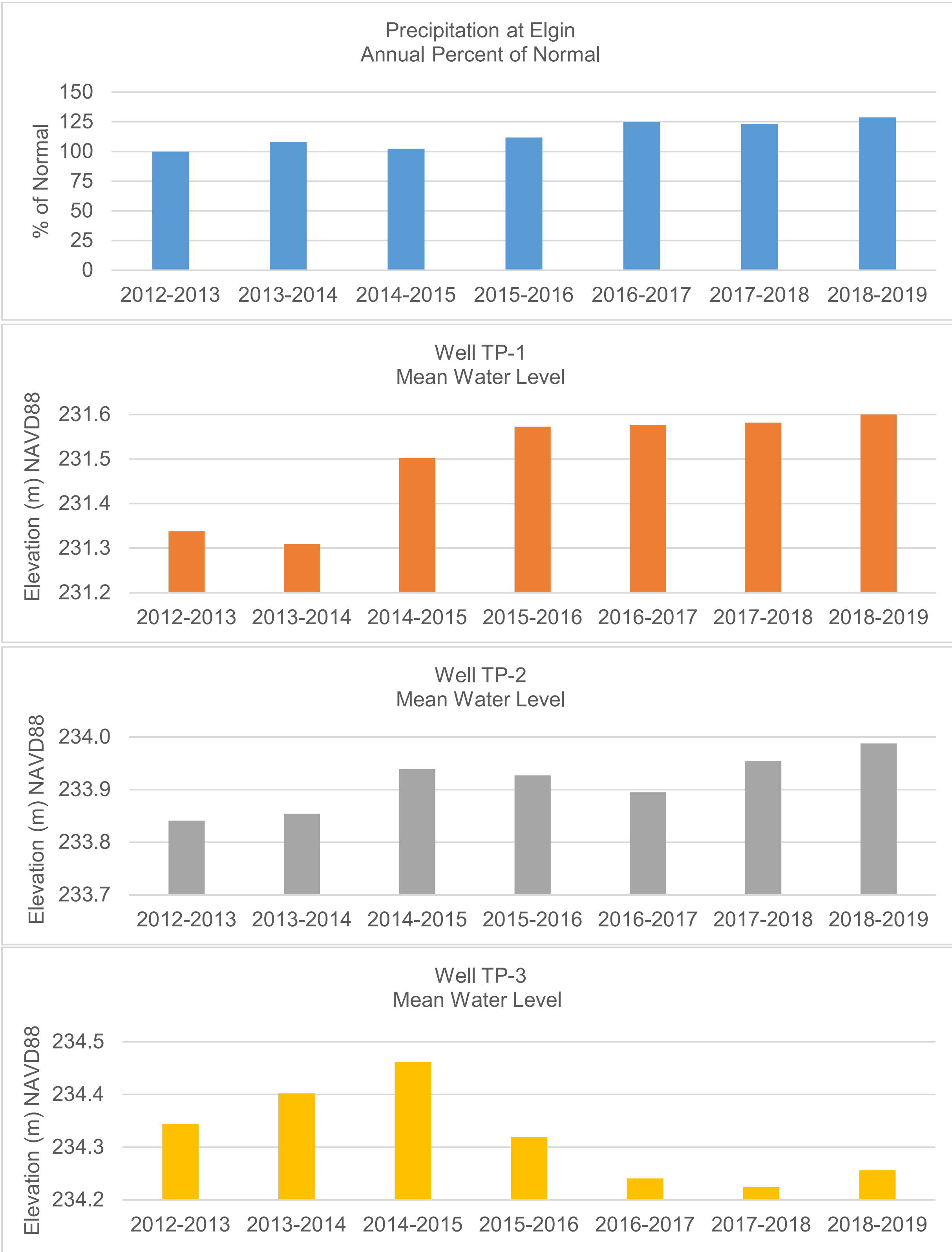

Figure 13. Comparison of total annual precipitation percent of normal and mean annual groundwater levels at Trout Park Nature Preserve.

support of the northern white cedar. Mean depth to water from land surface before and after reconstruction is given in Table 8.

Table 7. Mean annual water-level elevations in monitoring wells at Trout Park Nature Preserve compared to total annual precipitation recorded at the Elgin, Illinois, weather station (MRCC 2019).

Tollway Year (Aug 16-Aug 15)	Total Precipitation (in.)	PPT % Normal	Mean WLE TP-1 (m)	Mean WLE TP-2 (m)	Mean WLE TP-3 (m)
2012-2013	37.7	100	231.34	233.84	234.34
2013-2014	40.8	108	231.31	233.85	234.40
2014-2015	38.6	102	231.50	233.94	234.46
2015-2016	42.2	112	231.57	233.93	234.32
2016-2017	47.2	125	231.58	233.90	234.24
2017-2018	46.5	123	231.58	233.95	234.22
2018-2019	48.6	129	231.60	233.99	234.26

*Mean water levels for 2012 starting 12/12/2012.

Table 8. Mean depth to water measured in monitoring wells at Trout Park Nature Preserve.

Monitoring Well	Mean pre-construction depth to water (m)	Mean post-construction depth to water (m)	Change in mean depth to water (m)
TP-1	0.98	0.60	+0.38
TP-2	0.47	0.38	+0.09
TP-3	0.60	0.71	-0.11

SPECIFIC CONDUCTIVITY

Surface-water station TP-F in FRFFNP was placed in a fen similar to the one at TPNP, but up gradient of I-90 to represent water relatively unaffected by roadway runoff. Mean specific conductivity measured at station TP-F was 1,154 µS/cm before construction and 1,133 µS/cm after construction (Table 9), a decrease of 2%. As expected, the maximum and mean values of SpC measured at TP-F were the lowest recorded at any station for both the pre- and post-construction periods.

Mean specific conductivity in groundwater in TPNP increased in monitoring wells TP-1 (+22%) and TP-2 (+9%) following construction, while mean SpC in well TP-3 remained essentially unchanged, with a 1% increase recorded (Table 9). Before construction, the highest mean SpC was measured in monitoring well TP-3 (2,202 µS/cm) with lower means at TP-2 (1,940 µS/cm) and TP-1 (1,755 µS/cm). These values represent a 25% difference between the maximum and minimum mean SpC measured in the wells. After construction, mean SpC remained highest at TP-3 but overall mean SpC became more similar among the wells, with mean values of 2,145, 2,123, and 2,226 µS/cm for TP-1, TP-2, and TP-3, respectively, representing a difference of less than 5% between the maximum and minimum means measured in the wells.

Table 9. Summary statistics of specific conductivity measured by data loggers at ISGS monitoring stations located in Trout Park and Fox River Forested Fen Nature Preserves.

		Pre-construction (through 9/3/14)			Post-construction (from 5/18/17 through 8/15/19)			Percent change in mean specific conductivity
		Min	Max	Mean	Min	Max	Mean	
Monitoring well	TP-1	994	2,355	1,755	1,830	2,634	2,145	+22%
	TP-2	1,636	2,326	1,940	530	2,319	2,123	+9%
	TP-3	1,757	3,022	2,202	1,737	3,254	2,226	+1%
Surface-water station	TP-A	1,623	3,407	1,990	1,075	2,201	1,854	-7%
	TP-B	122	14,348	2,364	750	3,167	1,995	-16%
	TP-C	438	3,597	1,966	957	2,170	1,810	-8%
	TP-D	491	4,700	1,938	1,001	2,200	1,672	-14%
	TP-E	87	19,011	2,256	-	-	-	N/A
	TP-F	475	1,692	1,154	246	1,385	1,133	-2%

Before and after construction, SpC measured in wells at TPNP followed a seasonal pattern, where levels generally increased from late winter/early spring through mid-summer, then decreased from mid-summer through late winter/early spring (Figure 14). This represents a lag of approximately 6 months for the salt from the previous winters deicing season to appear in the monitoring wells. SpC in wells TP-1 and TP-2 generally showed a similar amplitude of seasonal fluctuation during the pre-construction period, although well TP-1 showed greater variability and TP-2 had slightly higher overall levels from season to season. Before construction, SpC in well TP-3 was generally higher than in wells TP-1 and TP-2, with seasonal peaks that were distinctly the highest of the three wells. Following construction, the amplitude of seasonal fluctuation of SpC in well TP-2 decreased, though SpC levels generally remained greater than in TP-1 during the fall and winter months. However, SpC levels in well TP-1 were typically higher than in well TP-2 during the spring and summer months. Well TP-3 continued to have distinctly higher peaks in SpC than wells TP-1 and TP-2 following construction.

Mean values of specific conductivity in surface water in TPNP decreased at each monitoring location after construction, with the largest decrease (16%) measured in the roadway runoff channel at TP-B (Table 9). Before construction, mean SpC was greatest in the roadway runoff channels at TP-B (2,364 µS/cm) and TP-E (2,256 µS/cm). Lower mean SpC values were recorded in the stream channel at TP-A (1,990 µS/cm), TP-C (1,966 µS/cm), and TP-D (1,938 µS/cm), with values decreasing downstream. Following construction, mean SpC remained highest at TP-B (1,995 µS/cm), though it became more similar to the values recorded at TP-A and TP-C in the stream. The difference between mean SpC at TP-B and TP-C was 20% before construction versus 10% after construction. The second largest decrease in mean SpC in surface water following construction was measured at TP-D, which decreased by 14%.

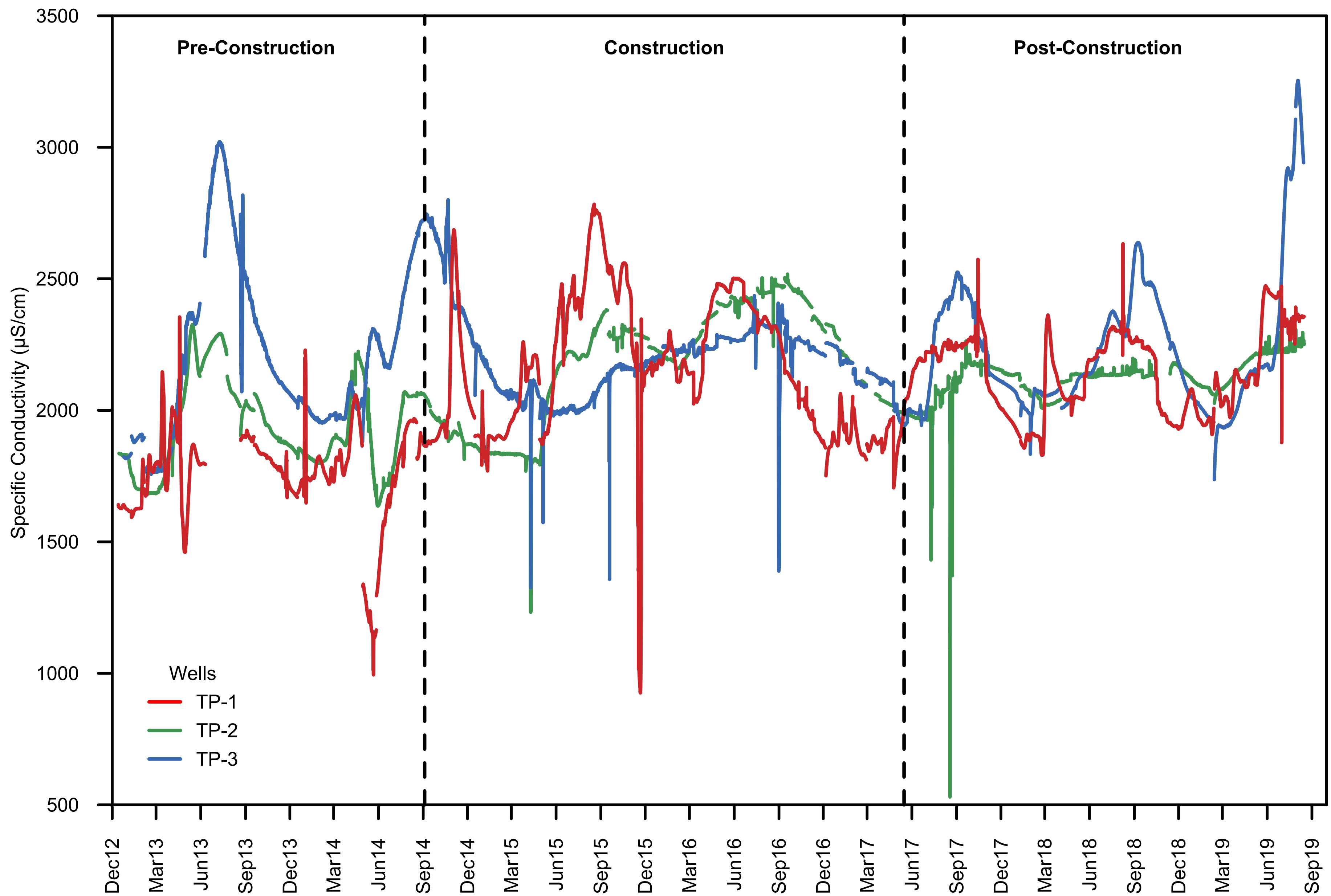

Figure 14. Specific conductivity in groundwater monitoring wells at Trout Park Nature Preserve.

Specific conductivity levels measured in both surface water and groundwater were occasionally punctuated by abrupt, but short-duration increases and decreases following periods of substantial rainfall (Figures 14, 15a, and 15b). These temporary events reflected periods of solute delivery (SpC increased) or solute dilution (SpC decreased) in shallow groundwater and surface-water systems, but did not generally affect base levels of specific conductivity over time. Such increases and decreases were recorded much more frequently at surface-water stations reflecting the more immediate and un-buffered response of surface water to precipitation as compared to the groundwater measured in the monitoring wells. The largest such influxes of solute-rich storm water into TPNP were recorded in the IL 25 and I-90 runoff channels during the 2012-2013 winter and in Spring 2014, at surface-water stations TP-E and TP-B, respectively (Figure 15b). Specific conductivity measured at the background surface-water station TP-F also had a distinct seasonal signature, increasing during the summer and fall months and decreasing during the winter and spring months (Figure 15a).

The overall increase in mean SpC of groundwater was likely a consequence of the recovery of groundwater level and likely reversal in slope of the water table after removal of the I-90 storm sewer. The increase in shallow groundwater levels led to dissolution of residual salt, which had likely accumulated in the shallow soils along I-90 over the previous decades of deicing activities. Further, the local shallow groundwater gradient at the preserve boundary reversed from toward the I-90 storm sewer before construction, to toward the preserve after construction (Figure 12). The overall effect of these changes was that water higher in solutes, and thus with higher conductivity, started flowing into the preserve in the vicinity of wells TP-1 and TP-2. Little change in SpC was measured in well TP-3, suggesting that the groundwater flow path at this well remained essentially the same following construction, and that the storm sewer had little to no effect on groundwater levels in this portion of the preserve. TP-3 is located nearest to I-90 (Figure 7), and therefore is likely most representative of groundwater conditions in the right-of-way. Meanwhile, as mean SpC increased in wells TP-1 and TP-2, the levels became more similar to the SpC level in TP-3, thus supporting the interpretation that the groundwater flow direction in the vicinity of those two wells had shifted toward the stream following removal of the I-90 storm sewer.

The overall decrease in mean SpC measured in surface water at TPNP may reflect the combined effects of the elimination of pathways for roadway runoff to enter the preserve, specifically the removal of the IL 25 culvert and installation of the concrete barrier wall along the eastbound shoulder of I-90. However, observed decreases in mean SpC also corresponded to increased precipitation during the post-construction period (Table 4), and are therefore partly attributed to more dilute groundwater discharging to the stream in TPNP. Prior to reconstruction of I-90, large amplitude peaks in specific conductivity were measured at surface-water stations TP-A, TP-B, TP-C, TP-D, and TP-E during the winters of 2012-2013 and 2013-2014 (Figures 15a and 15b). The highest levels were recorded at stations TP-B in the I-90 runoff channel and TP-E in the IL 25 runoff channel (Figure 15b). These peaks followed significant rainfall events, and represent pulses of water with high concentrations of solutes entering the preserve from the shoulder of I-90 (represented by TP-B) and from the I-90/IL 25 interchange (represented by TP-E and possibly TP-B as well). Peaks in specific conductivity were measured on the same days at TP-C and TP-D, indicating the rapid downstream transport of higher concentrations of solutes originating from roadway runoff. In contrast, peaks in specific conductivity at TP-A typically lagged other surface-water stations by about 6 days. As TP-A is located at the headwater seep and does not have a surface-water connection to the roadways, the observed lag indicates a slower travel time for solutes from other parts of the watershed, including IL 25. The exact pathway of this underground flow is unknown, and while the regional flow is likely from the east-northeast, the local topography suggests that the recharge area for this seep is mainly to the east-southeast (Figure 3).

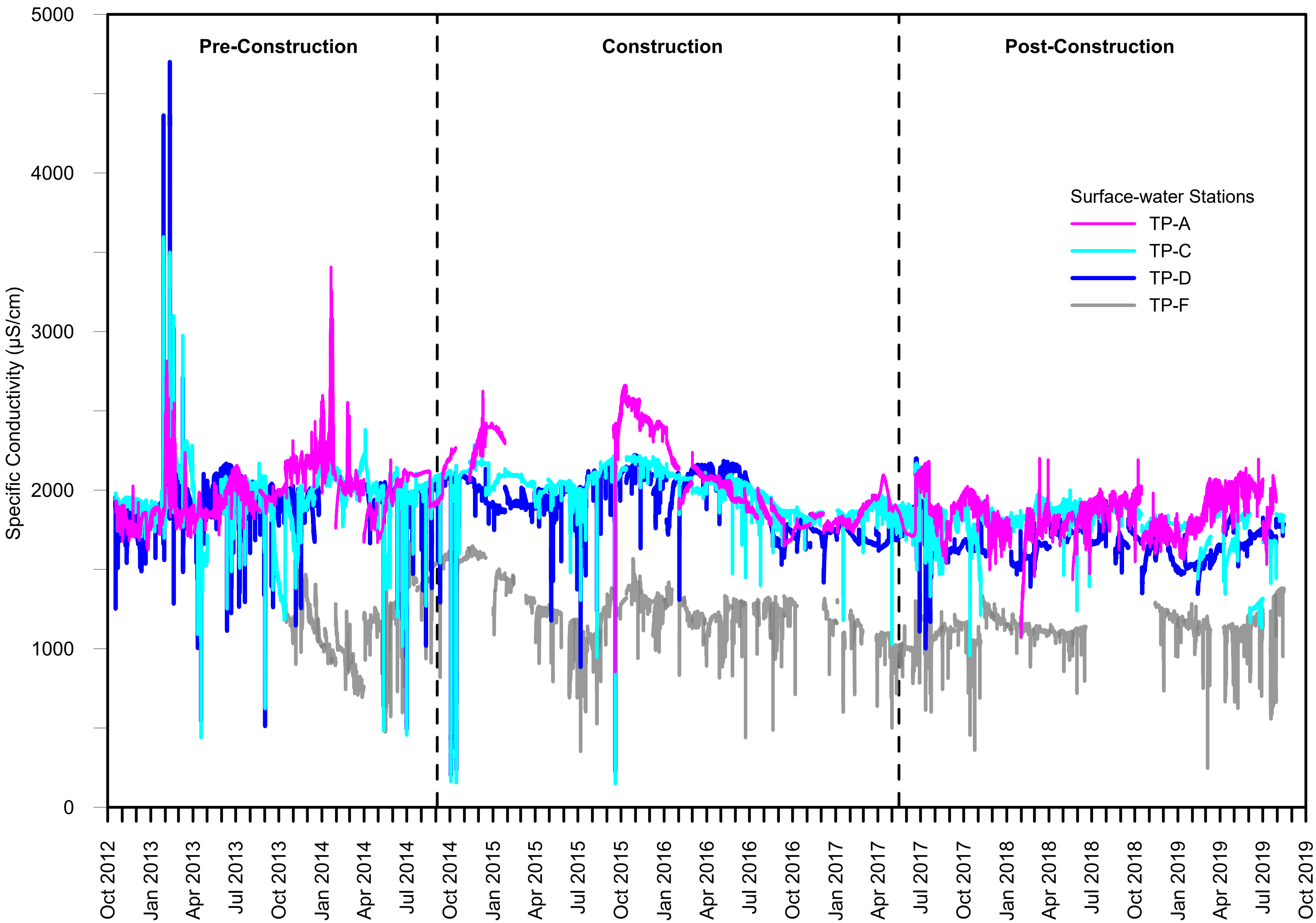

Figure 15a. Specific Conductivity at surface-water stations at Trout Park and Fox River Forested Fen Nature Preserves.

