40-Year Surface Water Quality Report (1984-2024)

Prepared for

Township of Stillwater, New Jersey
Environmental Commission

Prepared by

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January 20, 2025

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ACRONYMS AND ABBREVIATIONS

C1	Category One waters are those waters designated in the tables in N.J.A.C. 7:9B-1.15(c) through (i), for purposes of implementing the antidegradation policies set forth at N.J.A.C. 7:9B-1.5(d), for protection from measurable changes in water quality based on exceptional ecological significance, exceptional recreational significance, exceptional water supply significance or exceptional fisheries resource(s) to protect their aesthetic value (color, clarity, scenic setting) and ecological integrity (habitat, water quality and biological functions).
DQO	Data Quality Objectives. Defined by the USEPA as a systematic planning process for collecting environmental data that is of known quality and quantity to support decision-making. The DQO process is a tool to ensure that the data collected and analyzed for a project meets the requirements of the project's goals.
FW2	Fresh Water 2; means the general surface water classification applied to those fresh waters that are not designated as FW1 or Pinelands Waters.
M-K	Mann-Kendall test (non-parametric statistical trend test).
NJDEP	New Jersey Department of Environmental Protection
OLS	Ordinary Least Squares regression (parametric statistical trend test).
SLs	Screening Levels developed as described in this report for the parameters analyzed as part of the SWMP.
STV	Statistical Threshold Value means the value that approximates the 90th percentile of the water quality distribution and is not exceeded by more than 10 percent of the samples used to calculate the geometric mean for the purposes of bacterial quality criteria.
SWMP	Surface Water Monitoring Program initiated in 1984 by Township of Stillwater Environmental Commission
SWQC	NJDEP Surface Water Quality Criteria means those parameters of the Surface Water Quality Standards, expressed as constituent concentrations, levels, or narrative statements, representing a quality of water that is protective for supporting the designated use.
SWQS	NJDEP Surface Water Quality Standards means the NJDEP regulations (N.J.A.C. 7:9B), which set forth designated uses, use classifications, and

water quality criteria for the State’s waters based upon such uses, and the policies concerning these uses, classifications and criteria.

su	Standard units for pH
TAN	Total Ammonia Nitrogen; aka, “Nitrogen (Ammonia)”
TKN	Total Kjeldahl Nitrogen
TM	Trout Maintenance.
TP	Trout Production.
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
UCL	Upper Confidence Limit
WMW	Wilcoxon-Mann-Whitney
WQDE	NJDEP Water Quality Data Exchange

Executive Summary

This report summarizes surface water data collected by the Township of Stillwater Environmental Commission aka “the Township” or “Stillwater”) as part of a surface water monitoring program (SWMP) initiated in 1984 that includes periodic collection of surface water samples for laboratory analysis from up to 10 Sample Stations (aka “Stations”) located at eight small streams or brooks and the Paulins Kill (aka Paulinskill River). The sampling was performed on an approximately biennial basis from 1984 through 2024. In aggregate, a total of approximately 209 samples were collected and analyzed over the 40-year period since 1984, with most Sample Stations being represented by analytical data for over 20 samples. The SWMP surface water quality sample analytical parameters included:

Alkalinity
Aluminum
E. coli
Fecal Coliforms
Lead
Nitrogen (Ammonia)
Nitrate, Nitrogen
Nitrite, Nitrogen
Total Kjeldahl Nitrogen (TKN)
Orthophosphate
Phosphorus (Total)
pH
Specific Conductivity
Total Dissolved Solids (TDS)
Total Suspended Solids (TSS)

The SWMP employed relatively consistent protocols and methods for sampling locations, sampling frequency, sample analytical parameters, and the use of certified laboratories for sample analysis. As a result, the SWMP Data (i.e., sample analytical results from 1984 to 2024) represent a robust data set for statistical analysis and comparison of water quality data with New Jersey Department of Environmental Protection (NJDEP) regulations (i.e., primarily the NJDEP Surface Water Quality Standards [SWQS]).

Most of the streams in the 28-square-mile Township are tributary to the Paulins Kill, some directly or via various ponds and lakes (e.g., Paulinskill Lake, Swartswood Lake), while some streams feed into Blair Creek which has its confluence with the Paulins Kill downstream about 5 miles to the southwest of the Township. Basic land use and demographic information reflect the rural nature, low population, and corresponding quality of the natural free-flowing surface waterbodies in Stillwater. According to the SWQS, the Paulins Kill and most of its tributary streams are designated as Category One (C1) waterways by NJDEP, with several reaches classified as FW2 Trout Production or Trout Maintenance. Under the SWQS regulations, C1 waterways are afforded special protection to maintain their water quality, aesthetic value, and ecological integrity and to prevent measurable changes in water quality due to their Exceptional Ecological Significance, Exceptional Water Supply, Exceptional Recreation, and Exceptional Fisheries. NJDEP's anti-degradation policies are a primary mechanism in the SWQS to preserve C1 waterways.

The SWMP Data provide a distinct opportunity to assess the provisions of the SWQS C1 designation and related policies quantitatively, rather than only qualitatively, which is the case where robust water quality data are lacking and for parameters without promulgated SWQC.[1] Documentation and summaries of the quantitative statistical analysis performed to evaluate the SWMP Data for this report, (e.g., time series trend analysis, 95% Upper Confidence Levels, data distribution, data correlation, etc.) are included. In addition, relevant provisions of the SWQS are summarized and referenced in the following report sections, as deemed necessary to support the discussion and provide context.

Based on this review, the overall surface water quality is within acceptable NJDEP SWQC and Screening Levels (SLs) developed as described in this report for the parameters analyzed as part of the SWMP, and long-term water quality is generally stable, with minor exceptions, as noted in the report. The large number of samples and consistency in collection frequency and quality facilitated robust statistical analysis of the SWMP Data. Long-term water quality conditions established by statistical analysis of 40 years of water quality data represent an opportunity to set benchmarks for quantitative comparison of water quality data to assess compliance with the SWQS policy for the protection of C1 waters from "measurable change." While the SWMP Data are sufficient for this review, some uncertainties and data quality issues related to sample methods, handling, and parameter selection were identified and are discussed in this report.

Preliminary recommendations are provided for consideration, including:

- Revisions to SWMP Data Quality and Analytical Methods
    - Update Analytical Parameters and Methods

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[1] Other data sets (e.g., NJDEP GeoWeb WQDE) are sparse and cover a relatively short duration. Also, the SWQS do not include criteria for several of the SWMP Parameters.

    - Establish Data Quality Objectives (DQOs), Data Use and Reporting
    - Use of Field Meters for Analyze-Immediately Parameters
    - Standardize Data Documentation and Curation (e.g., use of a database)

- Review of SWMP Objectives
    - Consider Establishing C1 Benchmarks for future data comparative analysis
    - Compare SWMP Data with other data sources (e.g., NJDEP Data, NGO Data)
    - Collaborate with adjacent and nexus communities and NGOs
    - Revise Sample Collection Frequency
    - Consider Focused Short-term Investigations
    - Evaluate Seasonal Variability
    - Consider Additional Parameters

1.0 Introduction

The Township of Stillwater Environmental Commission ("the Township" or "Stillwater") monitored surface water quality in several local streams during the period from 1984 to 2024. The surface water monitoring included collecting over 200 samples for laboratory analysis at 8 to 10 surface water Sample Stations from 1984 to 2024, resulting in up to 26 samples for each of the 10 Stations. The Sample Stations are shown in Figure 1 and photographs of the approximate Station locations are provided as Attachment 1.

Most of the samples were collected in the fall on a biennial basis (i.e., every other year), except for two sampling events in the spring that occurred in 2002. In addition, a Stream Quality Survey was conducted for 8 of the 10 stations in circa 2004 that provided water quality ratings for each of the Stations based on macroinvertebrate counts and physical observations. For this report, the prior surface water quality monitoring and survey conducted from 1984 to 2024 noted above are collectively referred to as the Stillwater Surface Water Monitoring Program (SWMP).

1.1 Scope and Limitations

This report focuses on the analytical results from the SWMP and provides:

- a summary of the existing water quality data generated from the SWMP from 1984 through 2024,
- a characterization of water quality based on statistical analysis,
- discussion regarding the relevance of the various analytical parameters compared to New Jersey Department of Environmental Protection (NJDEP) Surface Water Quality Standards (SWQS) and related criteria, and
- findings and conclusions.

The sampling and investigations conducted as part of the SWMP included in this report are limited to lotic environments (e.g., brooks, creeks, streams, rivers). Lentic environments (e.g., ponds, lakes) were not included. However, some of the sample locations may provide insight into lake water quality via data from lake tributaries and data from surface waters downstream from lake outflow points.

Biological index survey data and various other information collected as part of the SWMP are described in a 2004 surface water report entitled, *Stream Surface Water Sampling – Chemical Data and Biological Analysis through Macroinvertebrates,* prepared for the Stillwater Township Environmental Commission in 2004 (S. Grodsky, 2004; a.k.a., "2004

SW Report")[2] However, the prior biological survey data and related information in the 2004 SW Report are beyond the scope and not summarized in this report.

The NJDEP SWQS and any related laws, regulations, guidance, policies, etc. are intricate and are not all addressed in this report. However, selected parts of the SWQS are included to assist with understanding how salient portions of the SWQS may apply or may be used to interpret the SWMP data. Nothing in this report is intended to represent a determination of compliance or applicability with any laws or regulations, or legal advice. Regulations excerpts and references are provided for convenience; however, the full text of the SWQS should be consulted directly as the final authority regarding a determination of regulatory applicability and compliance.

