Amendment to the
Sussex County Water Quality Management Plan

Total Maximum Daily Load
to Address Arsenic in the
Wallkill River and Papakating Creek
Northwest Water Region

Watershed Management Area 2
(Wallkill River, and Pochuck, Papakating, Rutgers Creeks Watersheds)

Proposed: July 19, 2004
Established: September 23, 2004
Approved (by EPA Region 2): September 29, 2004
Adopted:

New Jersey Department of Environmental Protection
Division of Watershed Management
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1.0 Executive Summary

In accordance with Section 305(b) of the Federal Clean Water Act (CWA), the State of New Jersey developed the proposed 2004 *Integrated List of Waterbodies* (36 N.J.R. 1238(b), March 1, 2004) addressing the overall water quality of the State's waters and identifying impaired waterbodies for which Total Maximum Daily Loads (TMDLs) may be necessary. The proposed 2004 *Integrated List of Waterbodies* identified five stream segments in the Wallkill River Watershed and one in the Papakating Creek Watershed as being impaired for arsenic, as indicated by elevated arsenic levels. This report, developed by the New Jersey Department of Environmental Protection (Department), establishes six TMDLs for arsenic in the Wallkill River and Papakating Creek watersheds located in Sussex County, Watershed Management Area (WMA) 2. The impaired segments are identified in Table 1 and depicted in Figure 1.

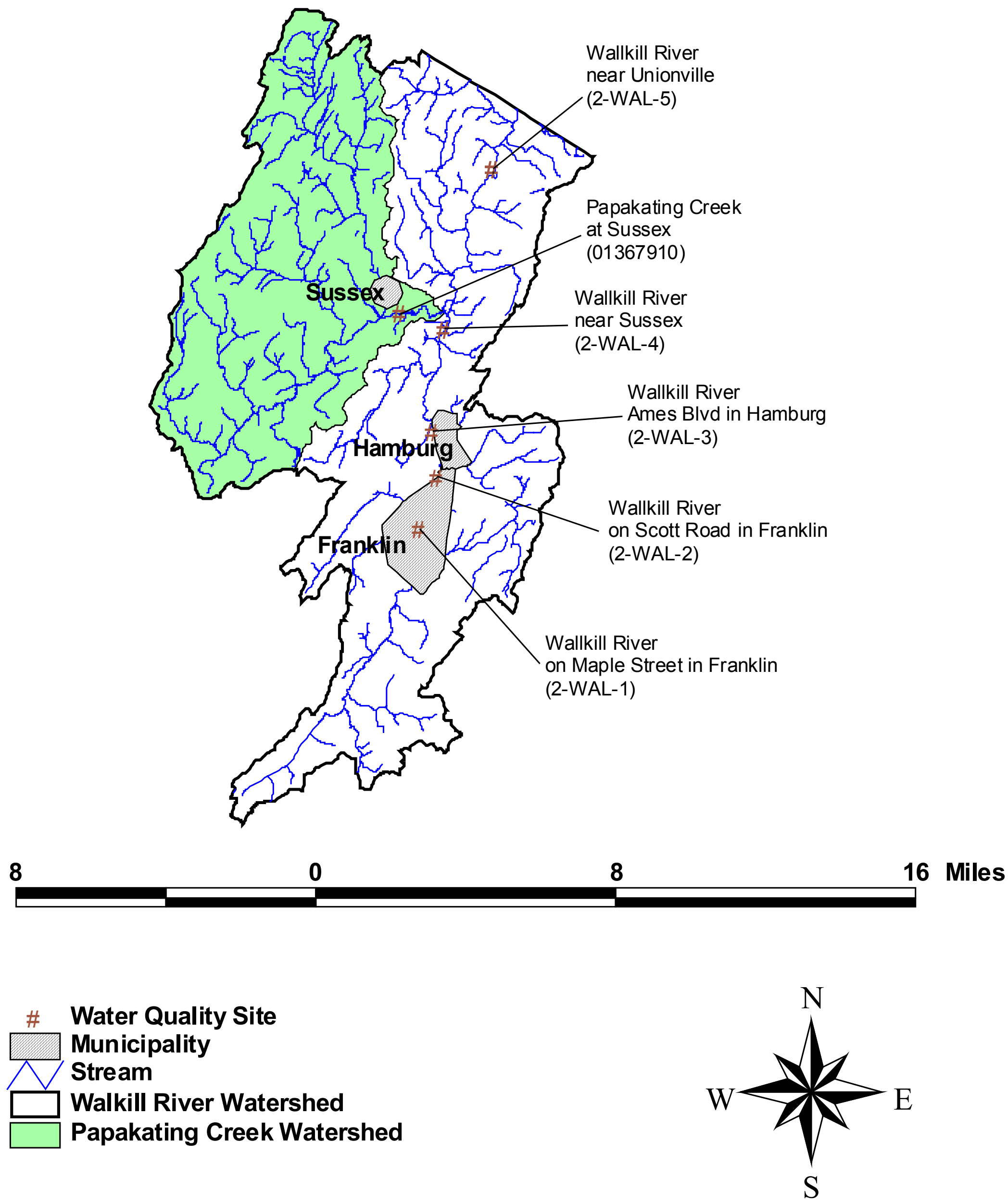
Table 1. Locations of Wallkill River and Papakating Creek TMDLs