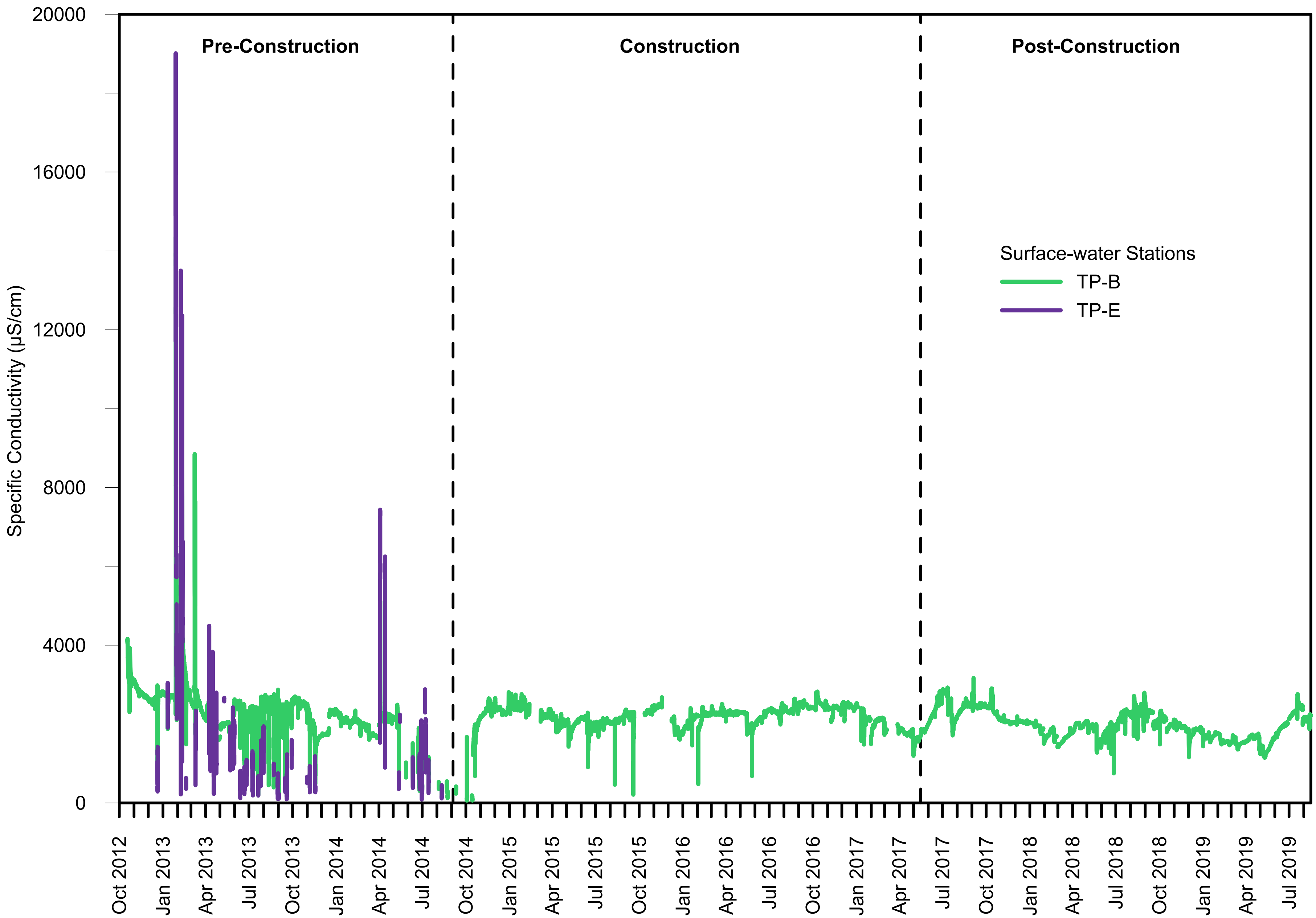

Figure 15b. Specific conductivity at surface-water stations at Trout Park Nature Preserve.

Following construction, after which all surface-water inputs from I-90 and IL 25 were eliminated, peaks in specific conductivity at all surface-water stations were of lower amplitude than those observed during the pre-construction period (Figures 15a, 15b and Table 9). This suggests that mitigation efforts were successful in reducing the amount of salt-enriched runoff from rapidly and directly entering the preserve from I-90 and IL 25. However, it is also likely that the increase in precipitation during the post-construction period also contributed to more dilute surface water overall in the preserve.

GRAB SAMPLES

Total Dissolved Solids

Mean TDS concentrations measured at the background surface-water station TP-F were 755 mg/L before construction and 691 mg/L after construction, a decrease of 8% (Table 10). As expected, maximum and mean TDS concentrations measured at TP-F were the lowest recorded at any station during both the pre- and post-construction periods as this station was chosen to represent waters less affected by roadways and development. Prior to construction, mean TDS at TP-F was 38% lower than the lowest mean TDS measured in surface water in TPNP, and following construction, mean TDS at TP-F was 40% lower than the lowest mean TDS measured in surface water in TPNP.

Table 10. Total dissolved solids (TDS) concentrations measured in grab samples from Trout Park and Fox River Forested Fen Nature Preserves.

		Pre-construction total dissolved solids concentration (mg/L)			**Post-construction total dissolved solids concentration (mg/L)**			**Percent change in mean total dissolved solids concentration**
		Min	**Max**	**Mean**	**Min**	**Max**	**Mean**	
Monitoring well	TP-1	713	1073	966	1016	1295	1149	+19%
	TP-2	900	1272	1057	1106	1197	1162	+10%
	TP-3	1024	1586	1220	1065	1339	1171	-4%
Surface-water station	TP-A	948	1439	1138	939	1174	1045	-8%
	TP-B	1104	1944	1339	891	1542	1213	-9%
	TP-C	1025	1195	1120	978	1126	1036	-8%
	TP-D	1021	1222	1105	978	1138	1032	-7%
	TP-F	685	832	755	619	759	691	-8%

Mean TDS concentrations in groundwater samples increased in wells TP-1 (+19%) and TP-2 (+10%) and decreased in well TP-3 (-4%) after construction (Table 10). Before construction, the highest mean TDS concentration was measured in well TP-3 (1,220 mg/L), with lower means at TP-2 (1,057 mg/L) and TP-1 (966 mg/L). These values represent a 23% difference between the maximum and minimum mean TDS measured in the wells. After construction, mean TDS concentration remained highest at TP-3, but overall mean TDS concentrations became more similar among the wells with mean values of 1,149, 1,162, and 1,171 mg/L for TP-1, TP-2, and TP-3, respectively, representing a 2% difference between the maximum and minimum means measured in the wells.

Mean TDS concentrations in surface water in TPNP decreased between 7% and 9% following construction, with the largest decrease measured in the roadway runoff channel at TP-B (Table 10).

Before construction, the highest mean TDS concentration in surface water was measured in the roadway runoff channel at TP-B (1,339 mg/L). Lower mean concentrations were measured in the stream channel at TP-A (1,138 mg/L), TP-C (1,120 mg/L), and TP-D (1,105 mg/L), with values decreasing downstream. After construction, mean TDS concentration remained highest at TP-B (1,213 mg/L). The maximum difference between mean TDS at TP-B and the remaining surface-water stations at TPNP only changed by 3%, a 19% difference before construction versus a 16% difference following construction.

TDS concentrations in groundwater showed a distinct seasonal pattern, generally increasing during late winter and spring, peaking in summer, and then decreasing during the fall and winter (Figure 16a). This follows a pattern similar to specific conductivity in groundwater and likely reflects pulses of dissolved road salt from the previous winter gradually moving into and through the local groundwater system. While the seasonal pattern in TDS is prevalent throughout all construction phases, the magnitude of seasonal variation in TDS concentrations decreased noticeably in the three monitoring wells in the post-construction period.

Seasonal patterns were also present in TDS concentrations in surface-water grab samples, though they were somewhat less distinct. Generally, they increased starting in late spring, peaked in summer, and decreased from fall through early spring, although prior to completion of construction, peak concentrations at TP-A and TP-B tended to occur during the winter (Figure 16b), providing more evidence that the IL 25 storm sewer was leaking. Variations in TDS concentrations measured in surface-water grab samples decreased at all stations in the post-construction period, specifically because peak levels were lower following construction. However, variations at TP-B were still relatively high during the post-construction period.

The overall pattern of changes observed in mean TDS concentrations in both groundwater and surface water after construction are unsurprisingly similar to those for specific conductivity. Likewise, the observed increase in mean TDS concentrations in monitoring wells TP-1 and TP-2 after construction likely reflects the increased delivery of solutes to groundwater in the preserve from the I-90 right of way following removal of the storm sewer. Further, the differential increase in mean TDS concentrations between TP-1 and TP-2 reflects the combined effect of the relative influence of the storm sewer on the groundwater gradient prior to construction, and the degree of rewetting and dissolution of residual salt along the preserve boundary. Conversely, the slight decrease in mean TDS concentration at TP-3 is consistent with no distinct change to the groundwater regime in this portion of the preserve, meaning no rebound in water level, no rewetting and dissolution of residual salts from the shallow surface, and no change in the groundwater gradient. Additionally, the slight decrease in mean TDS at well TP-3 likely reflects the overall dilution of groundwater resulting from increased precipitation during the post-construction period, likely due to residual salt in the former runoff channel.

The decreases in mean TDS measured in surface water at TPNP reflects the combined effects of the elimination of roadway runoff entering the preserve and dilution of surface water with respect to dissolved solids as a result of increased precipitation during the post-construction period.

Primary Constituents of Total Dissolved Solids

The primary constituents measured in groundwater and surface water at TPNP and FRFFNP include, in decreasing proportions, chloride (Cl), sodium (Na), calcium (Ca), sulfate (SO_4), magnesium (Mg), and sulfur (S) (Figures 17a and 17b). Proportionally, sodium and chloride, the primary constituents of road salt, accounted for 45% of TDS before construction and 41% of TDS after construction at the background surface-water station TP-F (Figure 17b).

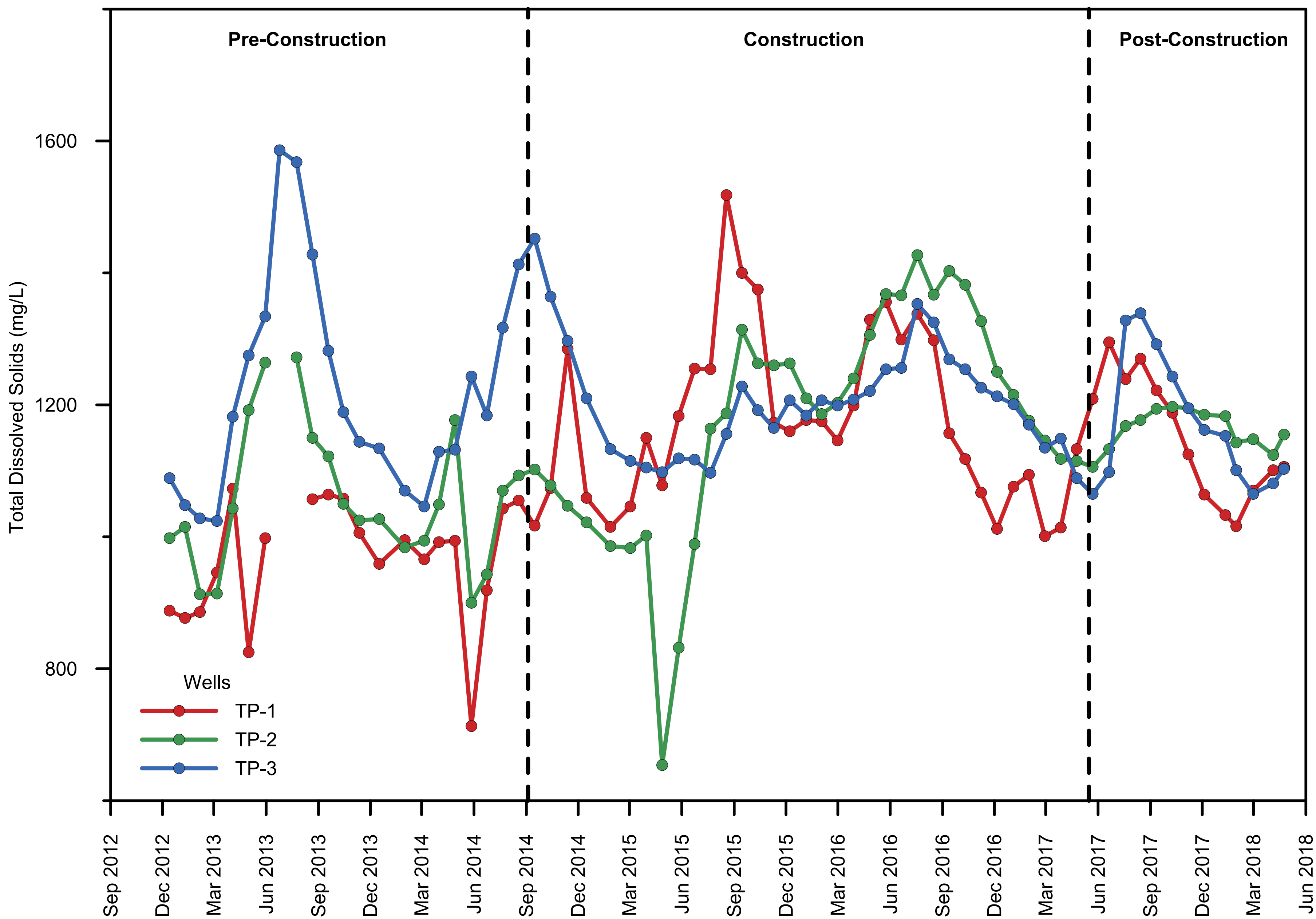

Figure 16a. Total dissolved solids concentrations in groundwater monitoring wells at Trout Park Nature Preserve.

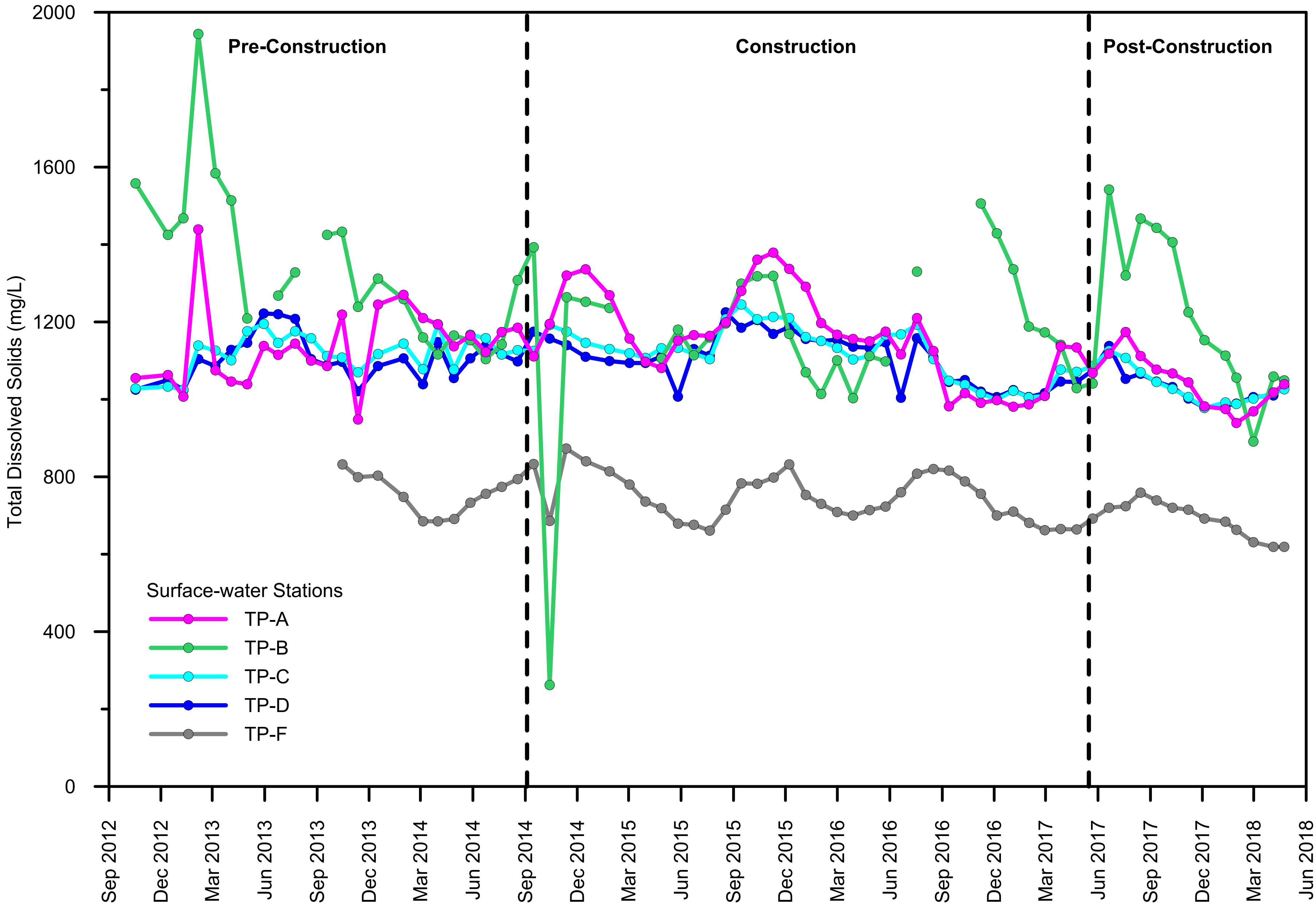

Figure 16b. Total dissolved solids concentrations at surface-water monitoring stations at Trout Park and Fox River Forested Fen Nature Preserves.