1.2 Sample Analytical Parameters and Surface Water Quality Standards

The surface water samples collected as part of the SWMP were analyzed for the following parameters (aka SWMP Parameters):

Alkalinity
Aluminum
Ammonia
Conductivity
E. coli
Fecal Coliforms
Total Kjeldahl Nitrogen (TKN)
Lead
Nitrate, Nitrogen
Nitrite, Nitrogen
Orthophosphate
pH
Phosphorus (Total)
Total Dissolved Solids (TDS)
Total Suspended Solids (TSS)

The NJDEP Surface Water Quality Standards (SWQS) are promulgated regulations that provide both narrative and numerical surface water quality criteria (SWQC) that apply to

[2] S.Grodsky, 2004. *Stream Surface Water Sampling – Chemical Data and Biological Analysis through Macroinvertebrates.* Prepared for the Stillwater Township Environmental Commission. 2004.

specific water bodies based on categories assigned to water bodies that define the level of protection each is to receive (N.J.A.C.7:9B).[3] The SWQS include SWQC for some but not all of the SWMP Parameters. The SWQS also include lists of waterbody names and categories that account for virtually all surface water bodies in the state. It should be noted that some of the stream names in the SWQS are not consistent with those historically used in the SWMP. Therefore, an effort was made in this report to reconcile the stream names to facilitate comparison with the SWQS regulations. The prior stream names and sample Stations from the 2004 SW Report are included for reference in Appendix A).

A list of the SWMP Sample Stations and stream names and related location information adopted for this report to facilitate consistency with the NJDEP SWQS waterbody names and categories is provided as follows:

			State Plane Coordinates	
Sample Stations - Location Identifiers (LOC ID)	**NJSWQS Classification**	**Sample Site Location Description**	**SP_X**	**SP_Y**
Site 01 - Blair Ck	FW2-NT(C1)	Sand Pond Road Bridge at end of Old Schoolhouse Rd, below confluence of North and South branch of Blair Creek.	371267	808760
Site 02 - Trout Bk (Fairview Lake Rd.)	FW2-TP(C1)	Fairview Lake Rd.; 365 Feet NW from intersection with Owassa Rd.	383584	819167
Site 03 - Trout Bk (Middleville)	FW2-TP(C1)	Middleville Rd. and Pond Brook Rd.	392415	809709
Site 04 - Swartswood CK (Quick Pond)	FW2-TM(C1)	a.k.a., Spring Brook; Mount Benevolence Rd. near Crandon Lodge.	395873	827994
Site 05 - Swartswood Ck UNT (Crandon Lk.)	FW2-TM(C1)	UNT; (a.k.a., Spring Bk); Hampton Rd. Bridge; 1875 Feet NE from intersection with Mt. Benevolence Rd.	396537	830135
Site 06 - Swartswood Ck	FW2-TM(C1)	a.k.a., Spring Brook; Swartswood Rd. Bridge	401983	820234
Site 07 - Paulins Kill (Main St. Bridge)	FW2-TM(C1)	Stillwater Rd.; Main St. Bridge	388967	801425
Site 08 - Pond Bk (Keen's Mill)	FW2-NT	a.k.a., Keen's Mill; Off of Rt. 521 next to Keen's Mill.	394745	810960
Site 09 - Paulins Kill (Lake Outfall Below Dam)	FW2-TM(C1)	Below the Paulins Kill Lake Dam	401881	808492
Site 10 - Pond Bk (VMP Bridge)	FW2-NT	Veteran's Memorial Park (VMP) bridge.	393880	807728

Footnotes: (Consult NJDEP SWSQ for clarification)
"C1" means Category One waters.
"FW2" means the general surface water classification applied to those fresh waters that are not designated as FW1 or Pinelands Waters.
"NT" means nontrout waters.
"TM" means trout maintenance (for the support of trout throughout the year).
"TP" means trout production (for use by trout for spawning or nursery purposes during their first summer).
"UNT" means unnamed tributary.

Key definitions and statements of policy in the SWQS relevant to the SWMP data evaluation presented in this report are summarized below.

[3] N.J.A.C. = New Jersey Administrative Code found at CHAPTER 9B SURFACE WATER QUALITY STANDARDS (nj.gov) ; last amended 2023.

Category one (C1) waters are defined as those waters designated by the NJDEP in the SWQS (N.J.A.C. 7:9B) for purposes of implementing the antidegradation policies, for protection from measurable changes in water quality based on exceptional ecological, recreational significance, water supply significance or fisheries resource(s) to protect their aesthetic value (color, clarity, scenic setting) and ecological integrity (habitat, water quality and biological functions). (See NJAC7:9B-1.4.)

"Primary contact recreation" means water-related recreational activities that involve significant ingestion risks and includes, but is not limited to, wading, swimming, diving, surfing, and water skiing. (See NJAC7:9B-1.4.)

"Secondary contact recreation" means recreational activities where the probability of water ingestion is minimal and includes, but is not limited to, boating and fishing. (See NJAC7:9B-1.4.)

Category One Waters shall be protected from any measurable changes (including calculable or predicted changes) to the existing water quality. Water quality characteristics that are generally worse than the water quality criteria except as due to natural conditions, shall be improved to maintain or provide for the designated uses where this can be accomplished without adverse impacts on organisms, communities, or ecosystems of concern. (See NJAC7:9B-1.5.)

General SWQS technical policies are as follows [see NJAC7:9B-1.5(e)]:

- Natural water quality may be used in place of the SWQC.
- Water quality criteria are expected to be maintained when stream flows are at or greater than the statistically low flow conditions (e.g., MA7CD10 flow), with some limited exceptions [see NJAC7:9B-1.5(e)].
- Maintenance of water quality criteria is expected in intermittent streams during all natural flow conditions, or immediately downstream when intermittent stream natural flow is insufficient to determine water quality.
- All analytical data to be incorporated by the Department in water quality monitoring shall be from laboratories certified by the NJDEP for the analytical parameters being tested.
- Use Geometric mean and statistical threshold values (STV) for implementing bacterial quality criteria where applicable.

Antidegradation policies applicable to all surface waters of the State are as follows [see NJAC7:9B-1.5(d)]:

- Existing uses and designations shall be maintained and protected.
- Maintenance, migration, and propagation of threatened or endangered species.
- No irreversible changes may be made to existing water quality.
- No changes shall be allowed in waters which constitute an outstanding National or State resource or in waters that may affect these outstanding resource waters.
- Ensure higher classification/antidegradation water quality and uses are not impinged upon by lower classification waters.

In all FW2 waters[4] the designated uses are [see NJAC7:9B-1.12(c)]:

- Maintenance, migration, and propagation of the natural and established biota;
- Primary contact recreation;
- Industrial and agricultural water supply;
- Public potable water supply after conventional filtration treatment (a series of processes including filtration, flocculation, coagulation, and sedimentation, resulting in substantial particulate removal but no consistent removal of chemical constituents) and disinfection; and
- Any other reasonable uses.

Excerpted pages from the SWQS that include relevant SWQC for the SWMP analytical parameters are attached for reference as Appendix B. For more detailed information, see the SWQS (NJAC7:9B) or visit the NJDEP SWQS website at https://www.nj.gov/dep/wms/bears/swqs-overview.htm.

1.3 Summary of Stillwater Township Demographics and Land Use

Natural water quality is inextricably linked to the co-located landscape including geology, soils, and land use/land cover, the latter of which are affected by human population density and related development and infrastructure.

Water naturally falls as rain and snow upon all land areas washing over exposed surfaces of natural and man-made materials. It runs in sheets and channels washing across the various surfaces eroding the earth and rock and carrying dissolved substances – both natural and synthetic. The runoff from rain and snow melt enters water bodies - sometimes in trickles and at times in torrents - carrying remnants of the land it crosses along the way.

[4] “FW2 waters” refers to the NJDEP general freshwater classification for most freshwater bodies in NJ.

On average New Jersey receives roughly 45 inches (i.e., nearly 4 feet) of precipitation (snow and rain) annually. Approximately 25% (~1-foot) of the average annual precipitation soaks into the ground and migrates to groundwater where it may be stored for hours to years before it is lost via evapotranspiration, pumped from wells, or eventually discharges to surface water. Most of the remaining annual precipitation (~75%) becomes stormwater runoff, with some seasonal loss to evapotranspiration. This summary is very general and is not intended to account for regional variability or all aspects of the hydrological cycle. However, it serves to illustrate two key concepts that are not only generally applicable, but that apply specifically to Stillwater: (1) surface water bodies receive a large percentage of the annual precipitation in the form of runoff, and (2) land use, precipitation, surface water, and groundwater are interconnected.

The Township of Stillwater is home to roughly 4,000 people and covers approximately 28 square miles or about 18,000 acres of land area.[5] As one of the least densely populated municipalities in the state, Stillwater has a relatively low percentage of impermeable cover (e.g., structures, parking lots, paved roads) and a limited number of properties zoned for commercial use. Large portions of the Township are preserved as farmland or open space, and farmland accounts for a significant amount of the land area.

While some large areas are used for agriculture, there are no major industrial sites and very few NJDEP Known Contaminated Sites (i.e., six) or contaminated areas, with none identified in the immediate vicinity of the SWMP Sample Stations, as indicated by NJGeoWeb map information (Appendix C). Notwithstanding, the Paulins Kill receives discharges from upstream sewage treatment plants located outside of Stillwater (USEPA, 1976)[6] that can impact water quality in Paulinskill Lake and the Stillwater reach of the Paulins Kill.

The NJDEP SWQS identifies five streams in the Township of Stillwater in (Blair Creek, Paulins Kill, Pond Brook, Swartswood Creek, and Trout Brook) with a nexus to related tributaries and several lakes. However, this does not include many small tributaries and rivulets that exist in many areas throughout the Township. The SWMP sampling did not include lakes and wetlands. Thus, the water quality of Township lakes and wetlands is beyond the scope of this report. NJDEP land-use maps indicating the aerial extent of Stillwater Township, surface, water bodies, wetland areas, etc. from the New Jersey GeoWeb database are provided in Appendix C.

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[5] NJDEP GeoWeb https://www.nj.gov/dep/gis/geowebsplash.htm [accessed 01/20/2024]

[6] USEPA, 1976. Report on Paulinskill Lake, Sussex County, New Jersey: EPA Region II. Working Paper No. 371. U.S. Environmental Protection Agency.