Station Name/Waterbody	Site ID #s
Wallkill River near Franklin	01367700, Wallkill C, 2-WAL-1
Wallkill River at Scott Road in Franklin	01367715, Wallkill D, 2-WAL-2
Wallkill River at Route 94 in Hamburg	01367729, 2-WAL-3
Wallkill River near Sussex	01367770, 2-WAL-4
Wallkill River near Unionville	01368000, Wallkill E, 2-WAL-5
Papakating Creek at Sussex	01367910, 01367909, 2-PAP-1

In the 2002 *Integrated List of Waterbodies* (35 N.J.R. 470(a), January 21, 2003), the Department identified five arsenic impairments in the Wallkill River and one in the Papakating Creek. Four of these impaired segments were also previously listed on the 1998 303(d) list. All six of the impaired segments continue to be listed on the proposed 2004 *Integrated List of Waterbodies*. The six segments were listed based on arsenic data collected through the Department's ambient stream monitoring network at eight stations since the late 1970s. The 2002 listings were also based on the 1998 303(d) Evaluation Monitoring. The 303(d) Evaluation Monitoring, also called 303(d) Reconnaissance Monitoring, was initiated in 1998 to provide high quality, current data using clean methods for total recoverable and dissolved metals in waterbodies included on the 1998 303(d) List as impaired for metals.

Figure 1. **Locations of Impaired Monitoring Stations for the Wallkill River and Papakating Creek Watersheds**

Wallkill River and Papakating Creek Arsenic Monitoring Sites



A TMDL is developed to identify all the contributors of a pollutant of concern and load reductions necessary to meet the Surface Water Quality Standards (SWQS) relative to that pollutant. The pollutant of concern for these TMDLs is arsenic. Several possible contributing causes to arsenic impairment have been identifed in this report, they are: leaching of naturally occurring mineralogy; legacy effects of mining operations; and agricultural use of pesticides.

This TMDL Report is consistent with EPA's May 20, 2002 guidance document entitled, *Guidelines for Reviewing TMDLs under Existing Regulations Issued in 1992* (Sutfin, 2002), which describes the statutory and regulatory requirements for approvable TMDLs. This TMDL shall be proposed and, upon approval by EPA, adopted by the Department as an amendment to the Northeast Water Quality Management Plan (WQMP) in accordance with N.J.A.C. 7:15-3.4 (g).

2.0 Introduction

This report identifies six locations for TMDLs which address arsenic impairment to the specified waterbodies (Table 1) in the Wallkill River and Papakating Creek Watersheds. New Jersey's proposed 2004 *Integrated List of Waterbodies* identifies six stations on Sublist 5 (also known as the 303(d) list) as being impaired for arsenic. These TMDLs and the associated implementation plan provide the basis for a watershed restoration plan to address arsenic impairments in order to attain the applicable SWQS. The Papakating Creek Watershed was the subject of an April 19, 2004 proposed TMDL for phosphorus; the phosphorus-impaired segments do not overlap with the segments identified in Table 1, which are the subject of these arsenic TMDLs. With respect to the six arsenic impairments addressed in this TMDL document, these waterbodies will be moved to Sublist 4 following approval of these TMDLs by EPA Region 2.