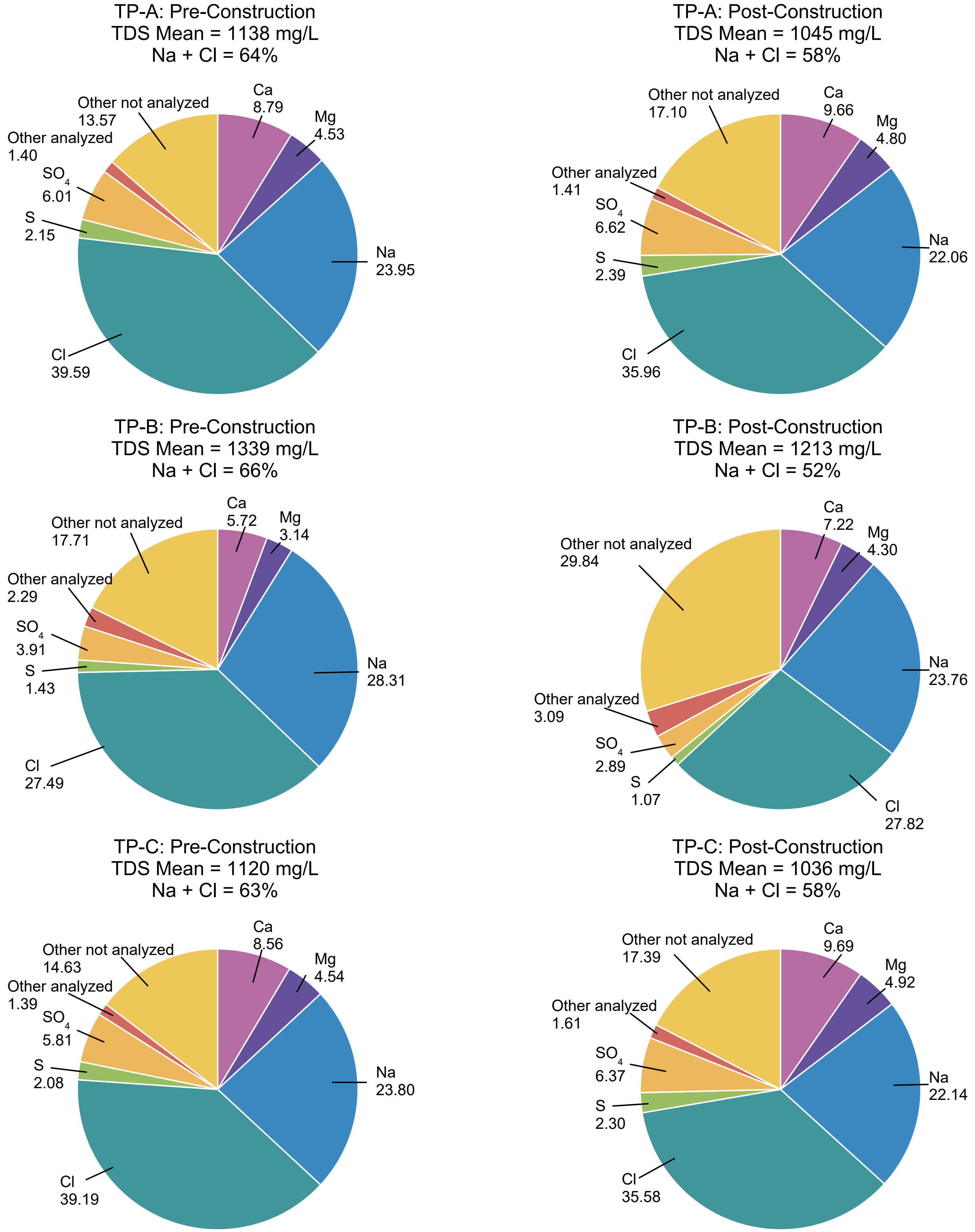

Figure 17a. Primary constituents comprising total dissolved solids in surface water at Trout Park and Fox River Forested Fen Nature Preserves.

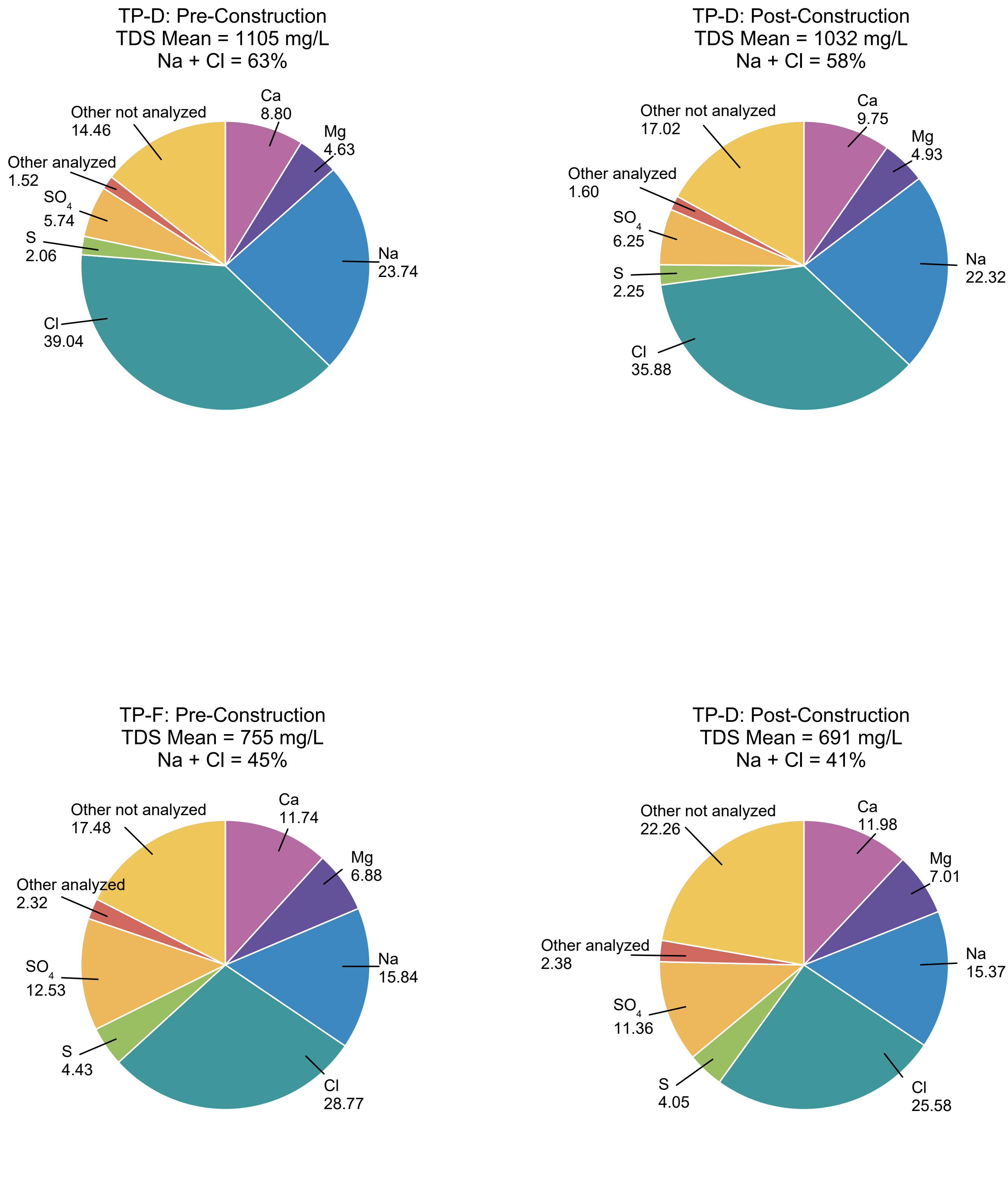

Figure 17b. Primary constituents comprising total dissolved solids in surface water at Trout Park and Fox River Forested Fen Nature Preserves.

By contrast, sodium and chloride accounted for 63-66% of TDS in surface water at TPNP before construction, and 52-58% of TDS in surface water at TPNP after construction. In groundwater at TPNP, sodium and chloride accounted for 61-70% of TDS before construction and 64% of TDS in all wells after construction (Figure 18). The primary ions comprising TDS are discussed in more detail below.

Chloride

Mean chloride concentrations measured at the background surface-water station TP-F were 218 mg/L before construction and 177 mg/L after construction, representing a decrease of 19% (Table 11). Minimum, maximum, and mean chloride concentrations measured at TP-F were the lowest recorded at any station during both the pre- and post-construction periods. Prior to construction, the mean chloride concentration at TP-F was 66% lower than the lowest mean chloride concentration measured in surface water in TPNP, and following construction, the mean chloride concentration at TP-F was 70% lower than the lowest mean chloride concentration measured in surface water in TPNP.

Table 11. Chloride concentrations measured in grab samples from Trout Park and Fox River Forested Fen Nature Preserves.

		Pre-construction chloride concentration (mg/L)			**Post-construction chloride concentration (mg/L)**			**Percent change in mean chloride concentration**
		Min	**Max**	**Mean**	**Min**	**Max**	**Mean**	
Monitoring well	TP-1	241	460	376	389	505	454	+21%
	TP-2	345	536	434	423	484	455	+5%
	TP-3	423	796	536	392	561	455	-15%
Surface-water station	TP-A	375	720	453	335	399	375	-17%
	TP-B	432	1037	584	302	556	434	-26%
	TP-C	391	481	439	346	384	368	-16%
	TP-D	391	489	431	344	390	370	-14%
	TP-F	169	283	218	152	205	177	-19%

Mean chloride concentrations in groundwater samples increased in wells TP-1 (+21%) and TP-2 (+5%) and decreased in well TP-3 (-15%) after construction (Table 11). Before construction, the highest mean chloride concentration was measured in well TP-3 (536 mg/L), with lower means at TP-2 (434 mg/L) and TP-1 (376 mg/L). These values represent a 35% difference between the maximum and minimum mean chloride concentrations measured in the wells. After construction, mean chloride concentrations were virtually the same in all three monitoring wells, with mean concentrations of 454 mg/L in well TP-1 and 455 mg/L in both wells TP-2 and TP-3.

Mean chloride concentrations in surface water in TPNP decreased at each monitoring location following construction, with the greatest decrease (26%) measured in the roadway runoff channel at TP-B (Table 11). Before construction, the highest mean chloride concentration in surface water was measured at TP-B (584 mg/L). Lower mean chloride concentrations were measured in the stream channel at TP-A (453 mg/L), TP-C (439 mg/L), and TP-D (431 mg/L), with values decreasing downstream.

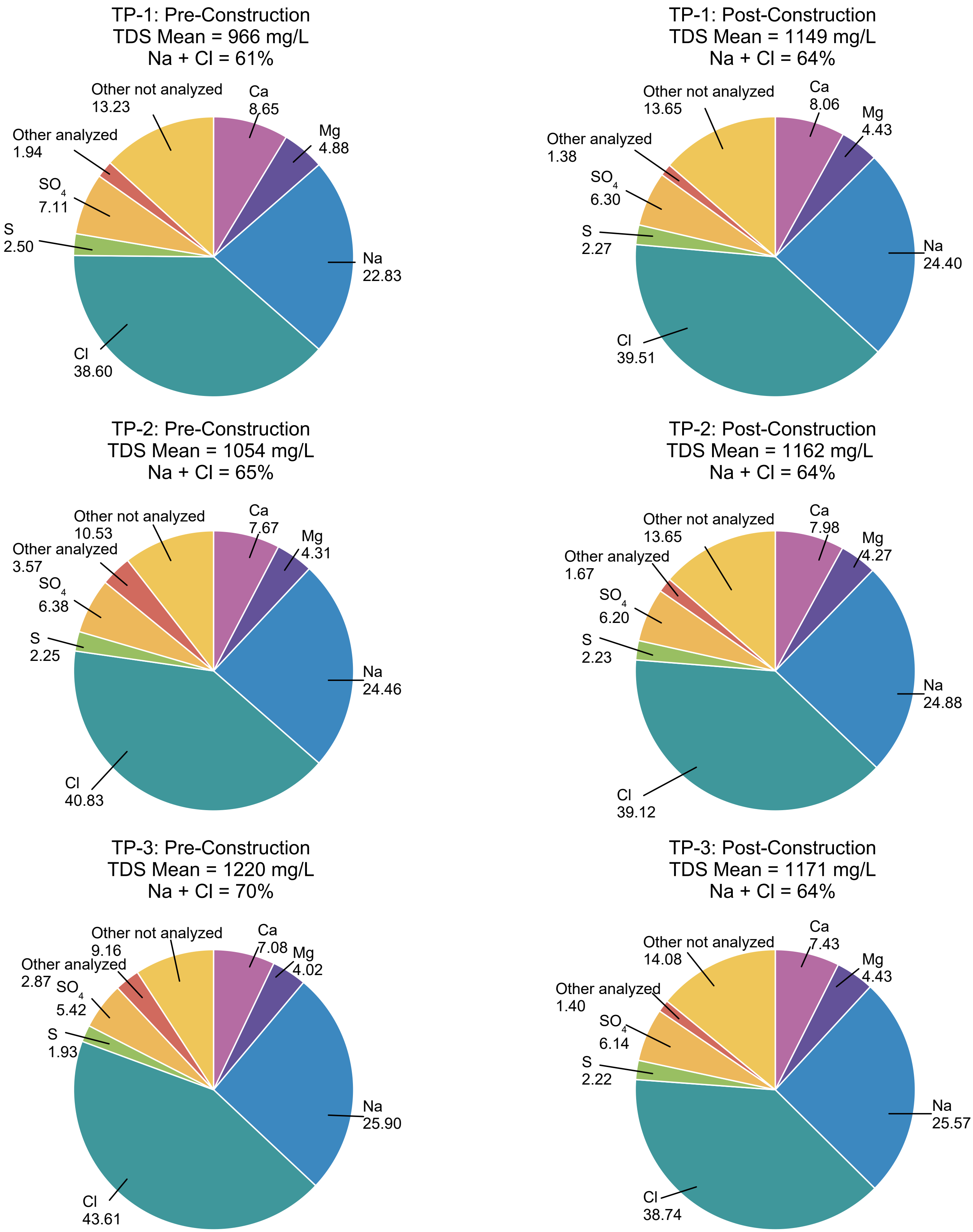

Figure 18. Primary constituents comprising total dissolved solids in groundwater at Trout Park Nature Preserve.

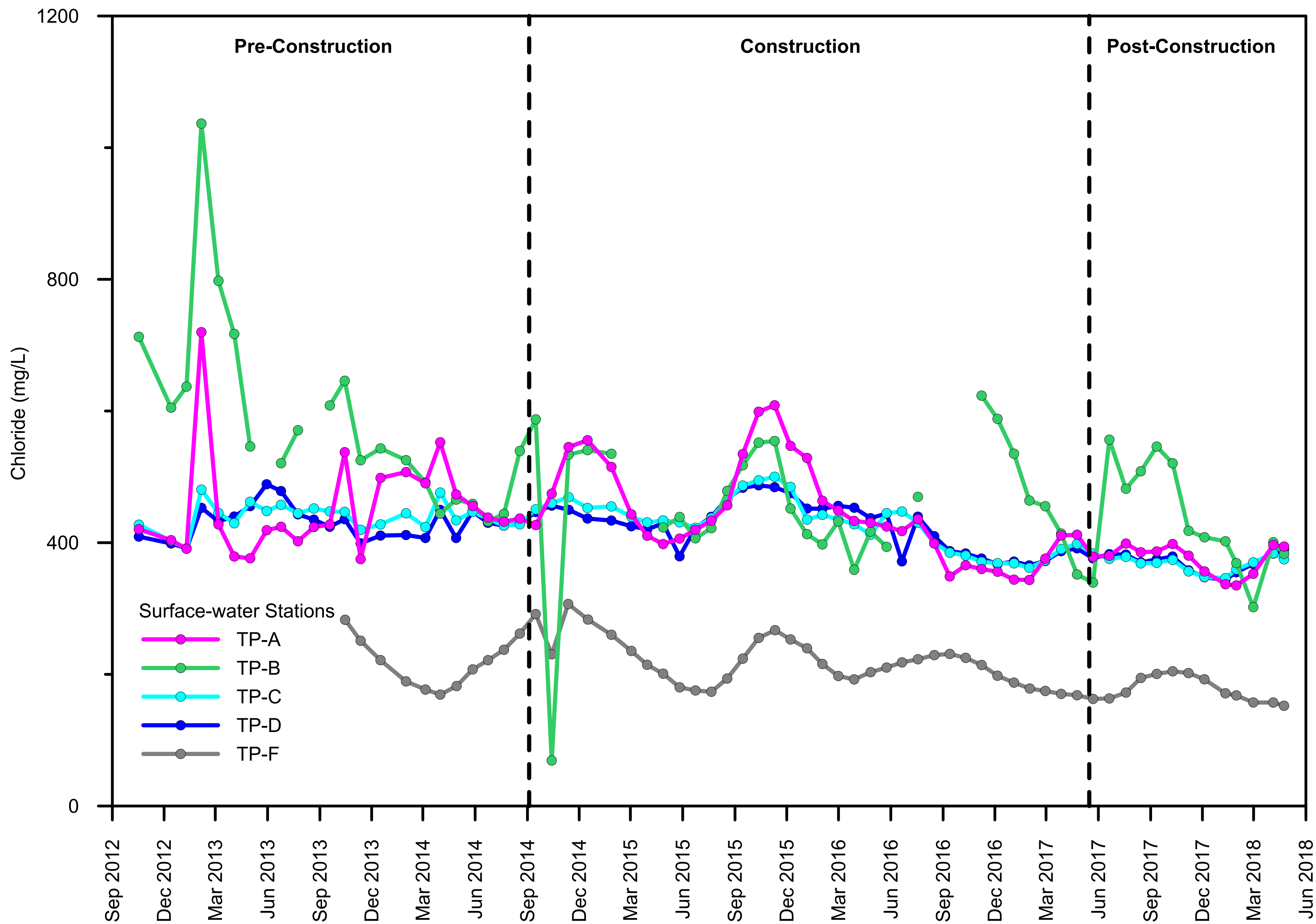

Figure 19a. Chloride concentrations at surface-water monitoring stations at Trout Park and Fox River Forested Fen Nature Preserves.

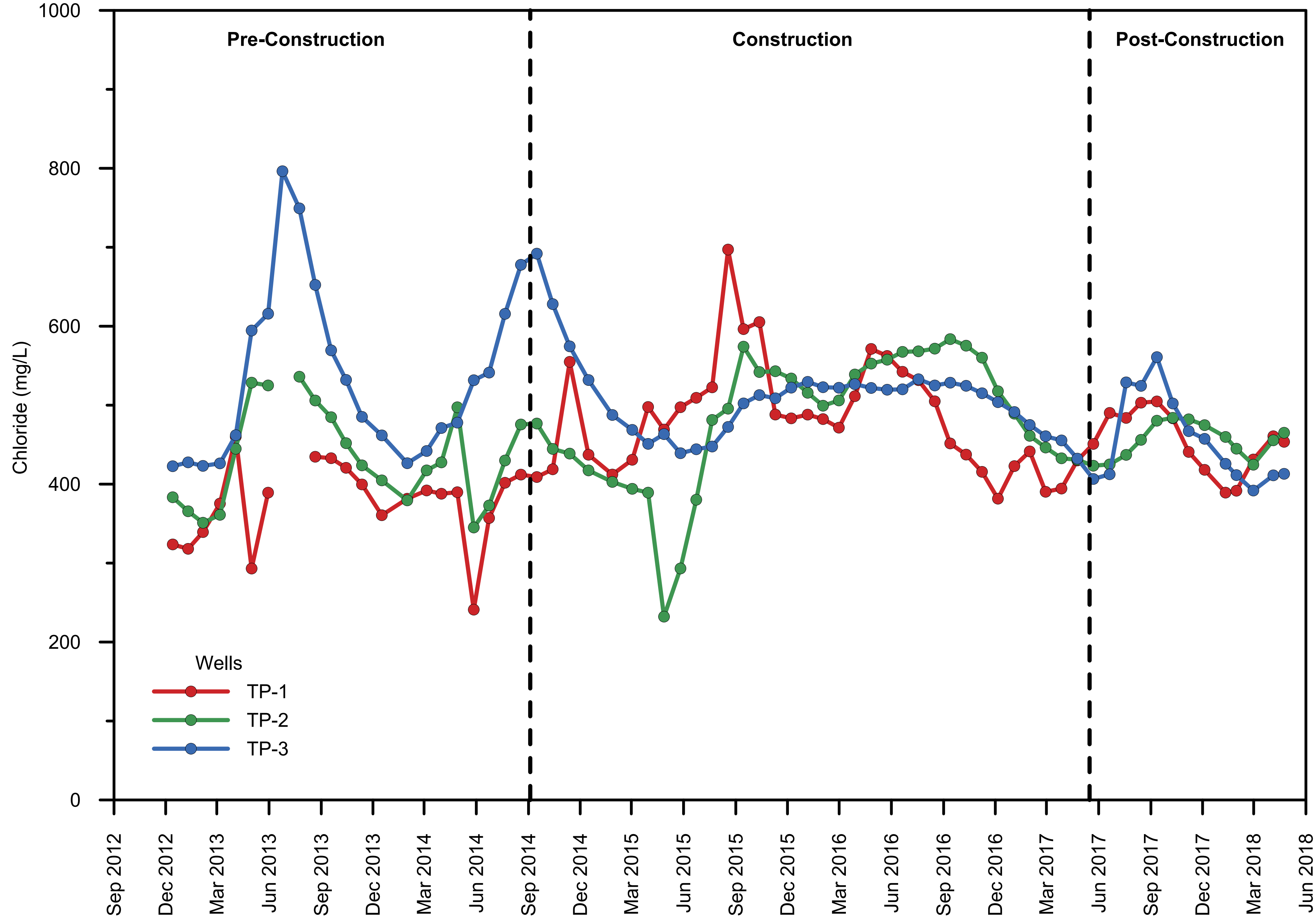

Figure 19b. Chloride concentrations in groundwater monitoring wells at Trout Park Nature Preserve.