In general, surface water quality is a function of the local and/or regional geology, hydrogeology, topography, soil and land use. Surface water quality is also subject to impacts from point-source and non-point source discharges, and groundwater or surface water runoff may be impacted by human land-use activities, such as industrial operations, agriculture, construction, roadways, public sanitary sewerage systems, septic systems, etc. While a review of the SWMP Sample Stations relative to land-use mapping may be informative, it is beyond the scope of this report, and may be considered for future evaluation of the Township surface water quality.

1.4 Geology and Environmental Setting

New Jersey has four distinct physiographic provinces, including (listed from the south to the north) the Atlantic Coastal Plain Province, the Piedmont Province, the Highlands Province, and the Ridge and Valley Province. Stillwater is located within the Ridge and Valley Province, which is the smallest of the four physiographic provinces and is confined to the northwest corner of the state. The Ridge and Valley Province includes the Kittatinny Valley, which is part of the Great Appalachian Valley that contains some of the oldest rocks of the province. One prominent geologic formation is the Martinsburg shale (composed of limestone) that formed during the Ordovician period. At the edge of this valley is the Kittatinny Ridge which is rises above 1,000 feet above mean sea level. The Kittatinny Ridge is oriented along a northeast–southwest axis.

Bedrock deposits influence the conditions of the local soils, surface water, and groundwater. The regional bedrock geology includes carbonate bedrock formations primarily composed of limestone and dolomite that make up over one-third of the bedrock in Stillwater.

Large portions of Stillwater are identified by the NJDEP as areas of groundwater recharge replenishing aquifers that serve as important groundwater resources for local and regional water supply. The recharge to groundwater occurs from seepage of surface water that ultimately derives from precipitation (snow and rain) and related stormwater runoff. The groundwater recharge in the Ridge and Valley Province derives entirely from precipitation. (This is why the quality of runoff water from roads, parking lots, and areas of pesticide and fertilizer use are concerns for protection of groundwater quality.) However, the interaction between surface water bodies (e.g., lakes, ponds, rivers, streams, etc.) and shallow groundwater zones is variable, and often groundwater seeps into surface water bodies in the form of springs or as constant stream base flow depending on the season and elevation of the groundwater, among other factors (e.g., local geology, local water use, etc.).[7]

Based on the above, the quality of the surface water is very closely related to local and regional groundwater quality and conditions of one can and does influence the other. The SWMP implemented over the past four decades focused on surface water quality and groundwater quality was not evaluated and is beyond the scope of this report. However, the SWMP Data may serve as an indicator for local or regional groundwater quality due to the physical interconnection of surface water and groundwater and the potential influence of the water quality of each for future study.

[7] For additional information see Environmental Resource Inventory Updates (2014/2015) https://stillwatertownshipnj.com/government/boards-and-commissions/environmental-commission/

2.0 Summary of SWMP Laboratory Analytical Results

As noted in Section 1 above, the SWMP included collecting over 200 samples for laboratory analysis at 10 surface water Sample Stations from 1984 to 2024, resulting in data for up to 26 samples for each of the 10 Stations for most of the SWMP Parameters. The SWMP laboratory sample analytical results (aka SWMP Data) for all samples, parameters, and Stations are provided in Tables 1 through 10. Summary statistics and discussion of the SWMP Data including statistical analysis and comparisons to SWQC are included in the following sections below, with supporting details, information, and documentation attached as appendices. Statistical analysis, noted below where applicable, was performed using the US Environmental Protection Agency's ProUCL statistical software (ProUCL, Version 5.2).[8]

2.1 Overview of Surface Water Sample Analytical Results

As an initial overview evaluation, summary statistics of the entire SWMP Data set (min., max., mean, sample size, etc.) are listed below, along with a high-level comparison of SWQC. For this level review, summary statistics and comparisons are presented for each SWMP Parameter and data are not separated by Sample Station. As noted below, the SWQS include SWQC for only 6 of the 13 SWMP Parameters. Screening Levels (SLs) based on the SWQC or assembled from other sources were adopted as needed to facilitate this review. The sources and references that support SWQC and SLs used for comparison in this report are included in Appendix B.

The SWMP data used for this evaluation relied on the laboratory results only. During the October 2024 sampling event, pH and temperature were measured for surface water samples at each of the 10 Stations in the field using a portable Fisher Scientific Accumet AP115 pH /temperature meter. The pH and temperature field measurements were not used in the statistical analysis, but are discussed in the following sections, where appropriate.

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[8] USEPA 2022. ProUCL Version 5.2. *Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations*. Office of Research and Development, EPA/600/R-07/041. October 2015 (Updated June 2022). https://www.epa.gov/land-research/proucl-software

		SWQC/SL (1)				Site Data Summary				Frequency					
Parameter	Units	Acute Biota	Chronic Biota	Human Health	General	Min. Conc.	Max. Conc.	Mean Conc.	SD	# Samples (n)	# Detected	# > Acute	# > Chronic	# > Human Health	# > General
Alkalinity, Total (2)	mg/l	--	--	--	200	5.52	190	45	44	209	209	--	--	--	0
Aluminum (2)	mg/l	0.98	0.38	--	--	0	0.906	0.99	0.1	134	97	0	8	--	--
E. coli	col/100ml	--	--	--	100	0	620	78	140	25	22	--	--	--	3
Fecal Coliforms (3)	col/100ml	--	--	--	100	0	900	51	96	207	182	--	--	--	20
Lead	mg/l	0.038	0.0054	0.005	--	0	0.088	0.009	0.016	145	104	8	27	27	--
Nitrogen, Ammonia (3)	mg/l	2.4	0.54	--	--	0	0.9	0.1	0.1	201	143	0	4	--	--
Nitrogen, Nitrate	mg/l	--	--	10	--	0	2.28	0.19	0.28	209	146	--	--	0	0
Nitrogen, Nitrite (2)	mg/l	--	--	--	1	0	0.26	0.02	0.05	200	132	--	--	--	0
Nitrogen, Total Kjeldahl (TKN) (2)	mg/l	--	--	--	6	0	21	0.64	1.58	200	148	--	--	--	1
pH	su	--	--	--	6.5-8.5	5.92	8.47	7.17	0.54	209	209	--	--	--	27
Phosphate, Ortho (3)	mg/l	--	--	--	0.1	0	0.1	0.03	0.03	208	163	--	--	--	0
Phosphorus	mg/l	--	--	--	0.1	0	0.54	0.048	0.077	200	167	--	--	--	13
Specific Conductivity (2)	umhos/cm	--	--	--	500	63.4	642	196	131	209	209	--	--	--	6
Total Dissolved Solids (TDS) (5)	mg/l	--	--	--	500	48	360	137	92	19	19	--	--	--	0
Total Suspended Solids (TSS)	mg/l	--	--	--	25/40	0	65	4.19	7.94	201	150	--	--	--	4

(1) Values are NJ Surface Water Quality Criteria (SWQC) in NJAC 7:9B, unless otherwise noted as Screening Levels (SL).
(2) Screening Levels adapted from sources other than NJ Surface Water Quality Standards NJAC 7:9B. (See Appendix B).
(3) SWQC are estimates calculated based on SWQS in NJAC 7:9B. (See Appendix B).
(4) SWQC in NJAC 7:9B require background or whole effluent toxicity testing to establish compliance.
(5) SL for TDS uses NJ Drinking Water TDS MCL.(See Appendix B).

The parameter concentrations in the above summary are not intended for compliance with the SWQS and do not necessarily represent non-compliance with the SWQC, as many of the above criteria are adapted from SWQC and/or are SLs developed for this report. In addition, some of the Site data represent legacy conditions, and SWQC have changed over the years. Thus, for strict determination, the older results would need to be compared to their contemporaneous SWQC, which is beyond the scope of this report. However, the above data summary serves as a high-level screening step to guide further evaluation.

In general, the frequency of detection above SWQC and Screening Levels (SLs) is relatively low for all SWMP Parameters. Aluminum and lead concentrations are skewed by historical conditions and elevated detection limits associated with older data from prior to 2002. The concentrations of aluminum and lead are all either Not Detected (ND) or below the SWQC and SLs in the more recent surface water data (2003 through 2012) from over 40 samples obtained from Stations 1 through 9.

The parameters with the highest detection frequencies above SLs, E*. coli*, exhibit detection frequencies above SWQC of 12% (3/25=0.12). However, the samples size for *E. coli* is low (i.e., n=25 samples) compared to most of the other parameters, which include larger sample sizes (e.g., n=209). A detection frequency of 13% is noted for pH measurements below the lower SWQC pH range of 6.5-8.5 standard units (su). However, since 2012 pH measurements at all Stations have consistently been within the SWQC range for pH (6.5-8.5). The frequency of detection above SWQC or SLs for Fecal coliforms, ammonia nitrogen, phosphorus, specific conductivity, TKN and TSS are all less than 10%. TKN was detected at 21 mg/L in the October 2024 sample from Site 2. However, this is an outlier compared to the TKN data for both Site 2 and the entire SWMP data set. The TKN data otherwise are all well below the SL of 6 mg/L.

Based on the overview data summary presented above, most of the data are within SWQC and SLs with exceptions as noted above. However, the SWMP Data represent a 40-year period and surface water quality can change over time. For example, elevated detection frequencies for some of the SWMP Parameters may be caused by data from samples collected many years ago and that may not represent current or prevailing conditions at a particular Station. Therefore, further evaluation of the SWMP Data was performed to identify potential trends in water quality, to calculate 95UCLs for consideration as benchmarks for use in evaluation of future sample data, and to identify Stations that exhibit elevated parameter concentrations.

2.2 Overview of Statistical Analysis

Further detailed evaluation of the SWMP Data is included below with a focused discussion of the SWMP Parameters supported by statistical and comparative analysis, noted where applicable.