3.0 Background

In accordance with Section 303(d) of the Federal Clean Water Act (CWA) (33 U.S.C. 1315(B)), the State of New Jersey is required biennially to prepare and submit to the USEPA a report that identifies waters that do not meet or are not expected to meet SWQS after implementation of technology-based effluent limitations or other required controls. This report is commonly referred to as the 303(d) List. In accordance with Section 305(b) of the CWA, the State of New Jersey is also required biennially to prepare and submit to the USEPA a report addressing the overall water quality of the State's waters. This report is commonly referred to as the 305(b) Report or the Water Quality Inventory Report.

In November 2001, EPA issued guidance that encouraged states to integrate the 305(b) Report and the 303(d) List into one report. Following USEPA's guidance, the

Department chose to develop an Integrated Report for New Jersey and has adopted the *2002 Integrated List of Waterbodies* and proposed the *2004 Integrated List of Waterbodies.*

The *Integrated List of Waterbodies* assigns waterbodies to one of five sublists. Sublists 1 through 4 include waterbodies that are generally unimpaired (Sublist 1 and 2), have limited assessment or data availability (Sublist 3), are impaired due to pollution rather than pollutants or have had a TMDL approved by EPA (Sublist 4). Sublist 5 constitutes the traditional 303(d) list for waters impaired or threatened by one or more pollutants, for which a TMDL may be required.

A TMDL represents the assimilative or carrying capacity of a waterbody, taking into consideration point and nonpoint sources of pollutants of concern, natural background and surface water withdrawals. A TMDL quantifies the amount of a pollutant a water body can assimilate without violating a state's water quality standards and allocates that load capacity to known point and nonpoint sources in the form of waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and a margin of safety (MOS).

Recent EPA guidance (Sutfin, 2002) describes the statutory and regulatory requirements for approvable TMDLs, as well as additional information generally needed for EPA to determine if a submitted TMDL fulfills the legal requirements for approval under Section 303(d) and EPA regulations. The Department believes that the TMDLs in this report address the following items in the May 20, 2002 guideline document:

1. Identification of waterbody(ies), pollutant of concern, pollutant sources and priority ranking.
2. Description of applicable water quality standards and numeric water quality target(s).
3. Loading capacity – linking water quality and pollutant sources.
4. Load allocations.
5. Wasteload allocations.
6. Margin of safety.
7. Seasonal variation.
8. Reasonable assurances.
9. Monitoring plan to track TMDL effectiveness.
10. Implementation (USEPA is not required to and does not approve TMDL implementation plans).
11. Public Participation.

4.0 Pollutant of Concern and Area of Interest

Pollutant of Concern

The pollutant of concern for these TMDLs is arsenic. Arsenic levels in segments of the Wallkill River and Papakating Creek Watersheds have been found to exceed New Jersey's SWQS at N.J.A.C. 7-9B et seq., as reported in the 1998 303(d) list, 2002 *Integrated List of Waterbodies* and the proposed 2004 *Integrated List of Waterbodies.* Table 2 and Figure 2 depict the spatial extent of the arsenic impairments. All of the listed impairments have a high priority ranking, as described in the proposed *2004 Integrated List of Waterbodies*.

Table 2. Arsenic Impaired Stream Segments in the Wallkill River and Papakating Creek Watersheds, Identified in the Proposed 2004 Integrated List of Waterbodies, for which Arsenic TMDLs are being Established