After construction, mean chloride concentrations remained highest at TP-B (434 mg/L), but the difference between chloride concentrations at TP-B and the lowest concentration measured in surface water in TPNP fell from 30% in the pre-construction period to 16% in the post-construction period.

Seasonal patterns in chloride concentrations in surface-water and groundwater grab samples generally follow those observed for TDS (Figures 19a and 19b). Likewise, variations in chloride concentrations measured in grab samples decreased at all monitoring stations in the post-construction period. However, variations in chloride concentrations at TP-B were still relatively high as compared to the other surface-water stations during the post-construction period.

Regression Model for Estimating Chloride Concentrations from Specific Conductivity

A linear regression model was constructed for estimating chloride concentrations from specific conductivity (Figure 20), which is anticipated to be used in future monitoring efforts. As expected, the model had a very strong correlation ($R^2 = 0.95$). The resulting predicted chloride values of the validator group (y) were then plotted against the observed chloride values of the validator group (x), with a resulting R^2 value of 0.96 indicating strong correlation between the actual and predicted chloride values. The root mean square error (RMSE), or the difference between the calculated for the predicted chloride concentrations of the validator group, was calculated to be 109 mg/L. The total range of observed chloride concentrations of the validator group was from 152 to 798 mg/L (646 mg/L), making the RMSE equal to approximately 17% of the range of chloride values.

Sodium

Mean sodium concentrations measured at control station TP-F were 120 mg/L before construction and 106 mg/L after construction, representing a decrease of 12% (Table 12). Minimum, maximum, and mean sodium concentrations measured at the background surface-water station TP-F were the lowest recorded at any station during both the pre and post-construction periods, and mean concentrations for both periods were 75% and 73% less, respectively, than the lowest mean sodium concentrations measured in surface water in TPNP.

Table 12. Sodium concentrations measured in grab samples from Trout Park and Fox River Forested Fen Nature Preserves.

		Pre-construction sodium concentration (mg/L)			**Post-construction sodium concentration (mg/L)**			**Percent change in mean sodium concentration**
		Min	**Max**	**Mean**	**Min**	**Max**	**Mean**	
Monitoring well	TP-1	181	250	218	248	310	280	+28%
	TP-2	202	325	260	267	303	289	+11%
	TP-3	247	450	317	259	343	299	-6%
Surface-water station	TP-A	221	353	273	214	245	230	-16%
	TP-B	306	558	379	213	337	287	-24%
	TP-C	247	285	267	221	242	229	-14%
	TP-D	236	297	263	223	237	230	-12%
	TP-F	97.1	137	120	92.6	119	106	-12%

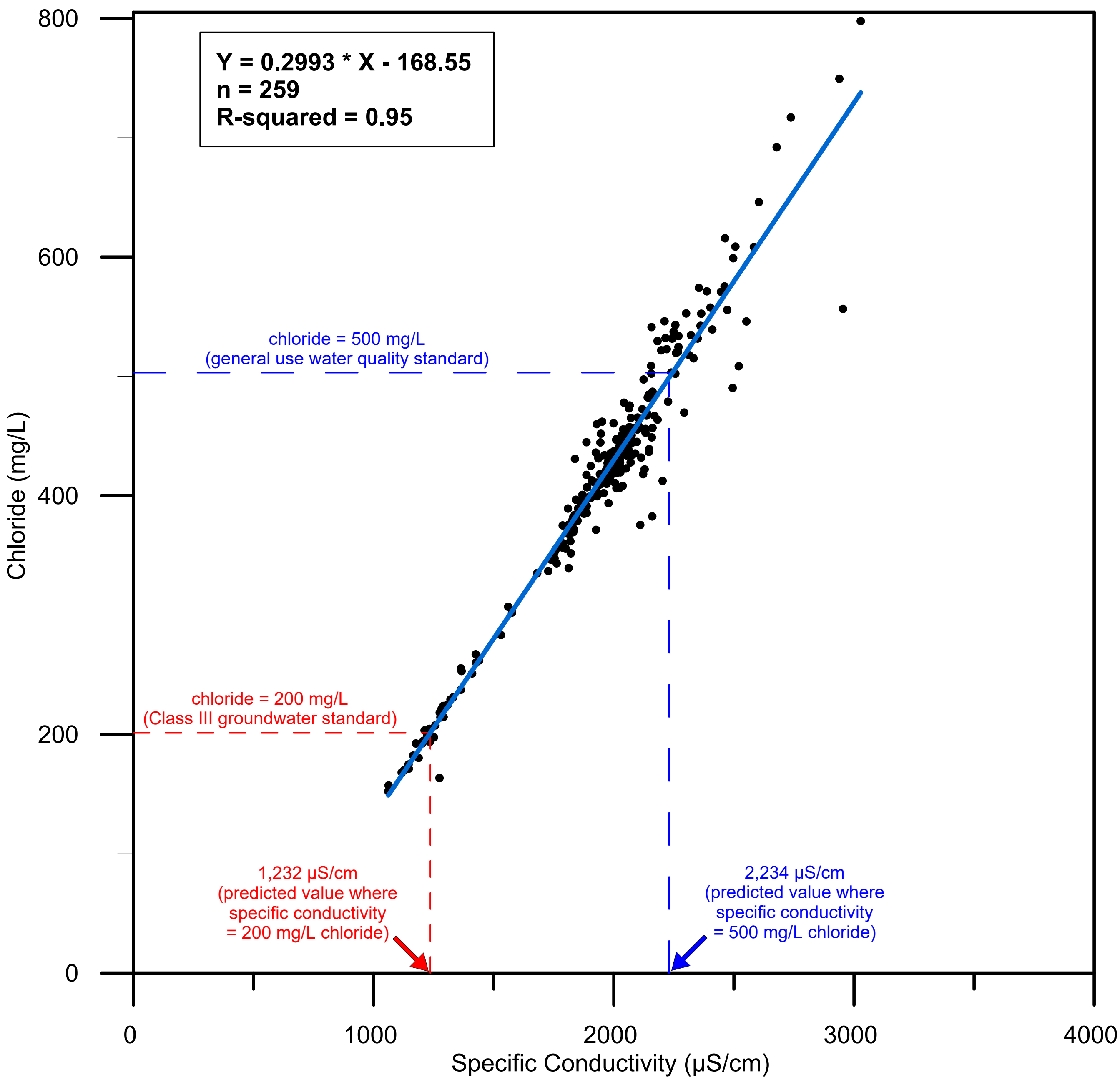

Figure 20. A plot of chloride versus specific conductivity at Trout Park and Fox River Forested Fen Nature Preserves and the linear regression model that will be used to predict surface water and groundwater chloride concentrations at Trout Park Nature Preserve in future monitoring. Water quality standards for groundwater (red) and surface water (blue) are shown for reference.

Mean sodium concentrations in groundwater samples increased in wells TP-1 (+28%) and TP-2 (+11%) and decreased in well TP-3 (-6%) after construction (Table 12). Before construction, the highest mean sodium concentration was measured in well TP-3 (317 mg/L), with lower means at TP-2 (260 mg/L) and TP-1 (218 mg/L). These values represent a 37% difference between the maximum and minimum mean sodium concentrations measured in the wells. After construction, mean sodium concentration remained highest at TP-3, but overall mean sodium concentrations became more similar among the wells with mean values of 280, 289, and 299 mg/L for TP-1, TP-2, and TP-3, respectively (Table 12), representing a 7% difference between the maximum and minimum means measured in the wells.

Mean sodium concentrations in surface water in TPNP decreased at each monitoring location following construction, with the greatest decrease (24%) measured in the roadway runoff channel at TP-B (Table 12). Before construction, the highest mean sodium concentration in surface water was measured in the roadway runoff channel at TP-B (379 mg/L). Lower mean sodium concentrations were measured in the stream channel at TP-A (273 mg/L), TP-C (267 mg/L), and TP-D (263 mg/L), with values decreasing downstream. After construction, mean sodium concentration remained highest at TP-B (287 mg/L), but concentrations went from 36% greater to 22% greater than the lowest mean sodium concentrations measured in surface water at TPNP.

Seasonal patterns in sodium concentrations in surface-water and groundwater grab samples (Figures 20a and 20b) follow those observed for TDS and chloride (described above). Likewise, variations in sodium concentrations measured in grab samples decreased at all monitoring stations in the post-construction period. However, variations in sodium concentrations at TP-B remained high as compared to the other surface-water stations during the post-construction period.

Calcium

Mean calcium concentrations measured at the background surface-water station TP-F were 88.6 mg/L before construction and 82.5 mg/L after construction, representing a decrease of 7% (Table 13). Maximum and mean calcium concentrations measured at TP-F were the lowest recorded at any surface-water station during both the pre and post-construction periods, though the pre-construction mean concentration (88.6 mg/L) was very similar to that measured in the roadway runoff channel at TP-B (89.2 mg/L). After construction, the mean calcium concentration measured at TP-F decreased, while concentrations at all surface-water stations in TPNP increased, with a difference of 19% between mean calcium at TP-F and the lowest mean calcium concentration measured at surface-water stations in TPNP.

Mean calcium concentrations in groundwater samples increased in wells TP-2 (+15%) and TP-1 (+8%), and remained the same in well TP-3 (+1%) (Table 13). Before construction, mean calcium concentrations were highest and most similar in wells TP-1 and TP-3 (85.6 and 85.9 mg/L, respectively), while following construction, mean calcium concentrations were highest and most similar in wells TP-1 and TP-2 (92.2 and 92.7 mg/L, respectively). Before and after construction, the percent difference between the maximum and minimum mean calcium concentrations measured in the monitoring wells was 6% and 7%, respectively.

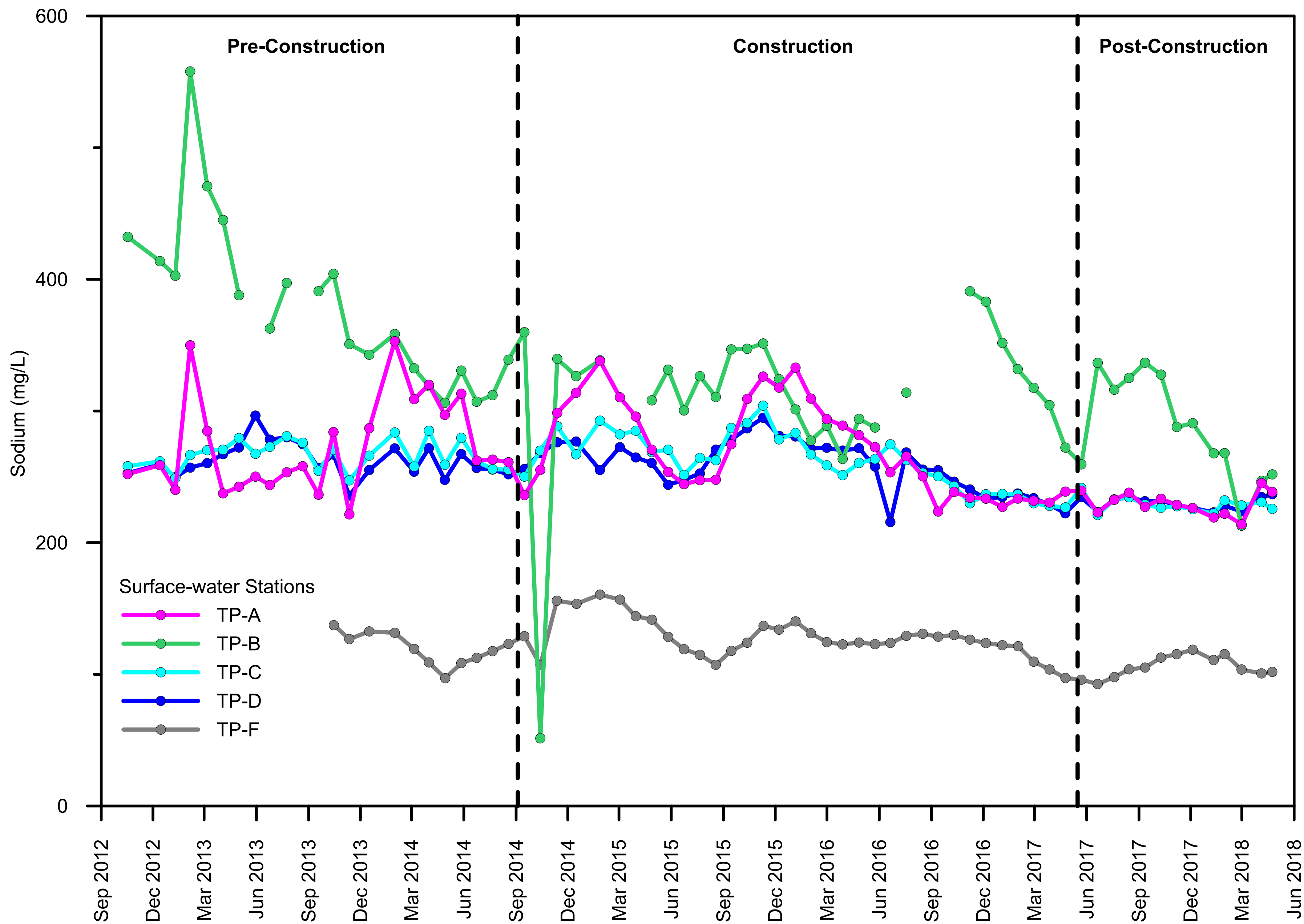

Figure 21a. Sodium concentrations at surface-water monitoring stations at Trout Park and Fox River Forested Fen Nature Preserves.

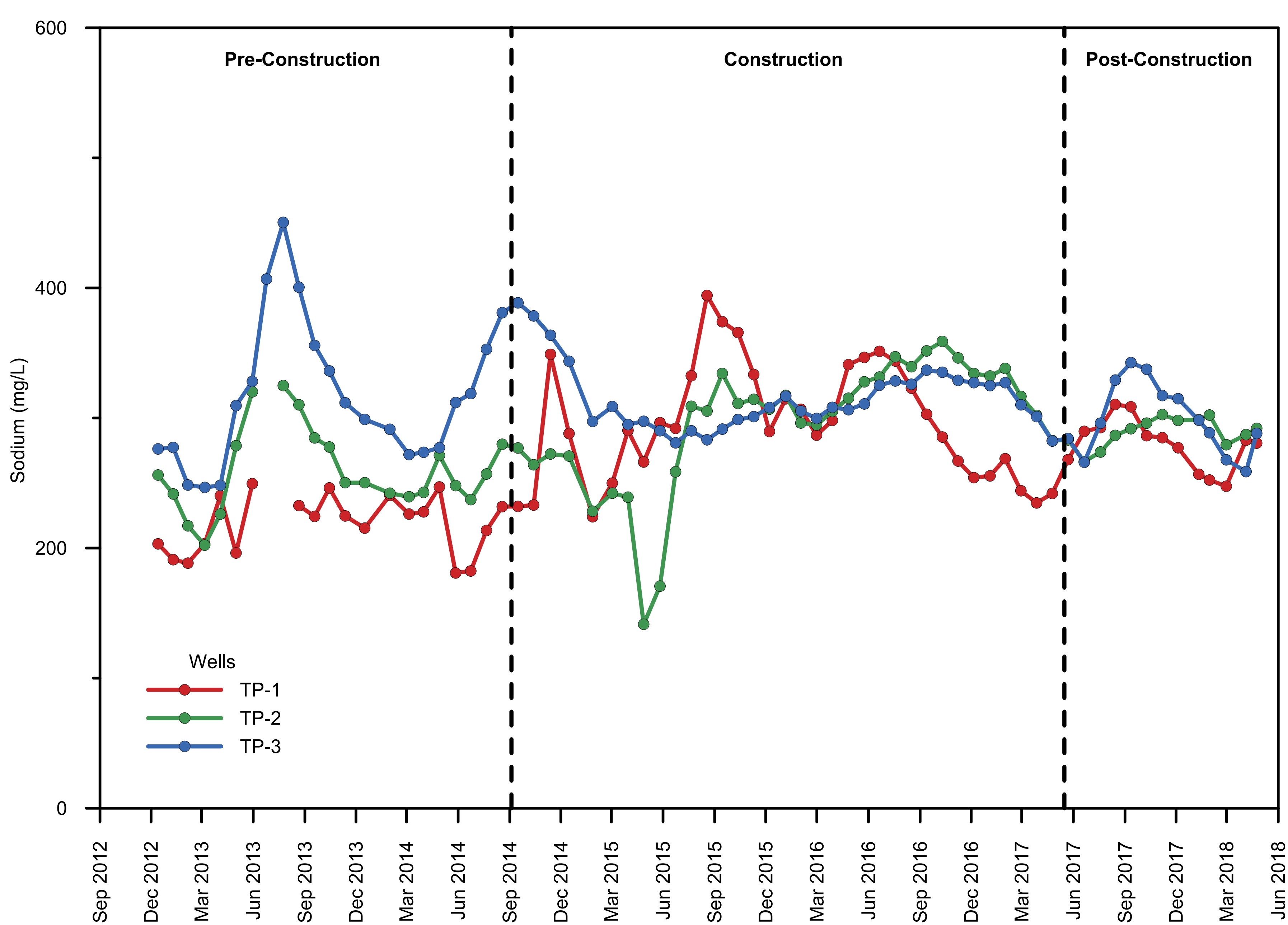

Figure 21b. Sodium concentrations in groundwater monitoring wells at Trout Park Nature Preserve.

Table 13. Calcium concentrations measured in grab samples from Trout Park and Fox River Forested Fen Nature Preserves.

		Pre-construction calcium concentration (mg/L)			**Post-construction calcium concentration (mg/L)**			**Percent change in mean calcium concentration**
		Min	**Max**	**Mean**	**Min**	**Max**	**Mean**	
Monitoring well	TP-1	57.8	104	85.6	86.9	98.3	92.2	+8%
	TP-2	57.3	96.3	80.5	84.3	103	92.7	+15%
	TP-3	67.6	118	85.9	80.1	93.9	86.7	+1%
Surface-water station	TP-A	77.3	125	100	95.6	106	101	+1%
	TP-B	60.4	118	89.2	88.1	134	113	+26%
	TP-C	83.5	107	96.0	94.6	107	100	+4%
	TP-D	85.6	111	97.5	94.6	104	100	+3%
	TP-F	76.9	102	88.6	77.2	91.5	82.5	-7%

Mean calcium concentrations in surface water in TPNP increased at each monitoring location following construction, with the greatest increase (26%) measured in the roadway runoff channel at TP-B (Table 13). Before and after construction, mean calcium concentrations in surface water were similar at stations TP-A, TP-C, and TP-D, with a 4% maximum difference in means before construction and a 1% maximum difference in means after construction. At station TP-B, the mean calcium concentration went from being 7% lower than the lowest mean concentration measured in the stream before construction to 12% higher than the lowest mean concentration measured in the stream after construction.