The statistical trend analysis employed hypothesis tests (Ordinary Least Squares regression or “OLS” parametric tests and Mann-Kendall or “M-K” non-parametric tests) for evidence of statistically significant increasing or decreasing long-term trends over the monitoring period (i.e., 1984-2024) for each SWMP parameter at each Station.

Ninety-five (95) percent upper confidence limits of the mean (“95%UCL” or “95UCL”) were calculated for each SWMP parameter at each Station. The 95UCLs are summarized in Section 2, below, and included in Appendix D).

Focused statistical analysis was also performed using OLS and M-K to test for potential correlation among some selected SWMP parameters (Alkalinity, pH, Fecal Coliforms, *E. coli*,).

Finally, parametric and non-parametric, two-sample hypothesis tests (Student t-Tests and Wilcoxon-Mann-Whitney or “WMW”) were completed to test for significant differences among groups of data from selected Stations and SWMP Parameters.

Descriptions of the specific statistical tests, results, and references to the attached documentation are provided below, where appropriate.

2.2.1 Time Series Trend Analysis

The long-term trend analysis performed for this report indicates that the water quality is generally stable with no statistical evidence of increasing or decreasing trends ($p>0.05$) for most SWMP parameters at most Stations. Statistical evidence of decreasing trends ($p<0.05$) was noted for the following Parameters and Stations:

Parameters with Statistical Evidence of Decreasing Long-Term Trends	Sample Station Nos.
Aluminum	2, 3, 4, 5, 7
Ammonia	1 through 7
Fecal Coliforms	4, 5, 7
Lead	1, 5, 7
Nitrate	1, 2
Nitrite	9
Orthophosphate	1, 2, 4, 5, 6, 7
Phosphorus	3, 4, 7
TSS	2, 3, 4, 6

Statistical evidence of increasing trends ($P<0.05$) was identified for Alkalinity at Station 5 and Specific Conductivity at Stations 5 and 6. However, the maximum and average (aka “mean”) Alkalinity concentrations at Station 5 and 6 are all below the SL of 200 mg/L, and the trend slope is low (i.e., < 1). Similarly, relatively minimal increases in Specific Conductivity measurements (i.e., from roughly 100 to 200 umhos/cm) over 40 years are not a concern, especially given there is no SWQC for Specific Conductivity (note that 500 umhos/cm is a SL not a SWQC).

The trend graphs with statistical parameters and critical values (e.g., P-values) for all SWMP Parameters and Stations are included in Appendix D.

2.2.2 95UCLs

The 95UCLs represent well-established baseline conditions for comparative analysis due to the consistency, methods, and frequency employed over the long-term (i.e., 40 year) SWMP sampling period for most Stations. The 95UCLs may also have applicability for quantitative implementation of anti-degradation policies afforded C1 waters pursuant to the SWQS.

A summary of the range of 95UCLs calculated for the SWMP Parameters at each Station is provided as follows:

Summary 95UCLs Calculated from SWMP Data (1984-2024)

Parameter (units)	Sample Stations										
	1	2	3	4	5	6	7	8	9*	10*	SWQC/SL (1)
Alkalinity (mg/L)	20.8	14.8	25.4	22.4	35.5	31.9	137.1	77.3	149.3	N/A	200
Aluminum (mg/L)	0.14	0.14	0.15	0.18	0.27	0.09	0.16	N/A	0.16	N/A	0.38
Fecal Coliforms (col/100ml)	60	57	36	19	84	31	181	24	158	355	100
Lead (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	0.005
Nitrogen, Ammonia (mg/L)	0.17	0.23	0.13	0.16	0.12	0.11	0.11	0.07	0.15	N/A	0.54
Nitrate (mg/L)	0.20	0.23	0.17	0.22	0.23	0.20	0.64	0.20	0.51	N/A	10
Nitrite (mg/L)	0.037	0.035	0.035	0.047	0.035	0.036	0.039	0.047	0.096	N/A	1
TKN (mg/L)	0.86	0.68**	0.80	0.52	0.78	0.72	0.85	1.03	0.57	N/A	6
pH (su)	6.9	6.8	7.2	7.1	7.2	7.3	8.0	7.8	8.0	N/A	6.5 - 8.5
Orthophosphate (mg/L)	0.04	0.04	0.03	0.04	0.03	0.03	0.04	0.04	0.05	N/A	0.1
Phosphorus (mg/L)	0.07	0.10	0.07	0.06	0.06	0.06	0.07	0.09	0.13	N/A	0.1
Specific Conductivity (umhos/cm)	118	131	134	132	201	168	456	245	554	N/A	500
TSS (mg/L)	6.6	4.0	2.8	4.3	9.4	3.4	6.6	16.9	15.9	N/A	25

Notes:

* 95UCL qualified due to low sample size (n<10).

** Calculated with outlier removed; see Report text for TKN.

N/A = not applicable; 95UCL not calculated due to low detection frequency.

ND = Not Detected above detection limit or SWQC; 95UCL not calculated due to low detection frequency.

(1) SWQC/SL = Most stringent Surface Water Quality Criteria or Screening Level developed for the SWMP.

Yellow highlighted values are above SWQCs or SLs.

Based on the 95UCLs listed above, the concentrations for most SWMP Parameters representing long-term water quality conditions for all Sampling Stations are well below the SWQC and SLs adopted for evaluation in this report. While this review is not intended to indicate strict compliance with SWQC or SLs, it does imply further surface water quality evaluation may be warranted for Fecal coliforms[9] and Specific Conductivity at selected Stations. However, the elevated 95UCL above the SL for Specific Conductivity downstream from Paulins Kill Lake (Station 9) is of less concern as there are no applicable SWQC (i.e., the value of 500 umhos/cm in the “SWQC/SL” column noted above is a SL; see discussion regarding SWQC and SLs) and there are no increasing trends for Specific Conductivity, as noted above.

Supporting data and documentation for the 95UCL calculations are included in Appendix D.

2.3 Detailed Review and Discussion of SWMP Parameters

SWMP Parameters that are chemically related are grouped together in the following sections to facilitate the evaluation narrative and aid the presentation.

2.3.1 Alkalinity and pH

<u>Alkalinity</u>
Alkalinity is a property of water that provides a measure of the buffering capacity for surface water to resist fluctuations in pH in an aquatic environment (i.e., resistance to changes in acidic or basic conditions). Therefore, Alkalinity and pH are discussed together.

The alkalinity concentrations measured in 209 surface water samples range from 5.5 to 190 mg/L with an average of 45 mg/L. The 95UCLs for alkalinity range from about 15 mg/L to 150 mg/L. The SWQS do not include SWQC for Alkalinity and all alkalinity concentrations are within the desired SL range of 20 mg/L to 200 mg/L listed above, the concentrations for most SWMP Parameters representing long-term water quality conditions for all Sampling Stations are well below the SWQC and SLs adopted for evaluation in this report. These concentrations are consistent with Stillwater’s limestone-dominated geography. Limestone contributes to naturally occurring alkalinity concentrations, which provides a buffering capacity that facilitates natural stability of pH in the range of 6.5 to 8.5 su around a neutral pH range of roughly 7 su.

While all alkalinity concentration is within the SL range, the alkalinity concentrations from the two Sample Stations located along Paulins Kill (Stations 7 and 9) are significantly

[9] Future biological quality evaluation should focus on E.coli and not fecal coliforms for consistency with current USEPA and NJDEP water quality criteria.

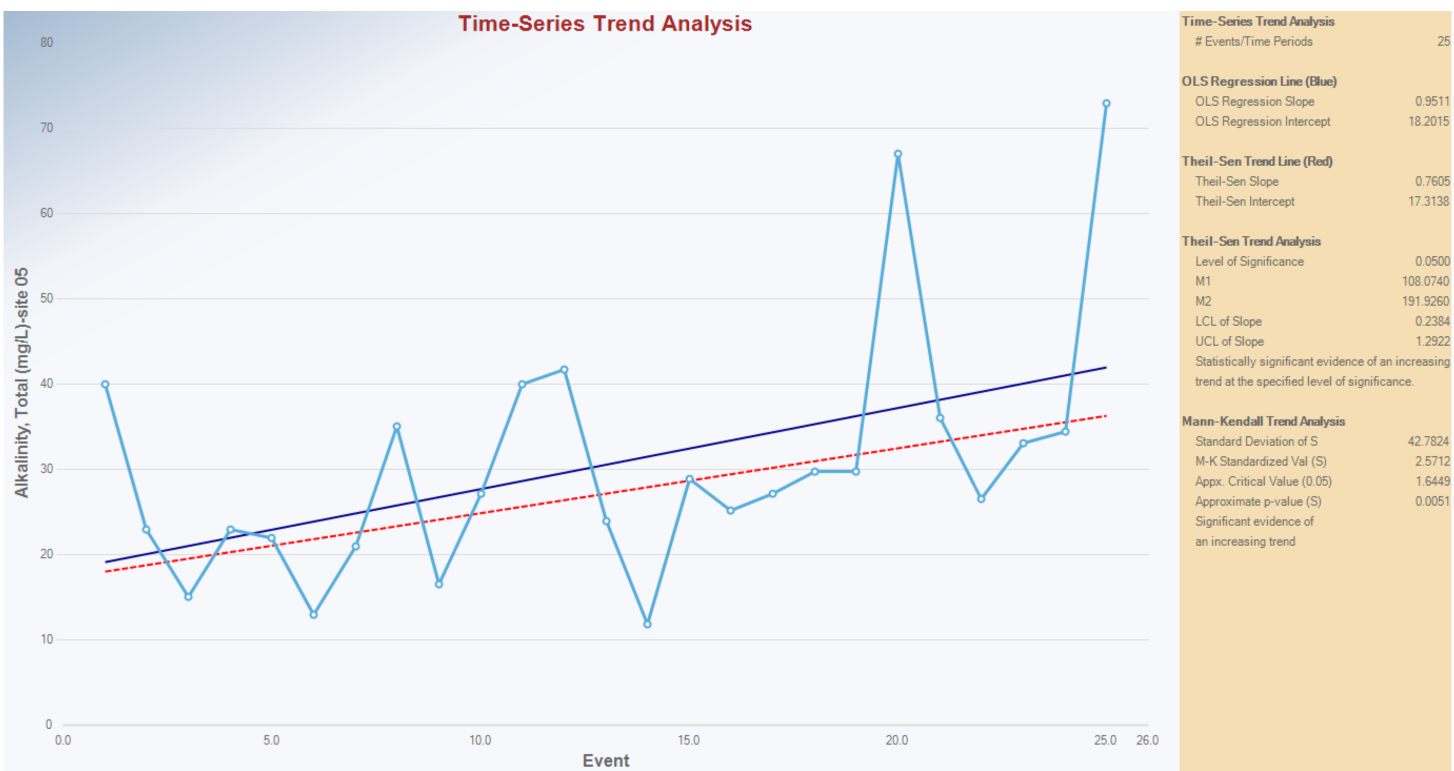
higher than the alkalinity concentrations at the other Tributary Stations (i.e., all SWMP Sample Stations other than 7 and 9).