Site ID	Sublist	Site Location and Waterbody/General Description	Approx. Mile
2-PAP-1	5	Papakating Creek At Sussex, on Route 23 near Lower Unionville. Extends upstream to confluence with Clove Brook and downstream to confluence with Wallkill River	2.7
2-WAL-1	5	Wallkill River near Franklin, Maple Street downstream of Franklin Pond. Extends upstream and downstream to the first confluence of tributary	1.6
2-WAL-2	5	Wallkill River at Franklin, on Davis Road near Scott Road. Extends upstream and downstream to the first confluence of tributary	2.2
2-WAL-3	5	Wallkill River on Ames Blvd (Rte 94), Hamburg. Extends upstream and downstream to the first confluence of tributary	3.5
2-WAL-4	5	Wallkill River near Sussex, on Glenwood Road off Route 23. Extends upstream to confluence with Beaver Run and downstream to confluence with Papakating Creek.	2.1
2-WAL-5	5	Wallkill River near Unionville, on Bassets & Owen Station Roads. Extends upstream to confluence with Papakating Creek and downstream to the border of NJ and NY.	7.8
		Total River Miles =	**19.9**

Approximately 19.9 total river miles are impaired for arsenic in the Wallkill River and Papakating Creek watersheds. Therefore, approximately 48.8% of the Wallkill River Watershed, excluding the Papakating Watershed, is impaired for arsenic and approximately 21.9% of the Papakating Creek watershed is impaired. However since implementation plans for these TMDLs cover entire watersheds, more river miles are addressed under these TMDLs than are actually listed as being impaired for arsenic.

Thus, these TMDLs will provide a comprehensive response to arsenic impairment in both watersheds.

Figure 2a. Spatial Extent of Impaired Segments for Which TMDLs Are Being Developed