The largest increases in mean calcium concentrations were measured in the roadway runoff channel at TP-B (+26%) and in well TP-2 (+15%), and are likely the result of reconstruction of the southern I-90 apron. Disturbance and regrading of the rock and soil comprising the apron exposed fresh mineral surfaces, making them more susceptible to chemical weathering and dissolution during subsequent rainfall events and as they interacted with rising groundwater levels following removal of the I-90 storm sewer. In addition, disturbance of the apron would likely have increased the permeability of the apron materials. This, along with the reversal of the groundwater gradient after the storm sewer was removed, provided the mechanism for transport of dissolved calcium in groundwater from the apron into the preserve. The observed lack of increase in calcium in grab samples from well TP-3, the well closest to I-90, suggests the groundwater flowpath to this well does not intersect the recently disturbed materials of the I-90 apron. Lastly, an additional source of excess calcium may have been introduced to the I-90 apron in the form of dust and debris from the grinding or cutting of concrete during reconstruction.

Calcium concentrations measured in surface water and groundwater grab samples generally increased and decreased with monthly precipitation (Figures 21a and 21b).

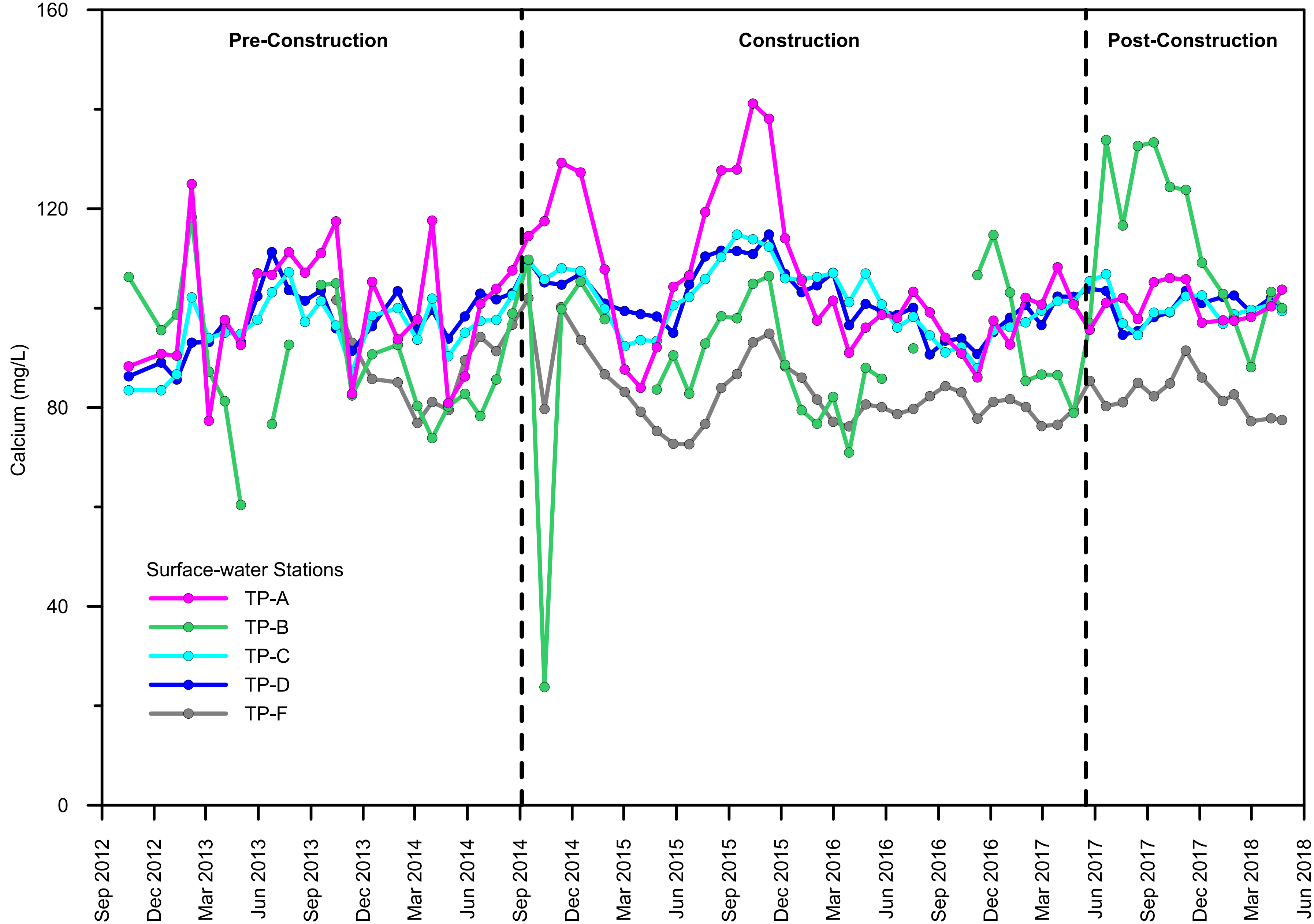

Figure 22a. Calcium concentrations at surface-water monitoring stations at Trout Park and Fox River Forested Fen Nature Preserves.

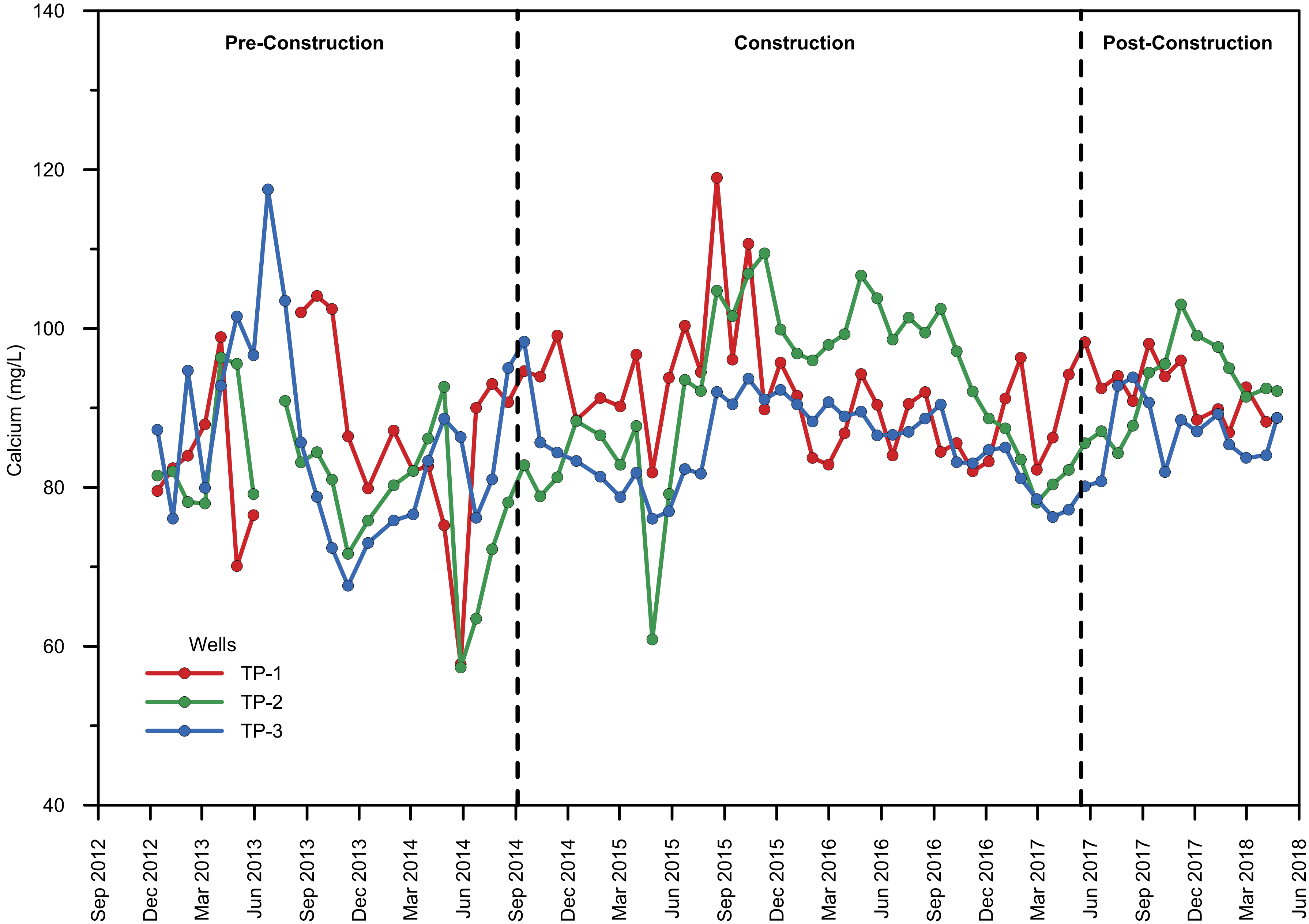

Figure 22b. Calcium concentrations in groundwater monitoring wells at Trout Park Nature Preserve.

When the rainfall occurred, the calcium was dissolved and transported from the soil into the groundwater, showing up as increases in calcium in the grab samples.

Magnesium

Mean magnesium concentrations measured at control station TP-F were 51.9 mg/L before construction and 48.3 mg/L after construction, representing a decrease of 7% (Table 14, Figure 23a). Prior to construction, the mean magnesium concentration was highest at TP-F, differing by no more than 2% from the concentrations at surface-water stations (TP-A, TP-C, and TP-D), and by 21% at TP-B. After construction, the mean magnesium concentration at TP-F was lower than all surface-water stations at TPNP, with a difference of 7% from the maximum concentration of all surface-water stations measured at TPNP.

Table 14. Magnesium concentrations measured in grab samples from Trout Park and Fox River Forested Fen Nature Preserves.

		Pre-construction magnesium concentration (mg/L)			Post-construction magnesium concentration (mg/L)			Percent change in mean magnesium concentration
		Min	**Max**	**Mean**	**Min**	**Max**	**Mean**	
Monitoring well	TP-1	31.7	57.9	48.5	46.5	54.0	50.7	+5%
	TP-2	32.8	55.0	45.3	44.4	52.8	49.6	+9%
	TP-3	39.5	63.0	48.7	46.9	56.5	51.7	+6%
Surface-water station	TP-A	39.2	67.0	51.5	46.4	55.0	50.1	-3%
	TP-B	26.1	56.7	41.9	38.7	64.2	52.0	+24%
	TP-C	46.1	55.5	50.8	48.1	54.7	50.9	0%
	TP-D	47.7	57.1	51.4	48.7	52.7	50.8	-1%
	TP-F	47.2	58.6	51.9	44.7	51.9	48.3	-7%

Mean magnesium concentrations increased in groundwater samples from all wells, with increases of 5%, 9%, and 6% measured in wells TP-1, TP-2, and TP-3, respectively (Table 14, Figure 23b). Both before and after construction, mean magnesium concentrations were highest and most similar in wells TP-1 and TP-3, with mean concentrations of 48.5 and 48.7 mg/L, before construction, and 50.7 and 51.7 mg/L after construction, respectively. The percent difference in the range of mean magnesium concentrations measured in the monitoring wells was 7% before construction and 4% after construction.

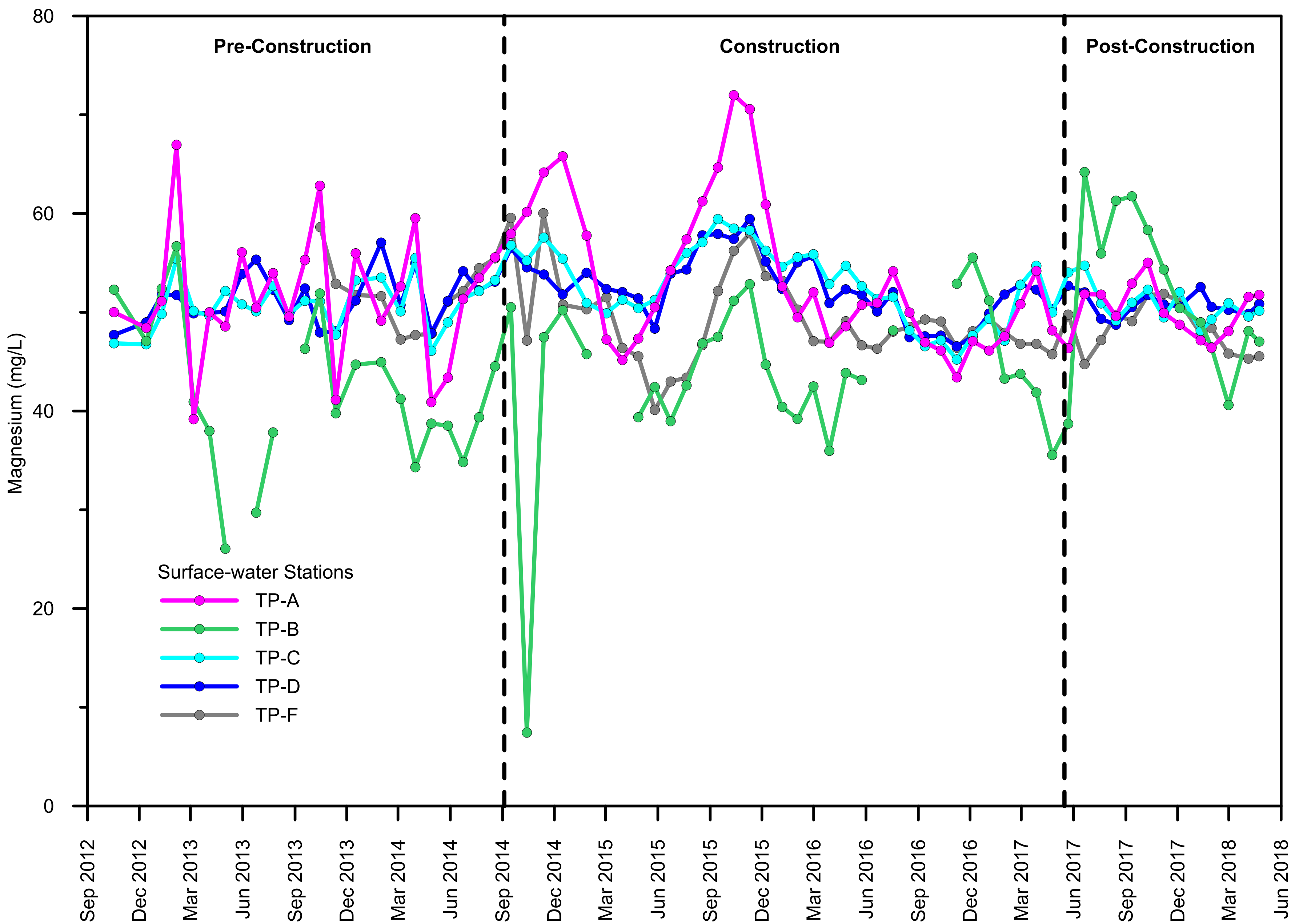

Figure 23a. Magnesium concentrations at surface-water monitoring stations at Trout Park and Fox River Forested Fen Nature Preserves.

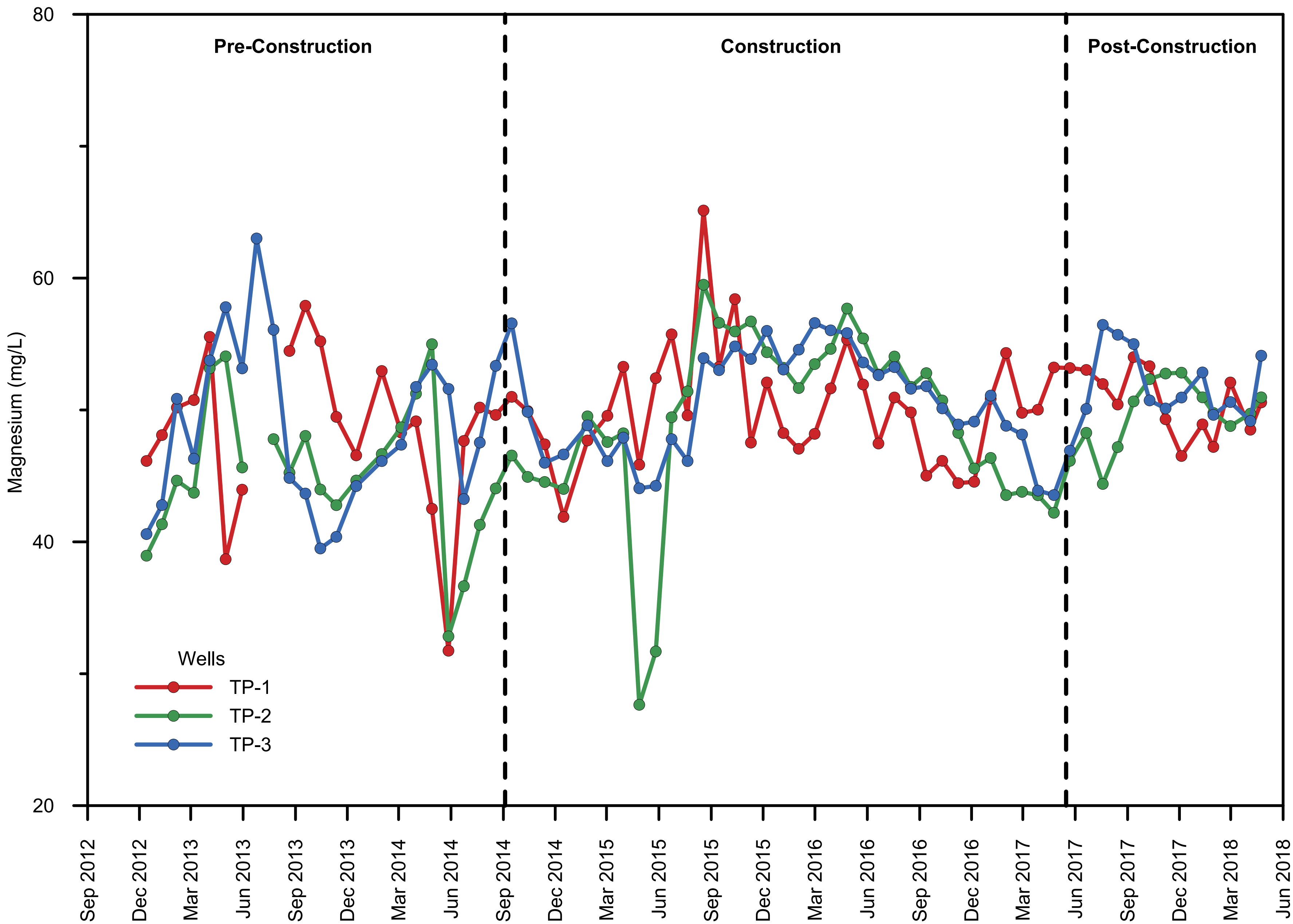

Figure 23b. Magnesium concentrations in groundwater monitoring wells at Trout Park Nature Preserve.

Mean magnesium concentrations in surface water in TPNP stayed the same or decreased at each monitoring location following construction, with the exception of TP-B in the roadway runoff channel, where an increase of 24% was measured (Table 14).

Mean magnesium concentrations in surface water were similar at stations TP-A, TP-C, and TP-D, with a 1% maximum difference in means before construction and a 2% maximum difference in means after construction. At station TP-B, the mean magnesium concentration was 19% lower than the lowest mean concentration measured in the stream before construction and 4% higher than the lowest mean concentration measured in the stream after construction.

Alkalinity

Mean alkalinity measured at control station TP-F was 273 mg/L before construction and 281 mg/L after construction, representing an increase of 3% (Table 15, Figure 24a). Maximum and mean alkalinity measured at TP-F were the lowest recorded at any surface-water station during both the pre and post-construction periods. Before construction, mean alkalinity at TP-F was 16% lower than the lowest mean alkalinity measured in surface water at TPNP. After construction, mean alkalinity at TP-F was 13% less than the lowest alkalinity measured in surface water in TPNP.