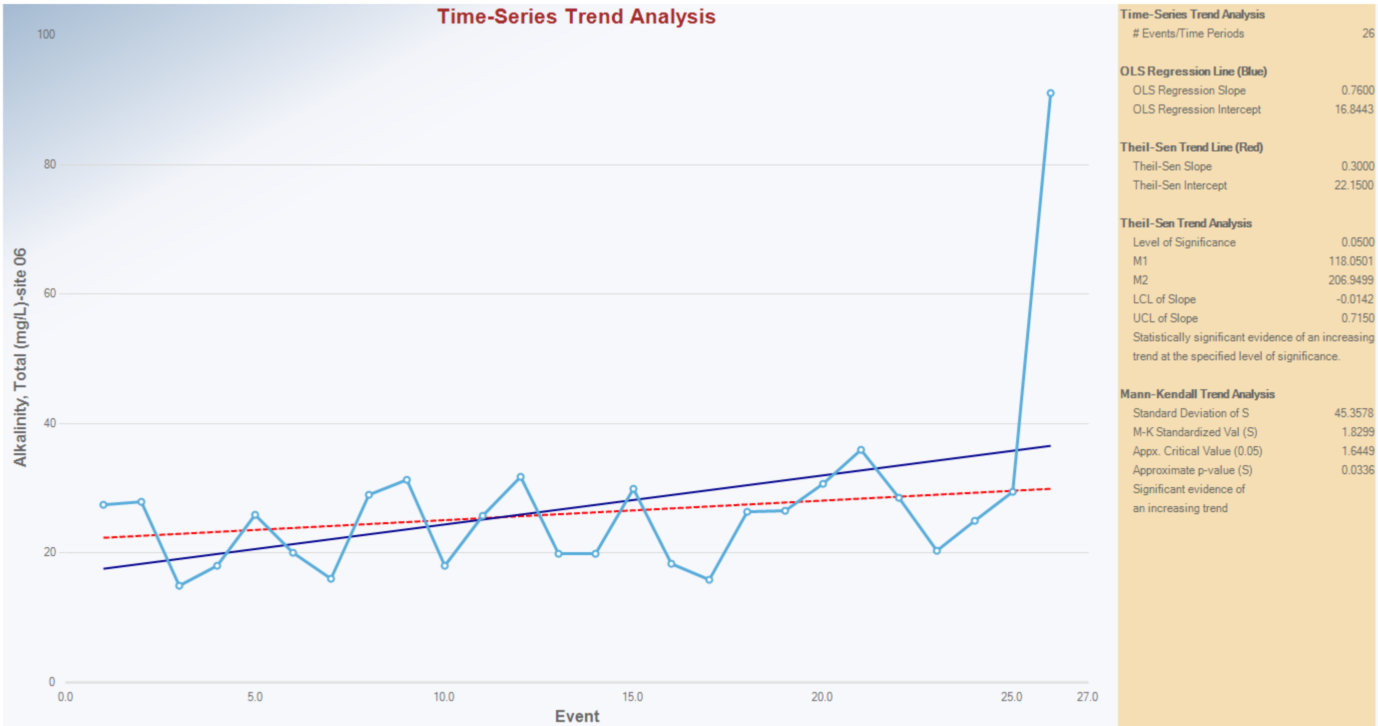
Summary Statistics for Alkalinity in Surface Water Stations on Paulins Kill vs. other Stations

	Paulins Kill Data Summary (Stations 7 and 9)					Data Summary (Stations 1-6, 8 and 10)				
Parameter (mg/l)	n (site)	Min. Conc.	Max. Conc.	Mean Conc.	SD	n (bkg)	Min. Conc.	Max. Conc.	Mean Conc.	SD
Alkalinity, Total	173	5.52	98	27.2	19.7	36	86.8	190	128	29.4

The differences in alkalinity concentrations from Stations along Paulins Kill and other Stations are statistically significant (p<<0.05), based on two sample hypothesis statistical tests (see Appendix E).

As noted above, statistical analysis of long-term trends indicates alkalinity concentrations are stable in surface water at Stations 1 through 9 (see Appendix D), with slightly increasing trends identified as statistically significant at Station 5 and at Station 6 (P<0.05).





The alkalinity concentrations from the October 2024 sampling event are elevated compared to the historical alkalinity concentrations for all Stations. In some cases, the alkalinity concentration in the samples from October 2024 appear anomalously high (e.g., see trend graph above for Station 06 showing alkalinity in the most recent sample at more than double the highest historical alkalinity concentration.) While the cause is not certain, the generally higher alkalinity concentrations may be related to the severe drought conditions that existed at the time of the October 2024 sampling. Under the drought conditions, essentially 100% of the surface water is made up of groundwater, which would be expected to exhibit higher alkalinity based on the local geology (i.e., limestone parent material). Notwithstanding, even the highest alkalinity concentrations are within the acceptable SLs.

pH

The laboratory pH measurements are generally within the SWQC range of 6.5-8.5 su, with some limited exceptions. During the period from 1988 to 2012, pH was measured below 6.5 (between 5.9 and 6.5) in 27 samples from Stations 1 through 6. However, since 2012, pH measurements have all been within the SWQC range of 6.5-8.5.

The samples collected during the October 2024 sampling event were analyzed by the laboratory for pH and temperature, in addition to the other SWMP Parameters. However, pH and temperature measurements are time sensitive. Therefore, as noted above, pH and temperature measurements were also obtained in the field with a portable meter during the October 2024 sampling event to address data quality concerns related to the time delay for the measurement of these parameters by the laboratory and potential to impact current and existing (past) data. The field and laboratory pH and temperature measurements for the samples collected in October 2024 are presented below.

Lab vs. Field Measured pH in Surface Water
Stations 1 through 10
Sampled October 2024

	pH (su)		Temperature (Degrees C)	
Station No.	Laboratory Report	Field Measured	Laboratory Report	Field Measured
1	7.2	6.54	21.9	10.2
2	6.8	6.93	22.2	8.2
3	6.8	7.93	22.3	9.8
4	6.6	7.43	22.3	9.7
5	7.0	7.38	21.7	8.4
6	7.4	7.86	21.7	8.6
7	7.6	8.45	22.2	10.8
8	7.3	7.55	21.7	10.4
9	7.8	8.44	21.7	14.5
10	7.1	8.07	22.5	9.3

Although the correlation is poor, the pH data are all within the SWQC range (6.5-8.5) for regardless of whether the measurements were performed on site in the field or later in the laboratory. However, the field-measured results are considered more accurate as they were obtained within 15-minutes of sample collection, pursuant to NJDEP requirements, and changes to pH may occur over a period of hours to days. Thus, the differences in the above pH field vs. laboratory data may be attributable to the delay in the time of measurement by the laboratory.

Regarding the temperature measurements, while modern pH meters typically correct pH measurements for temperature (i.e., pH data are not impacted by the differences in temperature), the difference in the temperature measurements noted above is significant. The laboratory reporting of sample temperature is reflective of the room temperature in the lab, which is irrelevant for the SWMP data evaluation. In contrast, the field temperatures are much lower than the lab-reported temperatures measured for all Stations on October 16, 2024. Further discussion of the impact of pH and temperature is addressed below for ammonia nitrogen.

Notwithstanding, pH data quality issues noted later in this report related to the timing from sample collection to sample pH measurement, the pH data obtained during the SWMP are considered reasonably accurate for screening against SWQC and conducting trend analysis.

Alkalinity concentrations exhibit a weak positive correlation with pH in surface water at several Stations based on statistical OLS trend analysis (see Appendix E).

2.3.2 Aluminum and Lead

The SWMP included periodic sampling and analysis for aluminum and lead from Stations 1 through 8 for the period 1984 through 2012. Aluminum is a common element in the earth's crust and is typically found at relatively high percentage levels in local earthen material (e.g., native rock, mineral soil, and clay). Lead is less common and not naturally abundant, with lower natural concentrations in soil. Thus, while aluminum at low concentrations may be expected, the presence of lead in surface water samples is less likely to be linked to natural background conditions.

The aluminum concentrations measured in 134 surface water samples range from not detected (ND) to 0.9 mg/L with an average of about 0.14 mg/L. The 95UCLs for aluminum range from about 0.09 mg/L to 0.27 mg/L. The SWQS do not include SWQC for aluminum and all aluminum concentrations are below the SL of 0.38 mg/L. As noted above, the aluminum concentrations exhibit statistically significant decreasing trends at several Stations for data collected through 2012, and aluminum concentrations in samples obtained after 2003 are much lower than from the pre-2003 sampling.

The lead concentrations measured in 145 surface water samples range from not detected (ND) to 0.09 mg/L with an average of about 0.016 mg/L. The 95UCLs for lead calculated using all the SWMP lead data range from about 0.004 mg/L to 0.023 mg/L. However, the lead data from samples collected after 2002 from Stations 1 through 9 are mostly not detected (ND), with detectable lead concentrations of 0.002 mg/L (below the most stringent SWQC of 0.005 mg/L) in only 2 of 43 samples. Thus, 95UCLs were not calculated using the more representative lead data (i.e., from post-2002), as these data do not meet UCL test assumptions due to the high incidence of non-detectable analytical results for lead during that period.