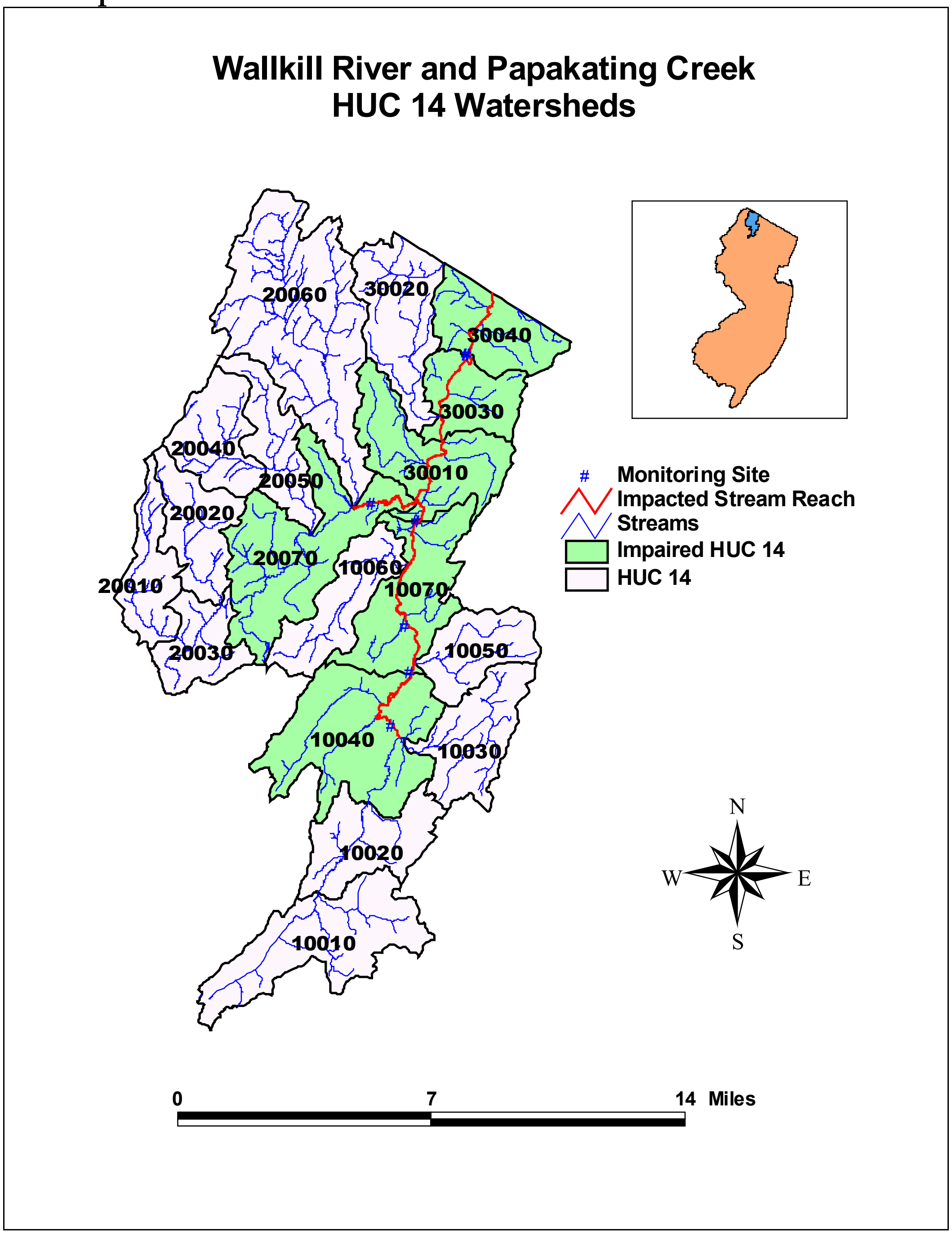