Table 15. Alkalinity measured in grab samples from Trout Park and Fox River Forested Fen Nature Preserves.

		Pre-construction alkalinity (mg/L as $CaCO_3$)			Post-construction alkalinity (mg/L as $CaCO_3$)			Percent change in mean alkalinity
		Min	**Max**	**Mean**	**Min**	**Max**	**Mean**	
Monitoring well	TP-1	247	349	285	282	316	300	+5%
	TP-2	226	416	281	302	328	315	+12%
	TP-3	230	365	273	296	361	328	+20%
Surface-water station	TP-A	261	364	325	302	342	319	-2%
	TP-B	203	373	321	354	520	434	+35%
	TP-C	294	335	323	317	338	329	+2%
	TP-D	304	336	325	324	343	333	+3%
	TP-F	263	285	273	276	286	281	+3%

Mean alkalinity in groundwater samples increased in all wells at TPNP following construction, with increases of 5%, 12%, and 20% in wells TP-1, TP-2, and TP-3, respectively (Table 15, Figure 24b). Before construction, the highest mean alkalinity was measured in well TP-1 (285 mg/L), with lower means at TP-2 (281 mg/L) and TP-3 (273 mg/L). These values represent a 4% difference between the maximum and minimum mean alkalinity measured in the wells. After construction, mean alkalinity remained highest at TP-3 (328 mg/L), but overall mean alkalinity became less similar among the wells with mean values of 300, 315, and 328 mg/L for TP-1, TP-2, and TP-3, respectively (Table 15), representing a 9% difference between the maximum and minimum means measured in the wells.

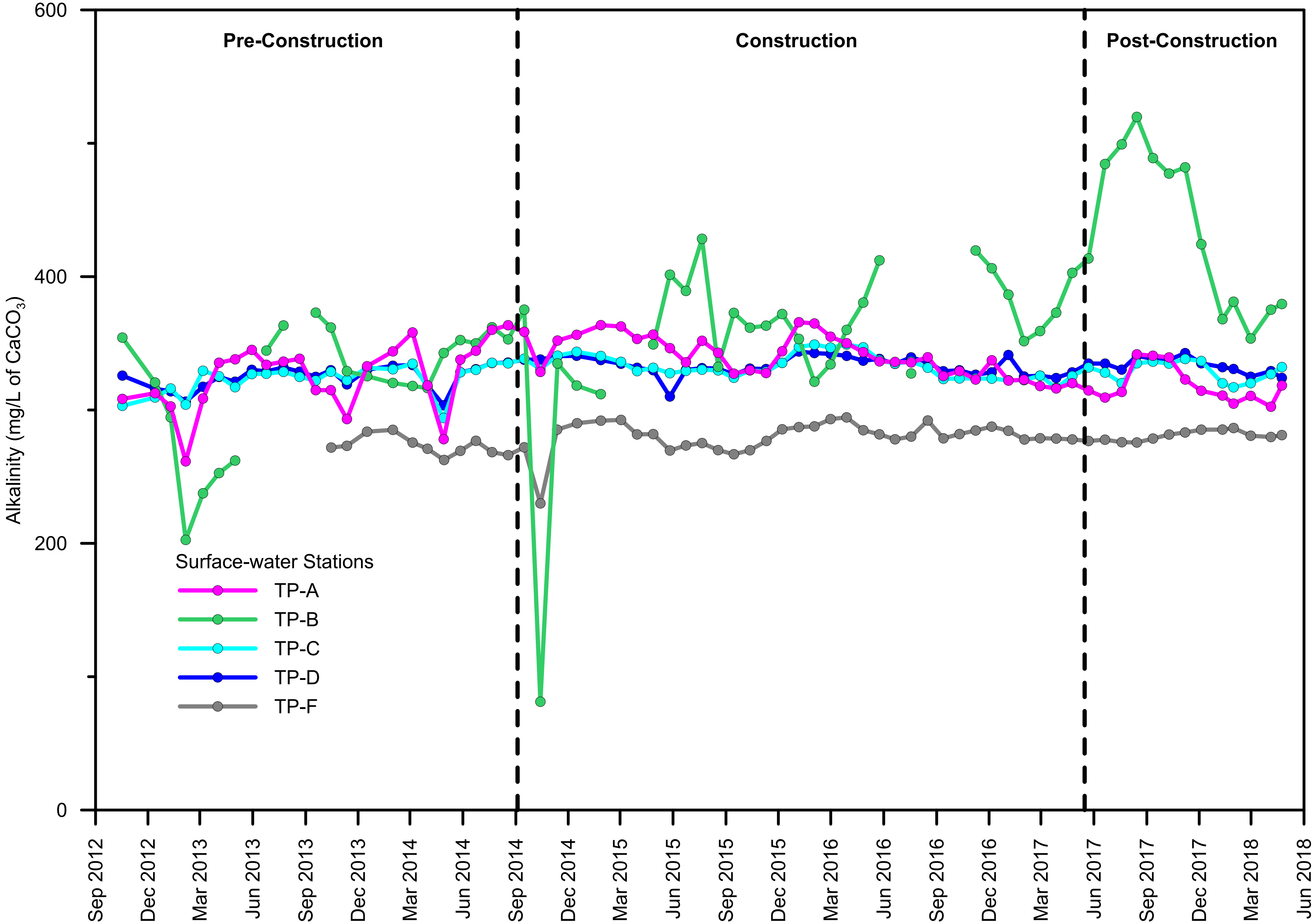

Figure 24a. Alkalinity at surface-water monitoring stations at Trout Park and Fox River Forested Fen Nature Preserves.

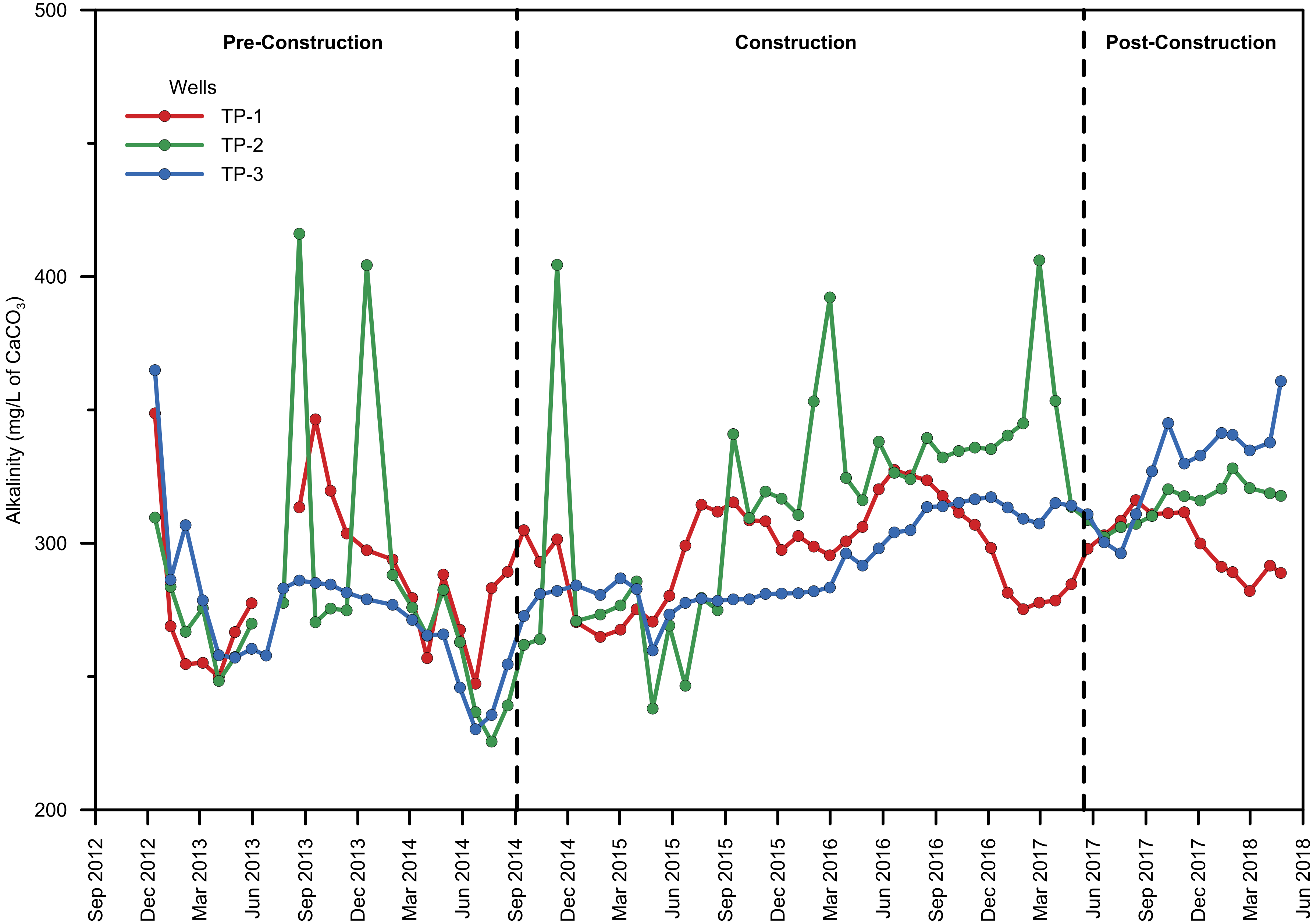

Figure 24b. Alkalinity in groundwater monitoring wells at Trout Park Nature Preserve.

Mean alkalinity in surface water in TPNP remained relatively stable at each monitoring location following construction, with the exception of TP-B, in the roadway runoff channel, which had an increase of 35% (Table 15). Before construction, mean alkalinity in surface water was very similar between stations, with only a 1% difference measured. Following construction, the highest mean alkalinity was measured at TP-B (434 mg/L), and represented a difference of 31% from the lowest mean alkalinity in post-construction surface water at TPNP. Pre-construction mean alkalinity was higher at surface-water stations TP-A, TP-B, TP-C, and TP-D (range: 321-325 mg/L) than in wells TP-1, TP-2, and TP-3 (range: 273-285 mg/L) and the background surface-water station TP-F (273 mg/L). Similarly, pre-construction mean concentrations of calcium and magnesium were higher in surface-water than in groundwater south of I-90.

Sulfate

Mean sulfate concentrations measured at the background surface-water station TP-F were 94.0 mg/L before construction and 78.1 mg/L after construction, representing a decrease of 17% (Table 16, Figure 25a). Maximum and mean sulfate concentrations measured at TP-F were the highest recorded at any surface-water station during both the pre and post-construction periods. Prior to construction, mean sulfate at TP-F was 32% higher than the highest mean sulfate measured at surface water stations in TPNP, while following construction, mean sulfate at TP-F was only 13% higher.

Table 16. Sulfate concentrations measured in grab samples from Trout Park and Fox River Forested Fen Nature Preserves.

		Pre-construction sulfate concentration (mg/L)			Post-construction sulfate concentration (mg/L)			Percent change in mean sulfate concentration
		Min	**Max**	**Mean**	**Min**	**Max**	**Mean**	
Monitoring well	TP-1	49.2	73.6	68.0	68.8	75.0	72.1	+6%
	TP-2	62.0	74.3	66.5	69.8	74.0	71.9	+8%
	TP-3	60.5	72.3	65.0	70.5	72.5	71.4	+10%
Surface-water station	TP-A	49.7	74.5	68.0	62.3	75.2	68.7	+1%
	TP-B	29.5	97.9	52.8	27.8	47.8	34.1	-35%
	TP-C	59.9	68.7	65.0	62.5	69.6	65.8	+1%
	TP-D	58.1	66.4	63.2	61.1	67.1	64.3	+2%
	TP-F	78.8	104	94.0	71.3	84.3	78.1	-17%

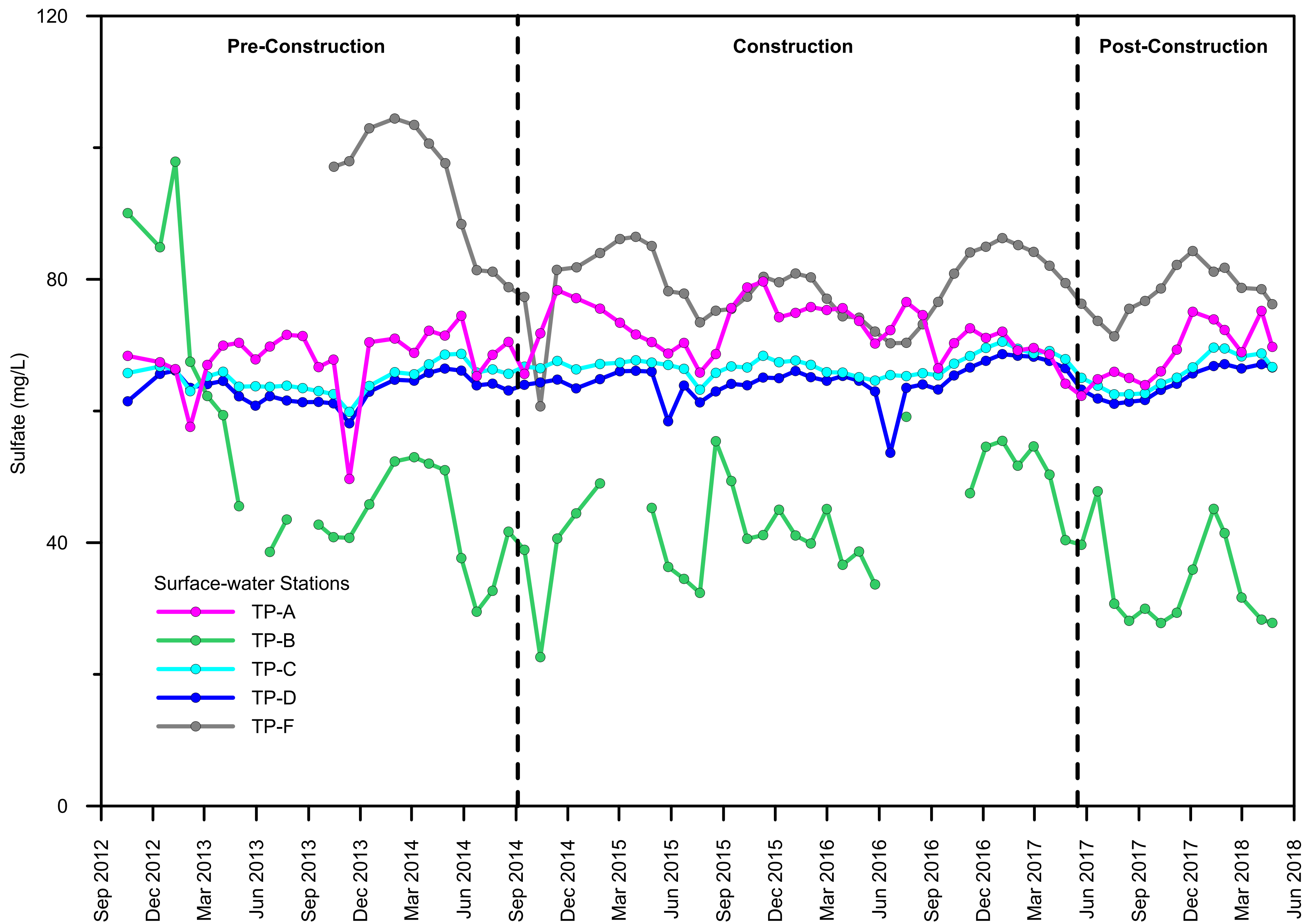

Figure 25a. Sulfate concentrations at surface-water monitoring stations at Trout Park and Fox River Forested Fen Nature Preserves.

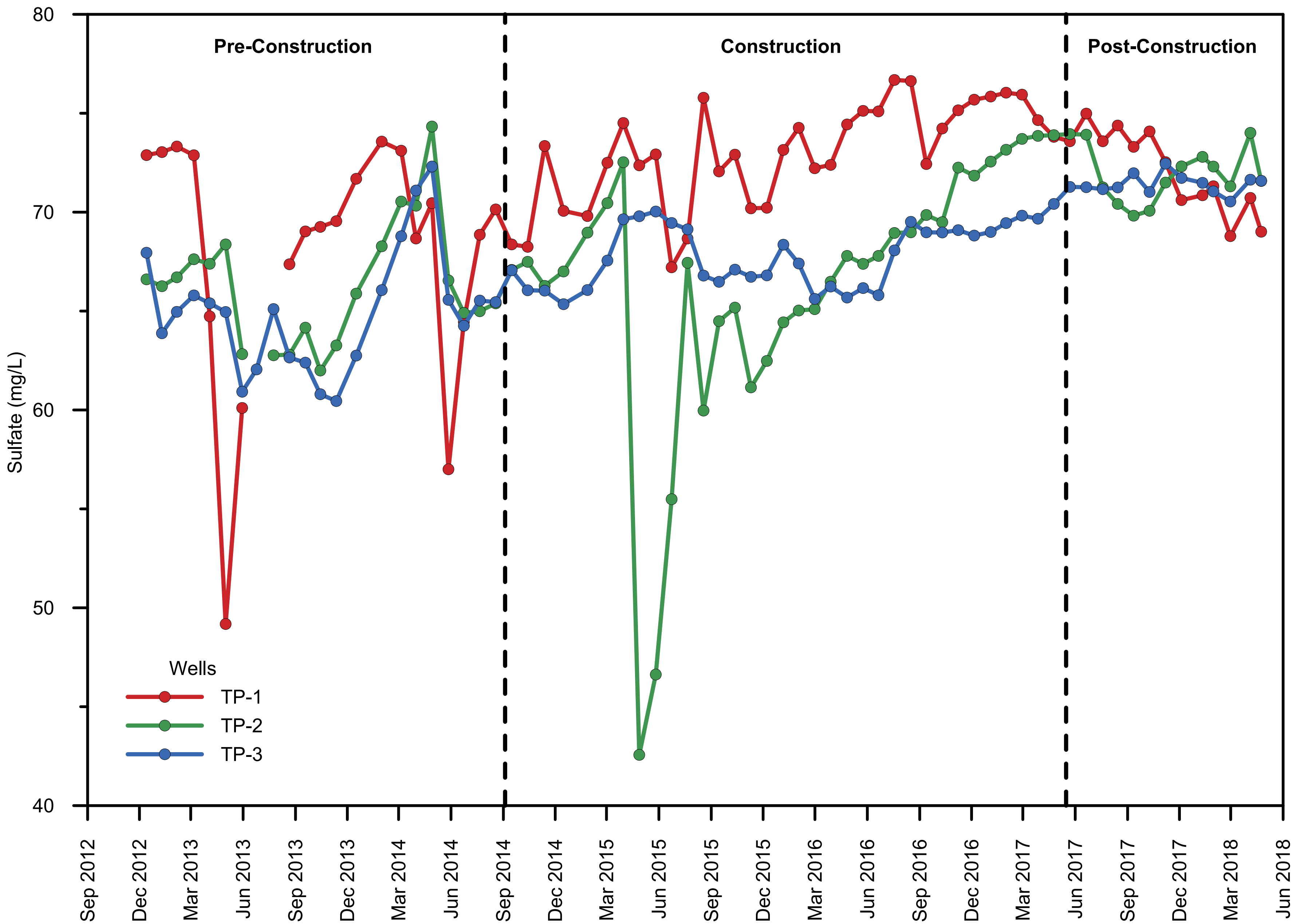

Figure 25b. Sulfate concentrations in groundwater monitoring wells at Trout Park Nature Preserve.