Based on this review, the historical aluminum and lead concentrations do not warrant further evaluation given the more recent data are all below applicable SWQC.

2.3.3 Fecal Coliforms and E. coli

Although not directly applicable, the SWMP Fecal coliforms and E. coli data were combined and compared to the SWQC for E. coli to provide a general understanding of the water quality among the various Stations over time.

Fecal coliforms were included as a test parameter for the entire SWMP, while analysis for E. coli was only recently added on a limited basis in 2015 through 2024. Therefore, the ability to use statistics or make comparisons to SWQC for E. coli is limited given the small number of samples. In addition, due to the NJDEP's past revisions to the SWQS, the Bacterial quality SWQC specifies E. coli as the test parameter for freshwater regimes, like those in Stillwater (i.e., all FW2 waters), and Fecal coliform as a test parameter only for saline waters (e.g., ocean water).

The SWMP Data are not strictly comparable to the Bacterial quality SWQC because:

1. the SWQC requires a statistically robust data set to establish 90-day geometric mean and Statistical Threshold Values (STV) (see Appendix B), and
2. the SWQC for E. coli only apply to fresh waters designated for Primary Contact Recreation (see definition in Section 1). (Note that while "Primary Contact Recreation" is a designated use for all Class FW2 water, the human exposure scenarios assumed do not comport with realistic use/exposure scenarios for many of the Stations due to the physical conditions [e.g., small stream size, accessibility, etc.]).

Therefore, for this review, the SWQC for E. coli are adopted as SLs. However, to address the dearth of E. coli results due to the small number of samples analyzed (i.e., n=25) and lack of historical data, correlation and statistical hypothesis tests were completed using the coincident E. coli and Fecal coliform SWMP Data to confirm the use of the Fecal coliform data as a surrogate for evaluating the Bacterial Quality for this review.

The summary statistics for the two sets of paired coincident data are provided below.

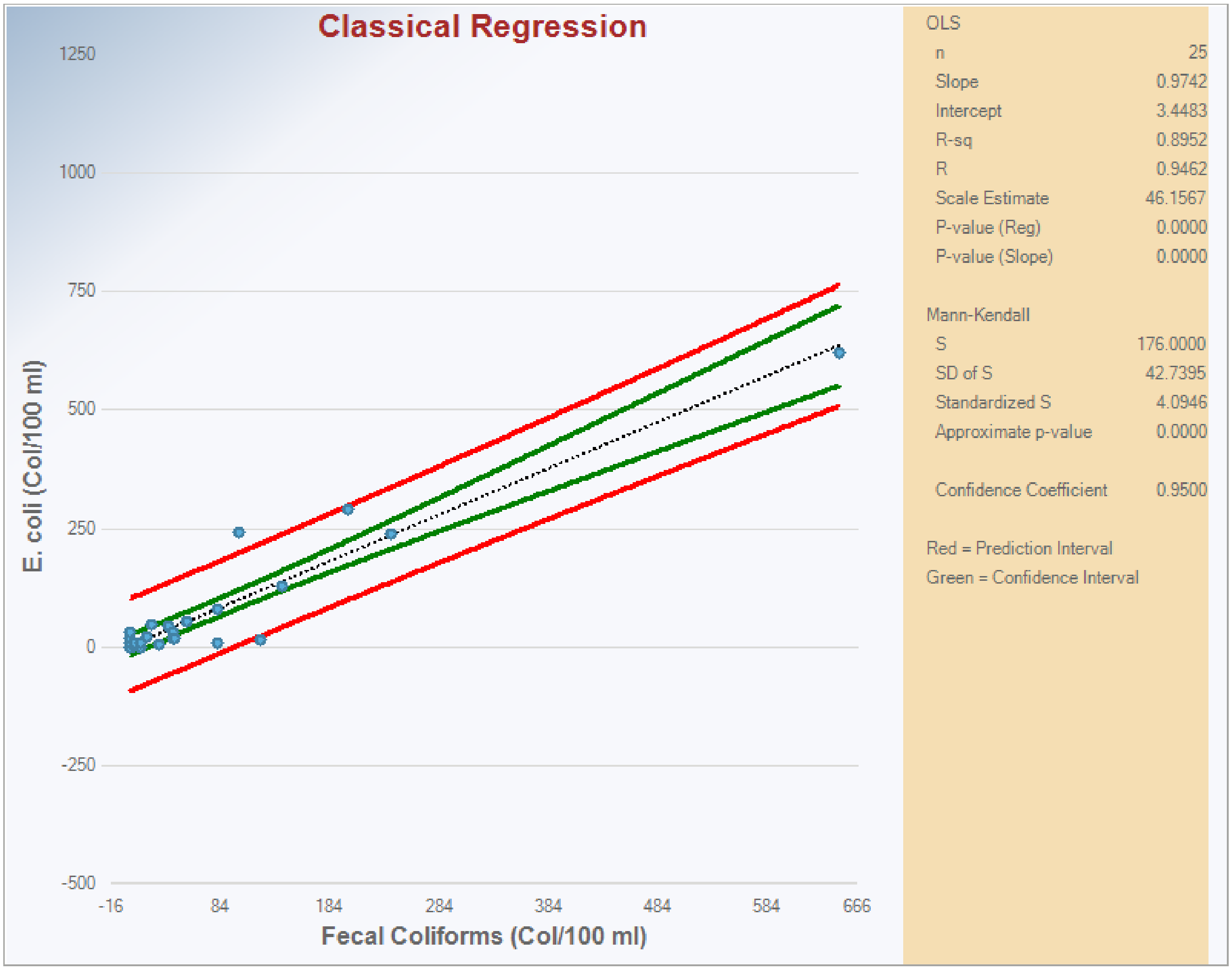
Summary Statistics - *E.coli* and Fecal coliform Coincident Data

	Site Data Summary					Frequency
Parameter (col/100ml)	**n (samples)**	**Min. Conc.**	**Max. Conc.**	**Mean Conc.**	**SD**	**# Detected**
E. coli	25	0	620	78	140	22
Fecal Coliform	25	0	650	77	136	20

Notes:

Coincident data represent paired analytical results from Stations 1-10 in 2015, and Station 10 from 2016, 2018, 2020, 2022 and 2024.

As listed above, the summary statistics of the paired coincident maximum, mean, standard deviation and detection frequencies for *E. coli* and Fecal coliform are very similar. The statistical analysis shows a significant positive correlation exists between the *E. coli* and Fecal coliform paired data (R^2=0.895; $P<0.05$) and the two data sets are not statistically different (WMW test; P=0.89) (Appendix E).



These findings are consistent with the US Environmental Protection Agency's (USEPA's) adoption of *E. coli* as an indicator of fecal coliform contamination (Appendix B). However, for this report, the most stringent SWQCs for *E. coli* (i.e., 100 col/100ml) is used as SLs in this report for evaluation of the larger Fecal coliform data set, without performing geometric mean and STV analysis due to the limited number of samples required for such analysis.

The E. coli concentrations in 25 surface water samples range from not detected (ND) to 620 col/100 ml, with an average of about 78 col/100 ml. The detection frequencies of *E. coli* above the SLs of 100 col/100ml is 12% (3/25=0.12). The *E. coli* sample size is too small for trend analysis and calculation of 95UCLs at each Station. However, these calculations were completed for Fecal coliform data, as noted above.

The Fecal coliform concentrations measured in 207 surface water samples range from not detected (ND) to 900 col/100ml, with an average of about 51 col/100ml. The 95UCLs for Fecal coliform range from 19 to 355 col/100ml. As noted per the 95UCL evaluation above, Fecal coliform 95UCLs are above the SL of 100 col/100ml at Stations 7, 9, and 10. Fecal coliform 95UCLs are below the SL of 100 col/100ml at all other Stations.

The trend analysis shows Fecal coliform concentrations exhibit statistically significant decreasing trends at Stations 4, 5, and 7, and are otherwise stable at the other Stations.

Based on this review, future monitoring for Fecal coliforms is not warranted due to the adoption of *E. coli* as the SWQS Bacterial quality indicator parameter for freshwater regimes. In addition, any future monitoring for Bacterial quality should include establishing appropriate Data Quality Objectives (DQOs) and updating sampling and analysis methods accordingly. Particular attention should be given to whether Stations and/or other locations comport with scenarios assumed for the SWQC (e.g., Primary Contact Recreation [see definition in Section 1]) to promote including realistic conceptual models and use/exposure scenarios that align with actual use and physical conditions (e.g., small stream size, accessibility, etc.).

2.3.4 Nitrogen Compounds

Nitrogen is a nutrient that is present in surface water and occurs naturally in several forms. Common analyses for nitrogen in surface water include ammonia (aka "Ammonia Nitrogen" or "Nitrogen, ammonia"), nitrate, nitrite, and Total Kjeldahl Nitrogen (TKN), which measures both organic and inorganic nitrogen including nitrate, nitrite, and ammonia nitrogen. The overview evaluation above indicates nitrogen compounds are below the SWQC and SLs except for ammonia. Therefore, the following discussion is focused on ammonia with a summary discussion of TKN as a measure of total nitrogen.

Ammonia Nitrogen

Ammonia or ammonia nitrogen is a form of nitrogen measured and reported as total ammonia nitrogen (aka TAN). The SWQS require the calculation of Site-specific SWQC for ammonia in freshwater bodies using sample pH and temperature. The ammonia nitrogen data are not strictly applicable for determining compliance with SWQC because sample pH and temperature measurements were not obtained immediately at the time of sampling (see Data Quality and Usability section, below). In addition, samples and related pH and temperature data were not obtained in the warmest weather conditions. Based on the formulae used for establishing ammonia SWQC, the ammonia SWQC decreases (i.e., becomes more stringent) as pH and/or temperature increase. Thus, the most stringent ammonia SWQC occur at the highest pH and temperatures.