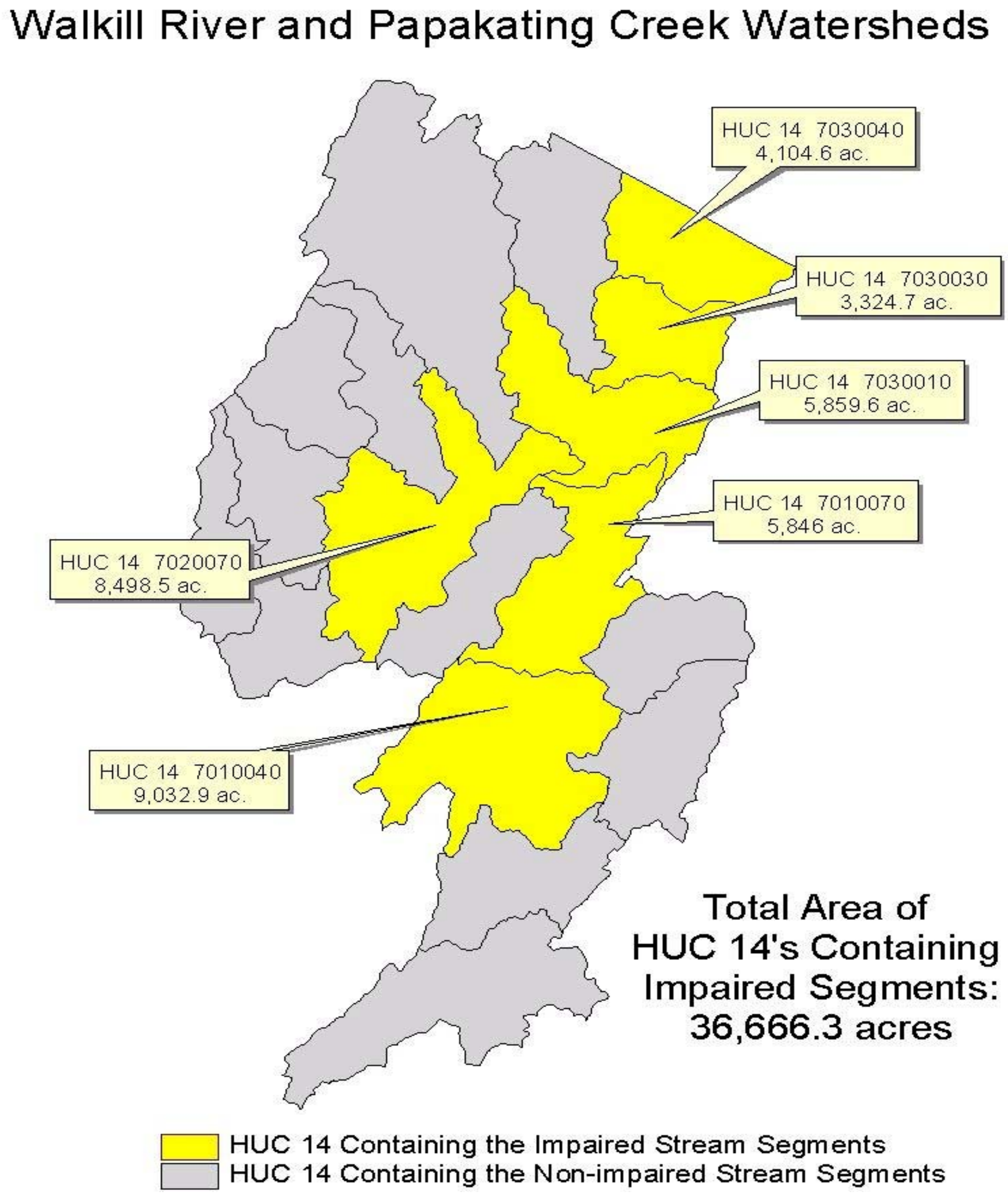