Mean sulfate concentrations in groundwater samples increased in all wells at TPNP following construction, with increases of 6%, 8%, and 10% in wells TP-1, TP-2, and TP-3, respectively (Table 16, Figure 25b). Before construction, the highest mean sulfate concentration was measured in well TP-1 (68.0 mg/L), with lower means at TP-2 (66.5 mg/L) and TP-3 (65.0 mg/L).

These values represent a 5% difference between the maximum and minimum mean sulfate concentrations measured in the wells. After construction, mean sulfate concentration remained highest at TP-1 (72.1 mg/L), but overall mean sulfate concentrations became more similar among the wells with mean values of 72.1, 71.9, and 71.4 mg/L for TP-1, TP-2, and TP-3, respectively (Table 16), representing a 1% difference between the maximum and minimum means measured in the wells.

Mean sulfate concentrations in surface water in TPNP remained relatively stable at each monitoring location following construction, with the exception of TP-B, in the roadway runoff channel, which decreased by 35% (Table 16). Before construction, the mean sulfate concentration measured at TP-B (52.8 mg/L), was the lowest measured at any monitoring station in TPNP, and was 18% lower than the next lowest concentration measured in surface water. Sulfate concentrations in the stream decreased downstream, with values of 68.0, 65.0, and 63.2 mg/L measured at TP-A, TP-C, and TP-D, respectively. After construction, the mean sulfate concentration at TP-B dropped to 34.1 mg/L, which was 61% lower than the next lowest concentration measured in surface water in TPNP.

Sulfur

Mean sulfur concentrations measured at the background surface-water station TP-F were 33.3 mg/L before construction and 27.8 mg/L after construction, representing a decrease of 16% (Table 17, Figure 26a). Maximum and mean sulfur concentrations measured at TP-F were the highest recorded at any surface-water station during both the pre and post-construction periods. Prior to construction, mean sulfur at TP-F was 31% higher than the highest mean sulfur measured at surface water stations in TPNP, while following construction, mean sulfur at TP-F was only 11% higher.

Table 17. Sulfur concentrations measured in grab samples from Trout Park and Fox River Forested Fen Nature Preserves.

		Pre-construction sulfur concentration (mg/L)			**Post-construction sulfur concentration (mg/L)**			**Percent change in mean sulfur concentration**
		Min	**Max**	**Mean**	**Min**	**Max**	**Mean**	
Monitoring well	TP-1	17.5	27.1	24.2	24.2	27.2	25.9	+7%
	TP-2	21.3	26.0	23.5	24.4	27.4	25.9	+10%
	TP-3	20.7	26.3	23.2	24.2	27.0	25.8	+11%
Surface-water station	TP-A	18.2	26.4	24.3	22.5	27.5	24.8	+2%
	TP-B	11.1	36.1	19.3	10.1	17.8	12.7	-34%
	TP-C	21.4	25.0	23.3	21.8	25.6	23.8	+2%
	TP-D	21.1	24.3	22.7	20.9	24.8	23.2	+2%
	TP-F	28.0	37.9	33.3	24.5	30.7	27.8	-16%

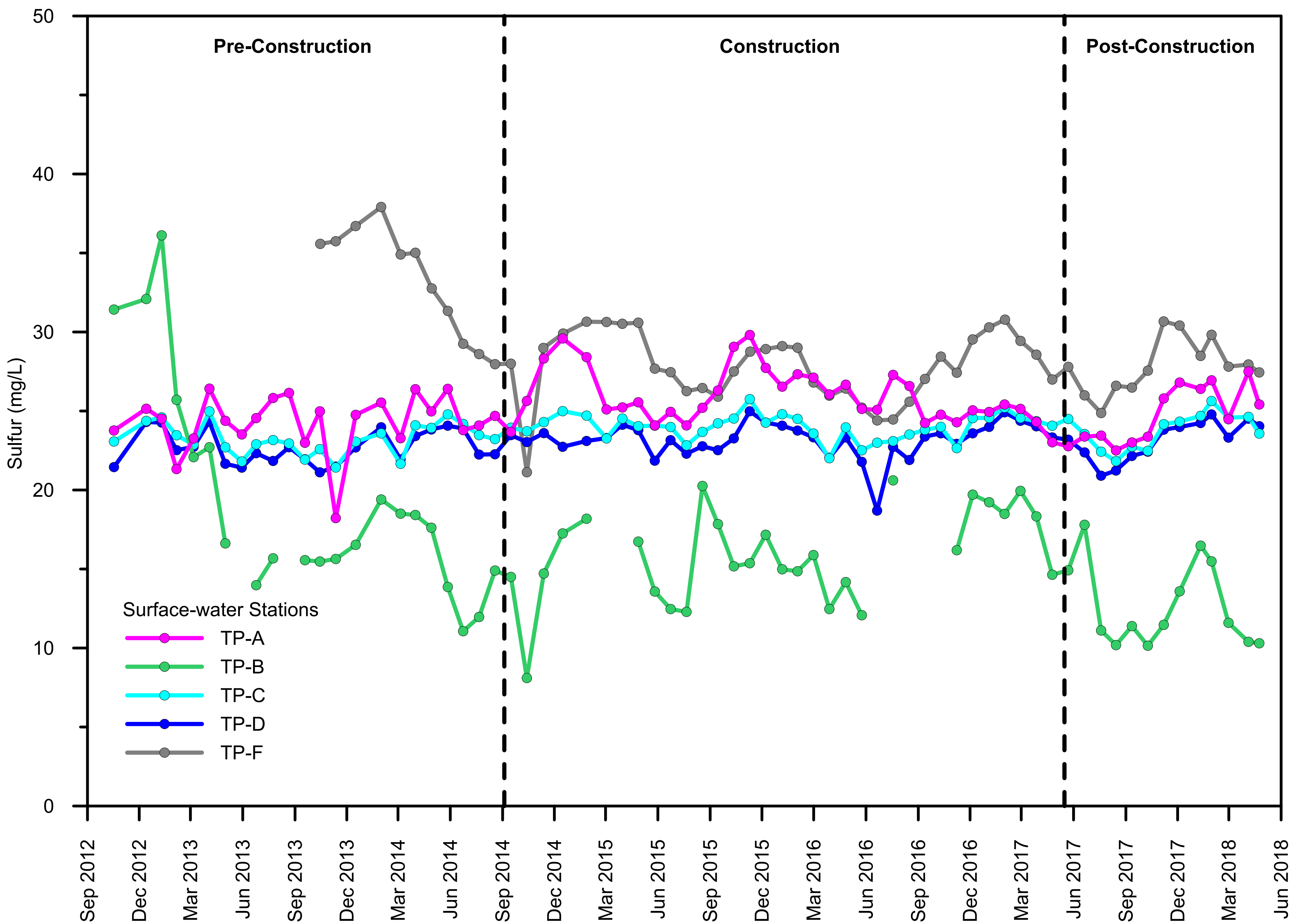

Figure 26a. Sulfur concentrations at surface-water monitoring stations at Trout Park and Fox River Forested Fen Nature Preserves.

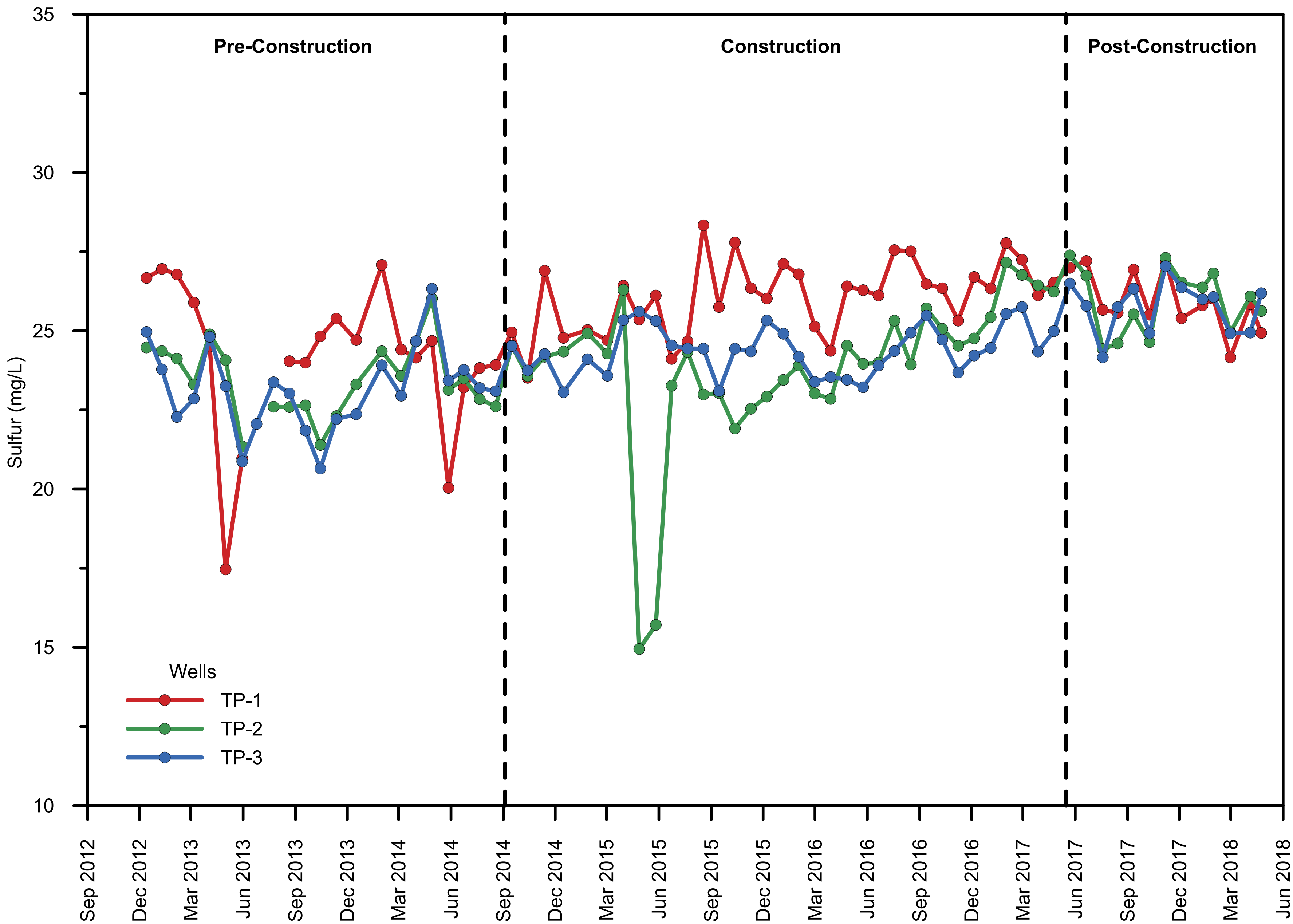

Figure 26b. Sulfur concentrations in groundwater monitoring wells at Trout Park Nature Preserve.

Mean sulfur concentrations in groundwater samples increased in all wells at TPNP following construction, with increases of 7%, 10%, and 11% in wells TP-1, TP-2, and TP-3, respectively (Table 17, Figure 26b). Before construction, mean sulfur concentrations were slightly higher in well TP-1 (24.2 mg/L), though only 4% greater than the lowest concentration measured in groundwater at TP-3 (23.2 mg/L). After construction there was essentially no difference in mean sulfur concentrations of water samples from groundwater monitoring locations, with mean concentrations of 25.9 mg/L measured in wells TP-1 and TP-2, and 25.8 mg/L measured in well TP-3.

Mean sulfur concentrations in surface water in TPNP remained relatively stable at each monitoring location following construction, with the exception of TP-B, in the roadway runoff channel, which decreased by 34% (Table 17). Before construction, the mean sulfur concentration measured at TP-B (19.3 mg/L), was the lowest measured at any monitoring station in TPNP, and was 16% lower than the next lowest concentration measured in surface water. Sulfur concentrations in the stream decreased downstream, with values of 24.3, 23.3, and 22.7 mg/L measured at TP-A, TP-C, and TP-D, respectively. After construction, the mean sulfur concentration at TP-B dropped to 12.7 mg/L, which was 58% lower than the next lowest concentration measured in surface water in TPNP.

Roadway Metals

Metals commonly encountered in roadway runoff and urban streams include cadmium, chromium, copper, iron, lead, manganese, nickel, and zinc (Herrera 2007, Paul and Meyer 2008, and Miner et al. 2014). These metals accumulate on roadways from non-point sources including worn brake linings, tires, and engine parts on trucks and automobiles (Paul and Meyer 2008).

All of these metals, except cadmium, were detected in one or more water samples collected for this project. From highest to lowest, the number of individual detections in grab samples for each metal are: manganese (170), iron (120), zinc (24), copper (20), chromium (1), lead (1), nickel (1) (Table 18). Copper, iron, manganese, and nickel were the only roadway metals that were detected at concentrations considered optimal for analysis, which is at least ten times the minimum detection limits (MDLs) for the respective constituents (Dan Webb, former manager of the ISWS Public Service Laboratory, personal communication) (Table 18). Of these, copper and nickel only had one occurrence above this threshold, so only iron and manganese are discussed further.

Neither iron nor manganese were detected in grab samples collected from the background surface-water station TP-F in FRFFNP. Both constituents were detected in every sample collected from the roadway runoff channel (station TP-B) in TPNP, and station TP-B was the only surface-water station where both metals were detected at concentrations considered optimal for analysis (greater than 10xMDL). Noticeably elevated concentrations of iron and manganese were measured in samples from the seep at TP-B between June 20, 2017 and January 29, 2018. The reason for this increase is likely due to the mobilization of iron and manganese particles recently exposed following reworking of the I-90 apron during reconstruction.

Table 18. Occurrence of common roadway metals in water samples collected from Trout Park and Fox River Forested Fen Nature Preserves. The number in parentheses equals detections > 10xMDL.

		Surface Water Stations					Groundwater Stations			Total Detects Per Period	Total Detects Overall
		TP-A	TP-B	TP-C	TP-D	TP-F	TP-1	TP-2	TP-3		
Cd	Before	0	0	0	0	0	0	0	0	0	0
	During	0	0	0	0	0	0	0	0	0	
	After	0	0	0	0	0	0	0	0	0	
Cr	Before	0	0	0	0	0	0	0	0	0	1
	During	0	0	0	0	0	0	0	0	0	
	After	0	0	1	0	0	0	0	0	1	
Cu	Before	1	4	0	0	0	1	2	1 *(1)*	9	20
	During	0	4	0	0	0	1	3	0	8	
	After	0	1	1	0	0	0	1	0	3	
Fe	Before	0	21 *(1)*	0	0	0	7	6 *(2)*	9 *(5)*	43	120
	During	0	28 *(15)*	1	0	0	3 *(1)*	11	11 *(2)*	54	
	After	0	13 *(12)*	1	0	0	0	3	6 *(1)*	23	
Pb	Before	0	0	0	0	0	0	0	1	1	1
	During	0	0	0	0	0	0	0	0	0	
	After	0	0	0	0	0	0	0	0	0	
Mn	Before	0	20 *(11)*	2	0	0	6 *(2)*	7 *(1)*	8 (5)	43	170
	During	1	28 (26)	0	5	0	5 *(1)*	12 *(6)*	31 (29)	82	
	After	0	13 (13)	5	6	0	1	7 *(1)*	13 (13)	45	
Ni	Before	0	0	0	0	0	0	0	0	0	1
	During	0	0	0	0	0	0	0	0	0	
	After	0	0	1 (1)	0	0	0	0	0	1	
Zn	Before	3	5	1	1	1	2	5	4	22	24
	During	0	1	0	0	0	0	1	0	2	
	After	0	0	0	0	0	0	0	0	0	
Total Metals Detected Pre (%)		2	30	2	<1	1	10	13	13		
Total Metals Detected During (%)		<1	27	<1	2	0	3	11	15		
Total Metals Detected Post (%)		0	26	9	6	0	1	11	18		
Total Metals Detected Each Station (%)		<1	28	2	2	<1	5	11	15		

Other Constituents

The following constituents, included in grab sample analysis, were not detected in either pre- or post-construction samples at any monitoring station in TPNP or FRFFNP: Arsenic, beryllium, cobalt, lithium, tin, and vanadium. Nutrients and total suspended solids in water samples were also analyzed in the lab, but were not the focus of this report and are not presented.

COMPARISON OF ISGS GRAB SAMPLES TO WATER-QUALITY STANDARDS

Surface Water

Analytical results for ISGS grab samples from surface-water stations TP-A through TP-F at TPNP and FRFFNP were compared to Sections 302.204 (pH) and 302.208 (Numeric Standards for Chemical Constituents) of the Illinois General Use Water Quality Standards (Subpart B, Chapter I, Subtitle C of Title 35 of the Illinois Administrative Code: Environmental Protection (Illinois Pollution Control Board, undated) to determine if measured levels of specific constituents exceeded standards. Numeric standards for certain constituents are set at a given value (e.g., chloride at 500 mg/L), while the standards for other constituents must be calculated individually using equations that take into account other sample parameters that affect toxicity, such as hardness, which is calculated based on the calcium and magnesium content of the sample. Constituents detected in surface-water grab samples from TPNP and FRFFNP and evaluated against these standards include barium, boron, chloride, chromium (hexavalent), copper, fluoride, iron, manganese, nickel, selenium, sulfate, and zinc. Of these constituents, the only exceedances noted were for chromium, chloride, and iron.

The acute standard for chromium (0.016 mg/L) was exceeded once at TP-C on 1/10/18 (0.0511 mg/L), however, no chromium was detected in the total recoverable metals sample collected at the same site and time, suggesting this exceedance may be in error or should at least be viewed cautiously. Exceedances of the chloride standard for surface water were most commonly measured in the roadway runoff channel at station TP-B. The occurrence of such exceedances declined from a high of 71% of samples collected before construction to a low of 31% of samples collected after construction (Table 19). All chloride exceedances, except one measured at TP-C, were observed in samples from either the headwater seep (TP-A) or the I-90 runoff channel (TP-B). At TP-A, all chloride exceedances occurred between the months of September and March, and no exceedances were measured in the post-construction period. At TP-B, chloride exceeded the standard in all 14 samples collected between October 2012 and January 2014 and again in August 2014, during the pre-construction period. During construction, exceedances in chloride were typically measured between the months of September and January of any given year, while post-construction exceedances were measured in June 2017, and again from August through October 2017. Iron concentrations exceeding the surface-water standard occurred exclusively in the roadway runoff channel at TP-B, with one exceedance measured during construction, and 10 exceedances recorded following construction.

Groundwater

Under the authority of Illinois Administrative Code 620.230, Class III Groundwater can be established for “groundwater that is demonstrably unique (e.g. irreplaceable sources of groundwater) and suitable for application of a water quality standard more stringent than the otherwise applicable water quality standard specified, groundwater that is vital for a particularly sensitive ecological system, or groundwater contributing to a DNP (dedicated nature preserve) that has been listed by the Illinois EPA”. The Illinois EPA published the final listing of Trout Park Nature Preserve as Class III Groundwater in the July 2012 edition (No. 697) of the Illinois Pollution Control Board’s quarterly newsletter, the Environmental Register (Illinois Pollution Control Board 2012). Because of this designation, the analytical results for ISGS grab samples of groundwater from monitoring wells TP-1 through TP-3 were compared to the Groundwater Quality Standards for Class III: Special Resource Groundwater, which, at the time of this report, were equivalent to Section 620.410 – Groundwater Quality Standards for Class I: Potable Resource Groundwater. Groundwater constituents evaluated under this standard for this report include inorganic chemical constituents, and pH.

The acceptable range for pH in Class I groundwater is 6.5 – 9.0. No groundwater samples from wells TP-1 through TP-3 exceeded this range at any point during the study. The Class I standard for chloride (200 mg/L) was exceeded in all groundwater samples collected during the course of this study (Table 20).

Table 19. Number of instances when the General Use Water Quality Standard for chloride (500 mg/L) was exceeded in grab samples collected from ISGS surface-water stations in Trout Park and Fox River Forested Fen Nature Preserves.