Acute and chronic ammonia SLs of 2.4 mg/L and 0.54 mg/L, respectively, were developed for this report as conservative screening levels using field pH and temperature measurements obtained in October 2024, as noted above. The recent pH and temperature measurements from October 2024 serve as surrogates for the prior pH and temperature data used in SWQS equations to calculate SWQC for ammonia (see Appendix B).

The SWMP Data Ammonia Nitrogen concentrations range from not detected (ND) to 0.9 mg/L with an average of about 0.1 mg/L. Ammonia Nitrogen concentrations are all below the acute SWQC of 2.4 mg/L and only exceeded the chronic SWQC of 0.54 mg/L in 4 of 201 samples representing a detection frequency above the SWQC of 2%. Three of the 4 exceedances occurred in 1985 or earlier, and one in 2024 at Station 10 at 0.57 mg/L. Ammonia Nitrogen concentrations at Stations 1 through 7 exhibit statistically significant decreasing trends ($p<0.05$).

<u>Total Kjeldahl Nitrogen (TKN)</u>

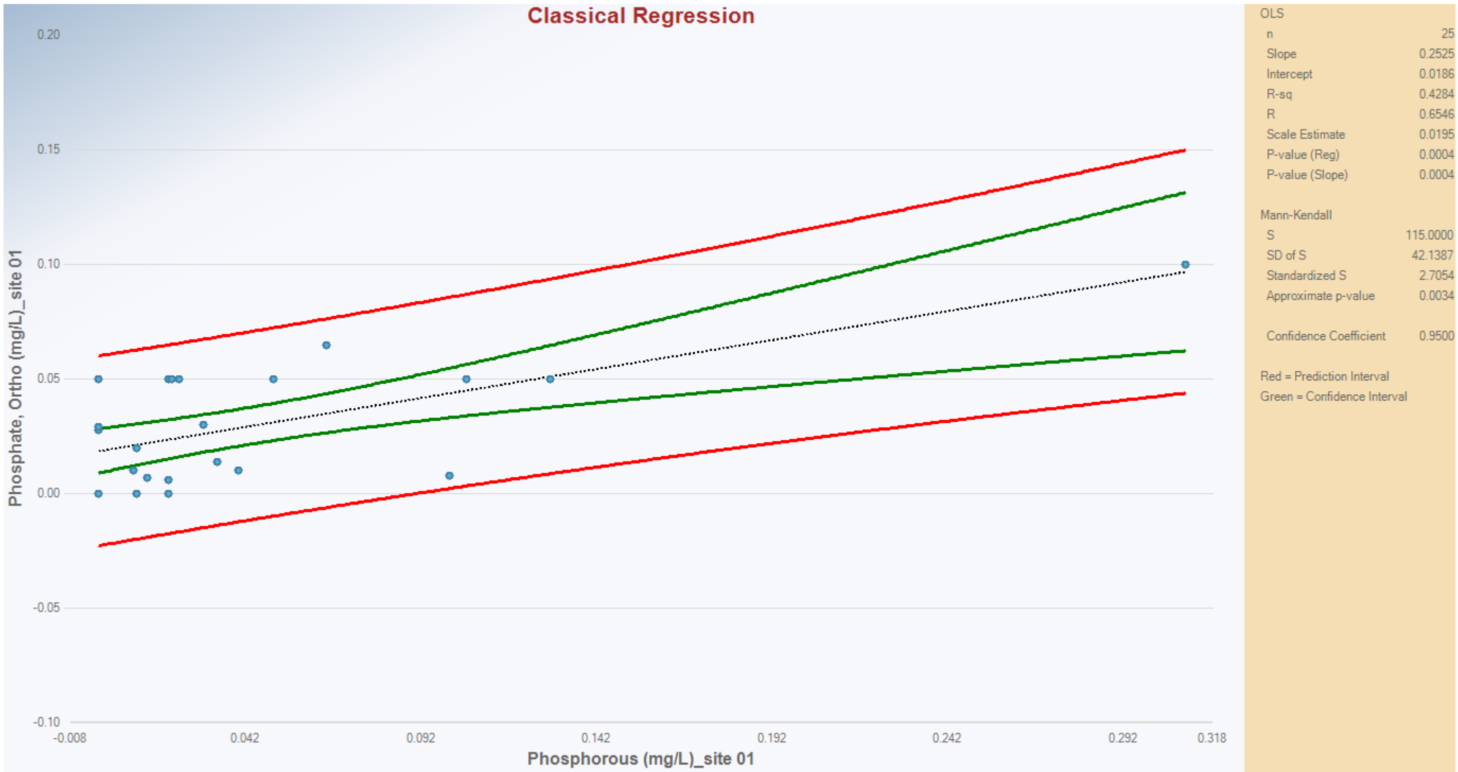
As noted above, TKN represents the combined forms of inorganic and organic nitrogen combined. From the overview of SWMP Data in Section 2 above, concentrations of the inorganic components of TKN (i.e., nitrate and nitrite) in surface water samples are well below their respective SWQC and SLs of 10 mg/L and 1 mg/L, respectively. Based on the trend analysis noted above, concentrations of nitrate and nitrite are mostly stable at all Stations, other than statistically significant decreasing nitrate concentrations observed over time at Stations 1 and 2.

The TKN concentrations measured in 200 surface water samples range from not detected (ND) to 21 mg/L with an average of about 0.64 mg/L. However, as noted previously, TKN was detected at 21 mg/L in the October 2024 sample from Site 2, which is more than an order of magnitude above the highest TKN concentration previously reported for Site 2 (i.e., 1.55 mg/L). The laboratory report indicates the sample required dilution to complete the TKN analysis for Site 2 only, and no other samples required such dilution. The TKN value of 21 mg/L is an outlier due to the need for dilution by the laboratory and based on comparison to the historical TKN concentrations for both Site 2 and the entire SWMP data set. Removing the 21 mg/L value from the data as an outlier is warranted since it is not representative of the water quality at Site 2 based on the robust historical data set. The TKN data otherwise are all well below the SL of 6 mg/L. The 95UCLs for TKN range from about 0.52 mg/L to 1.03 mg/L. The SWQS do not include SWQC for TKN and, absent the one noted outlier, all TKN concentrations are below the SL of 6 mg/L. Long-term trend analysis indicates the TKN concentrations are stable and do not exhibit statistically significant trends.

2.3.5 Orthophosphate and Phosphorus

Phosphorus is a naturally occurring element in rock and soil that is an important food chain nutrient and a limiting nutrient in surface water that can cause eutrophication at high concentrations.

The SWMP Parameters include analysis of Total Phosphorus and Orthophosphate. Total Phosphorus, reported as "Phosphorus", includes all forms of phosphorus including organic phosphorus and inorganic phosphorus, such as Orthophosphate, which is an inorganic, available form of phosphate. Although the SWQS include a SWQC for Phosphorus and not for Orthophosphate, theoretically, the latter is captured by the analysis of Phosphorus. This relationship is demonstrated with statistical correlation and hypothesis tests comparing all the SWMP Phosphorus and Orthophosphate concentrations for Stations 1 through 9 (Station 10 excluded due to small sample size). The concentrations of Orthophosphate from all Stations 1 through 9 are generally lower than the Phosphorus concentrations, but differences are not statistically significant (WMW test; $P>0.05$). Also, Phosphorus and Orthophosphate concentrations from all 9 Stations exhibit a statistically significant correlation (OLS regression; $p<0.05$), as shown below in the example regression graph for Site 1 (see Appendix E).



Phosphorus concentrations in the SWMP Data range from not detected (ND) to 0.54 mg/L with an average of about 0.05 mg/L. Phosphorus only exceeded the SWQC of 0.1 mg/L in 13 of 200 samples representing a detection frequency above the SWQC of 6.5%. However, this frequency may be artificially inflated since 10 of the 16 “exceedances” appear to be entered as reporting limits and not actual detected concentrations, as the same exact value is entered for Phosphorus for all Stations in 2020. Thus, the number of exceedances is likely much lower. The remaining 6 exceedances were reported for sampling dates in 2003 and earlier, and other than the 2020 data, all Phosphorus concentrations after 2003 are below the SWQC of 0.1 mg/L. The 95UCLs for Phosphorus range from about 0.06 mg/L to 0.13 mg/L. However, the latter 95UCL is likely exaggerated due to the apparent use of the reporting limit for 2020 data as noted above.

There are no SWQC for orthophosphate; a SL of 0.1 mg/L consistent with the SWQC for phosphorus was adopted for this evaluation. Orthophosphate concentrations range from not detected (ND) to 0.1 mg/L with an average of about 0.03 mg/L, below the SL of 0.1 mg/L. The 95UCLs for Orthophosphate range from about 0.03 mg/L to 0.05 mg/L. Based on the results of this review and the statistical analysis noted above, the Orthophosphate data corroborates the findings above regarding the relatively low frequency of exceedances.

Phosphate and/or Orthophosphate concentrations at Stations 1, 2, 3, 4, 7 exhibit statistically significant decreasing trends ($p<0.05$), and otherwise phosphate and orthophosphate exhibit stable concentrations at most other Stations.

2.3.6 Specific Conductivity and Total Dissolved Solids (TDS)

Specific Conductivity is the measure of electrical current that will pass through water, which increases with the kinds and amounts of dissolved substances in water. Thus, Specific Conductivity is a function of the TDS in water and these parameters are commonly linked together.

Specific Conductivity was detected in all 209 SWMP Samples ranging from 63.4 to 642 umhos/cm with an average of 196 umhos/cm. Six samples exhibit Specific Conductivity above the SL of 500 umhos/cm, all of which were obtained from Stations 7 and 9 on Paulins Kill. The 95UCLs for Specific Conductivity range from about 118 to 554 umhos/cm. There is no SWQC for Specific Conductivity and the frequency of detection above the SL (6/209) is about 3%. Evidence of statistically significant increasing trends was identified for Specific Conductivity at Stations 5 and 6 ($p<0.05$). However, the Specific Conductivity measurements at these two Stations are well below the SL.