	Number of instances when chloride concentration in surface-water samples exceeded General Use Water Quality Standard of 500 mg/L *(% of samples analyzed)*		
Surface-water station	**Pre-construction**	**Construction**	**Post-construction**
TP-A	4 *(17%)*	8 *(24%)*	0
TP-B	15 *(71%)*	10 *(36%)*	4 *(31%)*
TP-C	0	1 *(3%)*	0
TP-D	0	0	0
TP-F	0	0	0

Table 20. Number of instances when the Groundwater Quality Standards for Class I: Potable Resource Groundwater were exceeded in grab samples collected from ISGS groundwater stations in Trout Park Nature Preserve.

			Exceedances *(% of samples analyzed)*								
			TP-1			**TP-2**			**TP-3**		
Inorganic chemical constituent	Standard (mg/L)	MDL (mg/L)	Pre	During	Post	Pre	During	Post	Pre	During	Post
Sb	0.006	*0.059	-	-	1 *(8)*	-	-	1 *(8)*	-	-	1 *(8)*
Cl	200	0.16	20 *(100)*	34 *(100)*	13 *(100)*	21 *(100)*	34 *(100)*	13 *(100)*	22 *(100)*	34 *(100)*	13 *(100)*
Pb	0.0075	*0.041	-	-	-	-	-	-	1 *(5)*	-	-
Mn	0.15	0.0015	-	-	-	-	-	-	2 *(9)*	5 *(15)*	1 *(8)*
Tl	0.002	*0.017/ *0.047	2 *(10)*	10 *(29)*	-	1 *(5)*	8 *(24)*	-	5 *(23)*	4 *(12)*	-
TDS	1,200	12	-	11 *(32)*	5 *(38)*	2 *(10)*	17 *(50)*	-	9 *(41)*	18 *(53)*	4 *(31)*

*MDL > Standard, thus leading to potential for under-reporting of exceedances.

DISCUSSION AND CONCLUSIONS

Increases in shallow groundwater levels measured in all three ISGS monitoring wells (TP-1, TP-2, and TP-3) in Trout Park Nature Preserve were observed immediately after work on the I-90 storm sewer began, suggesting initially that decommissioning the original storm sewer produced the desired groundwater level increase in the preserve. However, shortly afterward, differences in hydrologic response developed among the monitoring wells, and these differences continued into the post-construction period. While water levels in TP-1 and TP-2 remained elevated with respect to pre-construction levels following removal of the storm sewer, the increase in water level at TP-2 was less pronounced, suggesting that groundwater levels in that area of the preserve had not been as strongly depressed by the storm sewer. The decrease in water level at TP-3, despite higher overall precipitation in the post-construction period, likely reflects a combination of little to no influence on local groundwater levels by the storm sewer, and reduced groundwater recharge from direct runoff along the northern preserve boundary as a result of the installation of the concrete barrier wall along I-90 and elimination of the I-90/IL 25 interchange runoff channel.

Surface water and shallow groundwater in Trout Park Nature Preserve had elevated levels of dissolved solids relative to the less affected reference site (TP-F) in Fox River Forested Fen Nature Preserve both before and after reconstruction of I-90. Analysis of water samples collected during this study show this was mainly due to substantially higher concentrations of dissolved sodium and chloride in the samples from Trout Park Nature Preserve. Throughout the highly urbanized watershed in which the two preserves are located, the most probable source for the observed sodium and chloride is from dissolved de-icing salts applied to local roadways and parking lots. Concentrations of these constituents were lower in water samples collected from Fox River Forested Fen Nature Preserve primarily because it is located upgradient of I-90, but also because it lies substantially farther away from IL 25 than does Trout Park Nature Preserve, and there is generally less development north of the interstate. While it is expected that the addition of the concrete barrier wall and the removal of the runoff channel for the I-90/IL 25 interchange will help decrease the amount of dissolved solids in the waters of Trout Park Nature Preserve over time, it is unlikely that concentrations will drop as low as those observed at TP-F, for the reasons mentioned above.

Decommissioning the original I-90 storm sewer had the unintended consequence of locally increasing concentrations of total dissolved solids, chloride, and sodium in shallow groundwater surrounding wells TP-1 and TP-2. This likely reflects a combination of at least two factors: 1) reversal of the groundwater gradient from the preserve towards the I-90 storm sewer to from I-90 towards the preserve and 2) the dissolution and transport of residual legacy road salt into the shallow groundwater along the northern margin of the preserve. Given that runoff from I-90 has been effectively eliminated by installation of the concrete barrier and removal of the runoff channel for the I-90/IL 25 interchange, any additional salt accumulation south of the barrier wall is expected to be greatly reduced compared to historical levels. For this reason, delivery of dissolved salt from I-90 into the preserve is expected to decrease over time.

Trends in concentrations of calcium, magnesium, and alkalinity in water samples from Trout Park Nature Preserve likely reflect a combination of increased precipitation in the post-construction period and localized reworking of the I-90 apron materials during reconstruction. The most distinct response observed was the increase in concentrations of calcium, magnesium, and alkalinity in the groundwater monitoring wells and at surface-water station TP-B, which is located in a seep near the I-90 apron. These increases at stations nearest the tollway suggest local dissolution of calcareous particles within the apron soils, as well as from pulverized concrete derived from construction activities and deposited onto the apron, that were made more readily available for transport into the preserve following the reworking of the I-90 apron. Transportation of these constituents into the preserve was aided by increased precipitation during the post-construction period. The other surface water stations in Trout

Park showed little change in calcium, magnesium, and alkalinity, likely because any affect from construction activities was buffered by the inputs from the wider groundwater catchment area.

Sulfur and sulfate increased slightly at most surface-water stations and all groundwater stations, and likely indicates more oxygenated groundwater in the post-construction period (i.e. sulfur and sulfate are oxidized forms of sulfur compounds). Appreciable decreases in sulfur and sulfate were observed at TP-F and TP-B and likely indicate some combination of increased uptake by plants, mineralization, and chemical reduction. However, the relative contribution of these mechanisms to decreases at these locations remains unclear due to the complex dynamics of subsurface hydrology, biological activity, and redox processes.

With the exception of iron and manganese, common roadway metals were encountered infrequently and generally at low concentrations in both the Fox River Forested Fen and Trout Park Nature Preserves. Iron and manganese were most commonly detected in water samples from the roadway runoff channel (TP-B) and in the monitoring wells. Concentrations of both constituents increased sharply during reconstruction and the post-construction period, likely as a result of the reworking of the I-90 apron materials during reconstruction.

ACKNOWLEDGEMENTS

People who have contributed to the success of this study include Jessica Ackerman, Kathleen Bryant, Keith Carr, Matthew Even, Melinda Higley, Colleen Long, Mackenzie Marti, Jim Miner, Jessica Monson, Audra Noyes, Josh Richardson, and Katharine Schleich of the ISGS, as well as the staff of the Public Service Laboratory at the ISWS. Funding for this report was provided by the Illinois State Toll Highway Authority under contracts #ITHA RR-07-9918 and #ITHA 2015-01230 MINER. Brand names of instruments used were for informational purposes only and do not constitute endorsements. This report reflects the views of the author, and may not reflect the opinions and policy of the Illinois State Geological Survey, University of Illinois, or the Illinois State Toll Highway Authority.

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Appendix A. Installation Dates, Coordinates, and Land Surface Elevations at ISGS Monitoring Stations in Trout Park and Fox River Forested Fen Nature Preserves

ISGS Monitoring Station	Date of Installation	Northing (m)	Easting (m)	Average Land Surface Elevation Pre-Construction (m)	Average Land Surface Elevation Post-Construction (m)	Δ Land Surface Elevation pre vs post (m)
TP-A	10/17/2012	599403.1	305632.7	235.553	235.532	-0.021
TP-B	10/17/2012	599440.8	305606.0	234.378	234.156	-0.222
TP-C	10/17/2012	599440.7	305592.6	233.863	233.696	-0.168
TP-D	10/17/2012	599393.9	305452.9	228.003	228.070	0.067
TP-E	12/11/2012	599419.7	305670.1	239.893	239.910	0.017
TP-F	10/15/2013	599684.5	305478.7	na	na	na
TP-1	12/12/2012	599421.1	305457.0	232.299	232.192	-0.107
TP-2	12/12/2012	599437.2	305542.0	234.319	234.291	-0.028
TP-3	12/12/2012	599449.5	305583.5	234.979	234.947	-0.031

Coordinates and land surface elevations measured with a Leica 1200 survey-grade GPS.
ISGS was unable to use GPS to obtain measurements for TP-F due to dense canopy within cedars at FRFFNP.
Coordinates provided for TP-F above are based on hand-plotted location depicted on Figure 7.

Appendix B. Well Logs for ISGS Monitoring Wells Installed in Trout Park Nature Preserve

Well TP-1	Top (cm)	Bottom (cm)
Brown, non-fibrous muck, dry, slight sand content	0	46
Brown muck with gray-white tufa dispersed, some layers, dry	46	58
Coarse to medium sand with gravel, slight silt content (<10%), mottled orange and brown, moist.	58	76
Increasing gravel content, no mottling. Becoming wet at ~88 cm, saturated at 91 cm.	76	113
Becomes white-ish at 113 cm with calcium carbonate.	113	143
sandy gravel with very well rounded gravel to 6 cm diameter	143	150

Total Depth: 150 cm
Casing: 2" PVC
total casing length: 247.0 cm
screen: 2" slotted PVC, from 53.5 to 130.8 cm below ground surface
stickup: 97.5 cm before cap: 98.0 cm with 2-piece metal locking cap
sand to 46 cm below ground surface
bentonite to land surface

Installation Date: December 12, 2012
Installation Time: 15:46 CST

Well TP-2	Top (cm)	Bottom (cm)
Black, non-fibrous muck, dry	0	15
Muck with dispersed tufa, gray-brown color, becoming wet at 53 cm	15	122
Fine brown sand, no gravel, saturated	122	198

Total Depth: 198.2 cm
Casing: 2" PVC
Total casing length: 244.5 cm
Screen: 2" slotted PVC, from 112.2 to 179.7 cm below ground surface
Stickup: 46.3 cm before cap: 46.8 cm with 2-piece metal locking cap
Sand to 39 cm below ground surface
Bentonite to land surface

Installation Date: December 12, 2012
Installation Time: 16:02 CST

Well TP-3	Top (cm)	Bottom (cm)
black, dry, slightly-fibrous peat	0	24
brown, dry muck with dispersed tufa grains	24	76
dark brown muck, stiff and blocky, slightly fossiliferous with 5 mm shells, black and wet at ~85 cm	76	107
black, sticky, slightly-clayey muck, fossiliferous with 1 cm whitish calcareous bodies	107	131
sticky, gray silty clay with sand, wet	131	183
brown sand and gravel, saturated, gravel is well-rounded dolomite > 4 cm	183	271

APPENDIX C. Grab Sample Collection and Preservation Procedures

Grab samples for water-quality analysis were collected by the ISGS using a peristaltic pump to draw sample water through platinum-cured silicone tubing. Prior to collection of the sample, the silicone tubing was connected to a flow-through cell attached to a Hydrolab MS5 multiparameter sonde. The sonde was used to check for stabilization of field parameters prior to sampling, including temperature, pH, specific conductivity, turbidity, and either oxidation-reduction potential (ORP) or luminescent dissolved oxygen (LDO). The pumping rate used for monitoring wells was approximately 0.5 L (0.13 gal) per minute or less in accordance with standard low-flow sampling procedures (ASTM Standard D6771-02 [ASTM International 2018]). Higher pumping rates (> 0.5 L [0.13 gal] per minute) were generally used at surface-water stations when sufficient flowing water was available in order to decrease the time spent collecting the sample. Samples collected for analysis of dissolved non-volatile organic carbon, metals, anions, total dissolved solids (TDS) and phosphate were filtered in the field using 0.45-micron disposable filters; all others were unfiltered. Samples collected for analysis of metals, total and dissolved non-volatile organic carbon, and ammonia-nitrogen were preserved in the field with acid (0.2% nitric acid, 0.5% phosphoric acid, 0.5% phosphoric acid, and 0.2% sulfuric acid, respectively), and all others were unacidified. One duplicate sample and one equipment blank were collected using the same methods and equipment during each of the 70 sampling trips to provide quality control according to laboratory protocols.

All samples were stored on ice or refrigerated below 4°C for transport back to the Illinois State Water Survey Public Service Laboratory in Champaign, Illinois. Samples were generally delivered to the laboratory within appropriate holding times for each type of analysis, though samples collected for nutrient analysis (NH_3-N and o-PO_4) have very-short (48-hour) holding times that, because of travel logistics associated with field work, were typically exceeded by 24 hours or less.

APPENDIX D: Analytes Measured and Laboratory Mehodologies Used for Sample Analysis

Parameter	**Analytes**	**Analytical Methodology**	**Field Preservation**
Alkalinity	Alkalinity	SM Method 2320B - Titrimetric	Cool to 4°C
Anions	F, Cl, NO_3, SO_4	USEPA Method 300.0 - Ion Chromatography	Cool to 4°C, Filter
Metals, dissolved	Al, As, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, S, Sb, Se, Si, Sn, Sr, Ti, Tl, V, Zn	USEPA Method 200.7 - Inductively Coupled Plasma (ICP)	Cool to 4°C, Filter, HNO_3
Metals, total recoverable	Al, As, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, S, Sb, Se, Si, Sn, Sr, Ti, Tl, V, Zn	USEPA Method 200.7 - Inductively Coupled Plasma (ICP)	
Ammonia/ammonium	NH_3 -N	USEPA Method 350.1 - Colorimetry	Cool to 4°C, H_2SO_4
Orthophosphate	oPO_4-P	USEPA Method 365.1 - Colorimetry	Cool to 4°C, Filter
Non-volatile organic carbon (NVOC)	total NVOC, dissolved NVOC	SM Method 5310B - High temperature combustion	Cool to 4°C, Filter (dissolved), H_3PO_4
Total dissolved solids (TDS)	TDS, 180 C	SM Method 2540C - Dried at 180° C	Cool to 4°C, Filter
Total suspended solids (TSS)	TSS	SM Method 2540D - Dried at 103-105° C	Cool to 4°C
pH	pH	USEPA Method 150.1 - Electrometric	Cool to 4°C

SM = “Standard Methods for the Examination of Water and Wastewater”: APHA, AWWA, & WEF
USEPA = methods by the U.S. Environmental Protection Agency

APPENDIX E. Quality Assurance and Quality Control Procedures

Blank and duplicate grab samples were collected during each sampling trip, with the exception of one visit, as part of a quality assurance/quality control (QA/QC) program. Sixty-eight duplicate pairs were collected, with 41 constituents (not including TSS or total metals) analyzed for each pair, for a total of 2,788 comparisons. A total of 28 pairs (1.0%) had a greater than 20% difference between the original and duplicate sample, with such differences observed in boron, fluoride, strontium, zinc, total dissolved solids, and ammonia-nitrogen (one occurrence each), thallium and dissolved non-volatile organic carbon (four occurrences each), total non-volatile organic carbon (six occurrences), and phosphorous (eight occurrences). Of the 20 pairs that were not phosphorous, 16 pairs were measured at concentrations that were less than 10 times the detection limit in both the original and duplicate samples, which is considered non-optimal for analysis and is typical of when larger percent differences occur between the original and duplicate samples (Miner et al. 2014). Of the four remaining pairs, only the duplicate sample was measured at greater than 10% of the detection limit in one instance of total non-volatile organic carbon. The three remaining pairs, where both the original and duplicate sample were measured at concentrations greater than 10 times the detection limit, included one instance each of strontium, total non-volatile organic carbon and dissolved non-volatile organic carbon. For all duplicate pairs, the mean difference was 2.8%.

Equipment Blanks

A total of 69 equipment blank samples were submitted to the laboratory to determine if field methods affected the concentrations of constituents reported. Blanks were composed of deionized water that was sampled using the same equipment and methods used to collect all other surface-water grab samples and duplicate samples. Not including pH, a total of 238 detections were made in 2,760 constituents (69 samples x 40 constituents per sample), or 8.6% of constituents analyzed. Each of the 69 samples had between 1 and 6 constituents detected, with an average of 3 constituents detected per sample. The following constituents were detected most frequently, listed in decreasing number of detections: total and dissolved non-volatile organic carbon (63 each), calcium (51), strontium (12), sodium (11), boron (10), phosphorous and ortho-phosphate (5 each), total dissolved solids (4), copper, magnesium, alkalinity, and chloride (2 each), and aluminum, barium, iron, potassium, manganese, and ammonia (1 each). The highest levels detected in the blanks included total dissolved solids (13 mg/L), alkalinity (11.3 mg/L), total non-volatile organic carbon (2.17 mg/L), and dissolved non-volatile organic carbon (2.11 mg/L). All other detections were less than 1 mg/L. Excluding pH and non-detections, the mean of all means detected for all constituents is 1.05 mg/L. Calcium was detected in 51 of 69 blank samples, but at levels less than 0.4 mg/L. As blanks were prepared from deionized water sourced from calcium bicarbonate tap water, the presence of low levels of calcium, magnesium, and strontium is unsurprising. Similarly, filters can contribute organic carbon, sodium, and chloride, which are highly mobile ions that often are detected in blanks.

Charge Balance Analysis

A third step employed in quality assurance/quality control was to perform charge balance analysis on all sample results returned from the Public Service Laboratory of the Illinois State Water Survey. Charge balance, or cation-anion balance analysis is done by converting ionic concentrations to units of equivalents per liter, then summing the anions and cations separately and comparing the results (Fetter 1994). Cations will equal anions in a balanced solution. If the sum of the cations is not within a few percent of the sum of the anions, then either the chemical analysis is flawed, or critical ionic species may have been left out of the balance analysis (Fetter 1994). For this report, charge balance analysis was performed using the United States Geological Survey’s PHREEQC Interactive software, version 3.3.12.12704 (Parkhurst and Appelo 2013). Constituents included in the analysis for each sample included aluminum, boron, barium, calcium, cadmium, copper, iron, potassium, lithium, magnesium, manganese, sodium, phosphorous, lead, sulfur, silicon, strontium, zinc, alkalinity (as mg/L $CaCO_3$), ammonia, fluoride, chloride, nitrate, and sulfate. Chemical analysis results for individual samples were considered acceptable when the percent error was less than or equal to 5%.

Of the 534 grab samples analyzed by the Illinois State Water Survey for this project, only six samples had a percent error >5% for the charge balance analysis. One sample was collected from surface-water station TP-D on 1/30/2014, with a percent error of 5.1%. The remaining samples were collected from monitoring well TP-2 on the following dates: 8/21/2013 (percent error = 5.5%), 12/16/2013 (percent error = 6.4%), 11/12/2014 (percent error = 5.4%), 6/23/2015 (percent error = 9.0%), and 8/18/2015 (percent error = 6.3%). Groundwater input to well TP-2 was generally limited, especially during the drier summer months before and during construction along I-90. As a result, water levels in well TP-2 generally decreased during sample collection, sometimes to the point where it was necessary to either lower the sample line intake to the very bottom of the well, or shut the pump off entirely in order to let water levels recover so that the entire set of sample bottles could be filled. In both cases, these drawdowns often led to increasing turbidity levels in water pumped from the well throughout the course of individual sampling events, either through disturbance of sediment at the bottom of the well, or possibly from mobilization of sediment from the formation. Because of these circumstances, and in order to ensure that samples could be collected, samples from well TP-2 were often collected prior to the stabilization of field parameters, especially turbidity, though sometimes specific conductivity as well. In the case of each of the four samples above that failed the charge balance analysis, field notes indicate that water levels in the well were running low and turbidity and/or specific conductivity were not stable prior to sample collection. All samples that failed the charge balance analysis were excluded from further analysis.