TDS was only analyzed for 9 samples obtained from Sites 1 through 9 in 2022, and for 10 samples from Sites 1 through 10 in 2024 (total n = 19). The TDS concentrations range from approximately 48 ppm to 360 ppm with an average of 137. The SWQC for TDS require establishing background and comparison to results of whole effluent toxicity test data, which are not available and are beyond the scope of this report. In addition, further evaluation of TDS may not be warranted due to the generally low concentrations of TDS. Due to the limited number of SWMP sample events (i.e., two events in 2022 and 2024), TDS data are too few and too recent for evaluation of a long-term baseline concentration for TDS for each Station.

TDS can be roughly estimated from Specific Conductivity using the equation:

Specific Conductivity*0.65 = TDSsc

Where,

- Specific Conductivity is in (umohs/cm; aka uS/cm)
- TDSsc is in mg/L

Paired Specific conductivity and TDS data from the 2022 and 2024 sampling events were further evaluated using statistical analysis for evidence of correlation and the potential to estimate historical TDS concentrations from Specific Conductivity data. Using the above equation, the Specific Conductivity data from 2022 and 2024 were converted to TDS (TDSsc) and compared to the coincident TDS data from 2022 and 2024. The results of the statistical analysis indicate a statistically significant correlation between the Specific Conductivity data and TDS data (R^2= 0.97; $p<0.05$), and TDS data are not statistically different from the data converted from Specific Conductivity results (TDSsc) (hypothesis t-test; P=0.3) (Appendix E).

2.3.7 Total Suspended Solids (TSS)

TSS concentrations range from not detected (ND) to 65 mg/L, with an average TSS concentration of 4.2. TSS was detected above the lower SWQCs of 25 mg/L in four of 201 samples (2%), 3 of which were also above the upper SWQC of 40 mg/L (1.5%). The 95UCLs for TSS range from about 2.8 to 16.9 mg/L, below the more stringent SWQC of 25 mg/L. All samples with elevated TSS concentrations were obtained from Stations 1, 5, and 8 during 1993 through 2012, and TSS concentrations after 2012 are within the SWQC. TSS concentrations at Stations 2,3, 4 and 6 exhibit statistically significant decreasing trends ($p<0.05$), and otherwise concentrations are stable.

3.0 Laboratory Data Usability and Limitations

There are several data quality issues that should be noted as they potentially impact data usability, especially for comparison to the SWQC and screening levels.

The SWMP did not include a quality assurance project plan (QAPP) and Data Quality Objectives (DQO's) were not defined. Based on the data quality issues described below there is some uncertainty regarding accuracy associated with the SWMP Data. Therefore, use of the SWMP for determining strict compliance with SWQC is not appropriate. However, comparison of the SWMP Data to the SWCS as a screening tool, rather than for determining compliance with SWQC, is informative. The general consistency of the sampling frequencies, methods, and Stations over such a long time (i.e., 40 years) promotes good precision and relative long-term reliability for most parameters. Reasonable uses of the SWMP data include, but are not limited to, statistical analysis, , trend analysis, establishing long-term baseline averages, projections, and informing future studies and sampling programs, and comparison to other data sets collected by others (e.g., NJDEP, local and regional lake associations, etc.).

The stream flow conditions were not recorded and are not available for the SWMP Sample dates, which limits the ability to confirm consistency with SWQS and SWQC that require consideration of stream flow rate for use (e.g., statistical low-flow conditions).

Pursuant to the NJDEP regulations (NJAC7:18), temperature and pH are "analyze-immediately" parameters, meaning they should be measured in the field at the sampling site within 15 minutes of sample collection. However, the SWMP Sample temperature and pH were measured at the laboratory up to several days after sample collection. For example, the laboratory analysis report for the SWMP Samples collected in 2022 indicates temperature and pH were measured 5 to 6 days after sample collection. Thus, the reported temperature values likely represent laboratory room temperature and not the actual surface water in-stream conditions at the time of sampling and are qualified as not usable. Temperature data were not included in this report. The pH data are included and, while qualified due to the lag-time from sample collection to time of measurement, pH data are acceptable for screening level evaluation. Significant pH changes in Samples maintained by the laboratory are not likely, especially for clean water samples and due to the buffering capacity of natural water against shifts in pH (i.e., alkalinity). Therefore, the pH data are deemed usable for qualified data quality objectives as screening data.

As noted earlier in this report, the SWQS require calculation of Site-specific SWQC for ammonia in freshwater bodies using sample pH and temperature. The ammonia nitrogen data are not strictly useable for determining compliance with SWQC because sample pH and temperature measurements were not obtained by a NJ certified laboratory immediately at the time of sampling. However, as noted in the discussion of the ammonia data earlier in this report, ammonia SW SLs were estimated using pH and temperature values measured in the field during the October 16, 2024 sampling event as a conservative surrogate to represent reasonable worst case conditions regarding the evaluation of ammonia concentrations for this review.

The SWMP lead data are not strictly comparable to the aquatic life protection criteria (i.e., acute and chronic SWQC) because they represent total recoverable lead concentrations, and the SWMP Samples were not analyzed for dissolved lead. The SWQC for lead include aquatic life protection criteria (acute at 0.038 mg/L and chronic at 0.0054 mg/L) that are comparable to dissolved lead concentrations, and human health criteria are comparable to total recoverable lead concentrations. Further, simple comparison of the SWMP lead data to the human health SWQC for lead is not appropriate due to the consideration of human exposure scenarios assumed in the development of the SWQC (e.g., Primary Contact Recreation [see definition in Section 1]), which may not comport with realistic use/exposure scenarios for many of the Stations due to the physical conditions (e.g., small stream size, accessibility, etc.). Therefore, comparison of the lead data from the SWMP to the acute and chronic SWQC is very conservative.

4.0 Comparison of SWMP Data with Other Data Sources

During the preparation of this report, other sources of biological and chemical data were identified outside the SWMP Data. Most notably, the NJDEP's Water Quality Data Exchange (WQDE) includes chemistry data from surface water sampling conducted within Stillwater at several locations nearly co-located with some of the SWMP Stations and for some of the same parameters. The WQDE data represent only a few samples collected during the period from 2012 to 2018. The WQDE data are sparse and do not represent a robust data set, i.e., there are too few data to perform statistical analysis. Although a detailed comparison is beyond the scope of this report, the values reported in the WQDE for water chemistry parameters are consistent with the SWMP data (NJGeoWeb – see Appendix F).

Another source of water quality information is NJDEP's NJ Integrated Water Quality Assessment Report 2022 and related NJGeoWeb database: https://dep.nj.gov/wms/bears/integrated-wq-assessment-report-2022/#surface-water-quality-standards

Other sources of data may be available from various NGOs and lake associations that are potential sources of additional water quality data for Stillwater and the vicinity.

5.0 Conclusions and Recommendations

5.1 Conclusions

Most of the surface water bodies in the Township are classified as Category 1 (C1) waters and many are identified as either FW2 Trout Maintenance (TM) or Trout Production (TP) in the SWQS. Thus, in addition to having to meet numerical criteria for FW2 waters, the C1 designation ascribes more stringent requirements including application of anti-degradation and “no measurable change” policies of the SWQS.

While some large areas are used for agriculture, there are no major industrial sites and very few NJDEP Known Contaminated Sites or contaminated areas, with none identified in the immediate vicinity of the SWMP Sample Stations, as indicated by NJGeoWeb map information. Demographic and land use NJGeoWeb mapping also indicate a relatively low population density and low amount of development over large portions of the Township. These conditions generally facilitate good water quality.

The large number of samples and consistency in collection frequency and quality (i.e., analysis performed by NJDEP Certified Laboratories) support robust statistical analysis of the SWMP Data.

The analytical data collected from the SWMP indicate the overall water quality is good among the 10 Sample Stations, and the SWMP data appear to generally comport with data from the NJDEP WQDE for similar parameters at 3 locations. However, E. *coli* represents a potential concern at limited Stations, which may be considered for future evaluation.

5.2 Recommendations

The following recommendations are provided based on the review of the SWMP analytical data above in the prior sections of this report.

<u>Preliminary recommendations:</u>

- Revisions to SWMP Data Quality and Analytical Methods
    - Update Analytical Parameters and Methods
    - Establish Data Quality Objectives (DQOs), Data Use and Reporting
    - Use of Field Meters for Analyze-Immediately Parameters
    - Standardize Data Documentation and Curation

- Review of SWMP Objectives
    - Consider Establishing C1 Benchmarks for future data comparative analysis
    - Compare SWMP Data with other data sources (e.g., NJDEP Data, NGO Data)
    - Collaborate with adjacent and nexus communities and NGOs
    - Revise Sample Collection Frequency
    - Consider Focused Short-term Investigations
    - Evaluate Seasonal Variability
    - Consider Additional Parameters

Other considerations for future study:

- Surface water salinity survey in waterways downstream and adjacent to roadways treated with salt during winter months.
- Survey for the presence/absence of herbicides/pesticides in waterways downstream and adjacent to agricultural land.
- To promote data usability and to avoid the potential for rejection of data due to poor data quality, any future sampling should incorporate field analysis for analyze-immediately parameters (DO, pH, temperature) using properly calibrated instruments in accordance with substantive requirements of the NJDEP Certified Laboratory regulations (NJAC 7:18).
- Lakes water quality survey.
- Mapping locations along surface waterways with risk of Septic system discharges.
- Design and implement periodic SWMP to evaluate/document conformance with SWQS goals and objectives. For example, five-year updates to compare against established baseline water quality, Repeat rapid bio-assessment study.
- Toxic Algal Blooms evaluation.
- Survey of high-risk areas for Stormwater runoff impacts.
- Citizens Science and Environmental education initiatives to raise awareness about local watersheds, land use, and water quality.

6.0 References

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