Figure 2b



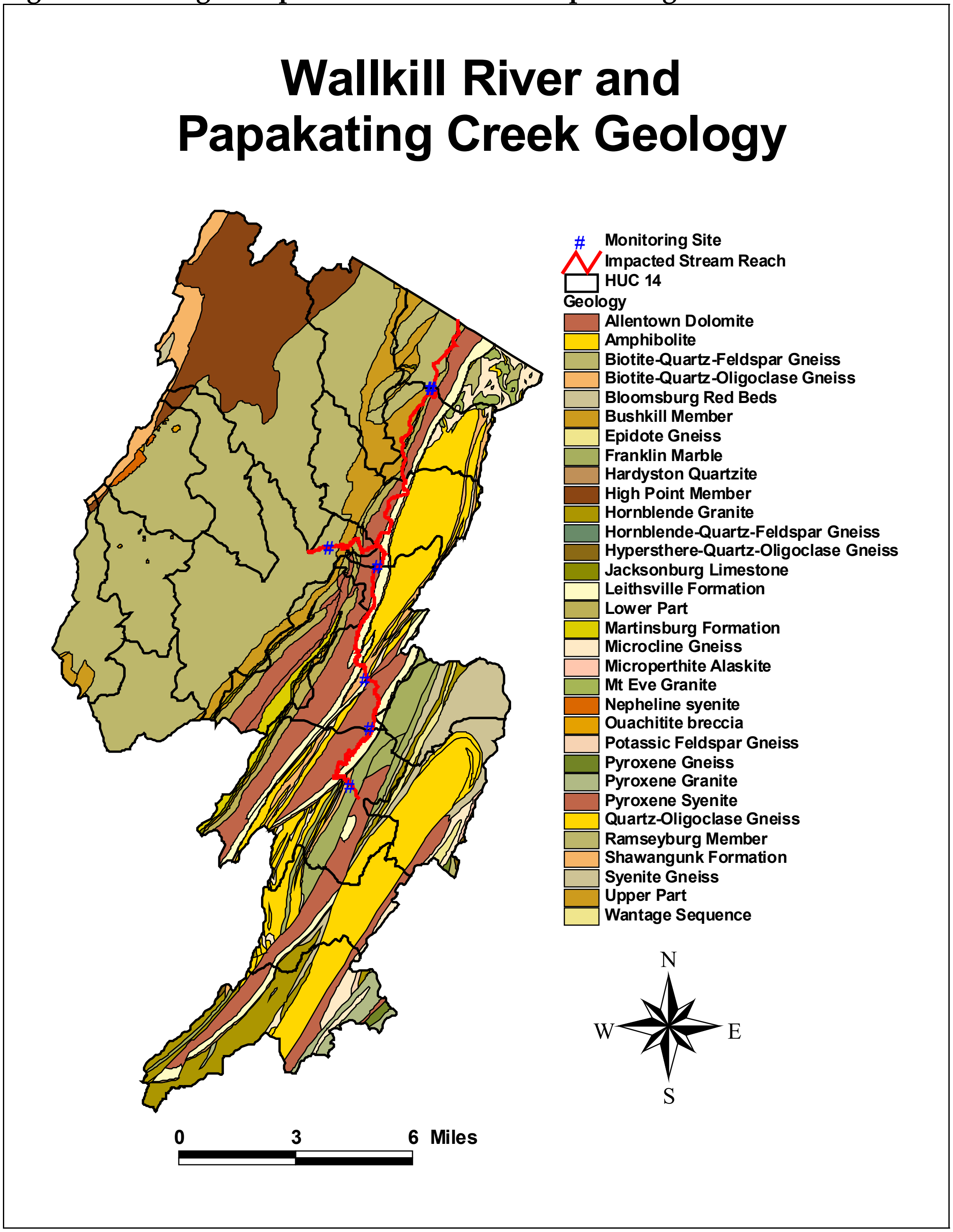
Geology of the Wallkill Basin

The majority of the Wallkill Basin is located in the Appalachian Valley and Ridge physiographic province of New Jersey; the remainder is in the Highlands Province portion of the Reading Prong. In general, the rock strata date from the Precambrian age to late Paleozoic and are comprised primarily of limestone, argillite and gneissic Precambrian facies. The Wallkill River Watershed was impacted by at least 3 periods of glaciation, which is evidenced by characteristic glacial till and drift deposits as well as glacial scouring and glacial features.

In the Valley and Ridge Province, the erosion of less resistant limestone, dolomite and shale deposits created valleys from 400 to 600 feet above sea level. The harder quartzite and conglomerate beds containing quartz, feldspar, gneiss and shale remain as the higher altitude ridges. The most familiar, the Kittatinny Mountain Ridge, is formed from dolomitic limestone and layers of quartz sand. The river valleys are underlain by limestone, shale and siltstone formations. The eastern portion of WMA 2 falls within the Reading Prong portion of the New Jersey Highlands. The rock strata are granite and gneiss with the ridges primarily composed of hard crystalline resistant rock.

Limestone is extremely prevalent within the basin. Limestone is easily eroded by water resulting in many areas with karst topography demonstrated by sinkholes, underground streams and caves. The features generally reflect complicated underground flow systems providing direct conduits for ground water contamination due to stormwater flows, spills, agriculture, septic systems and improper well construction. The presence of limestone also indicates a natural elevated or basic (alkaline) pH.

Figure 3. Geologic Map of the Wallkill and Papakating Watersheds



Description of the Wallkill River Watershed

The Wallkill River Watershed is located in Watershed Management Area 2 (WMA 2) in the northwestern portion of New Jersey (Figure 2). The Wallkill River Watershed encompasses approximately 90.2 sq. mi. and is located in Sussex County in northwestern New Jersey. The headwaters of the Wallkill River originate at Lake Mohawk in Sparta Township. The river drains north along the trace of the Kittatinny Limestone, through Franklin Pond, toward New York State and the Hudson River.

Description of the Papakating Creek Watershed

Also located in WMA 2, this 15 mile long creek runs through north-central Sussex County and flows into the Wallkill River east of Sussex Borough. The Papakating Creek is a tributary to the Wallkill River and enters the river from the west, below and north of Franklin Pond. This watershed is approximately 60.6 square miles in area, and has three major tributaries, which include the West Branch Papakating Creek, the Neepaulakating Creek and Clove Brook. Soils are glacial in origin while the topography in the region ranges from gently rolling in the east to strongly sloping in the west.

Land Use

The predominant land use in the Wallkill River Watershed is undeveloped forest, water and wetlands. Urban land use is the main type of altered land use. The predominant land uses in the Papakating Creek Watershed include forest and woodland, agriculture and urban development. Of the 16,449 acres of forested land, 2850 acres or approximately 17%, of that land is dedicated federal or state open space, which essentially precludes this land from future development pressure.

Figure 2 and Table 3 depict the breakdown of land use per watershed at the hydrologic unit code (HUC) 14 level. HUC delineations are part of a national system for identifying watersheds in a nested fashion that was developed by the United States Geological Survey, the Natural Resources Conservation Service and the EPA. The HUC-11 codes for the Wallkill and Papakating Creek Watersheds are 02020007000, 02020007010, 02020007020 and 02020007030. This delineation can be further subdivided into HUC-14 drainage areas, which are then denoted by the addition of three digits as shown in Table 3 below. HUC 14 watersheds noted with the last 5 numbers of 100##, 200##, and 300## are located on the Wallkill River upstream of the confluence of Papakating Creek, within the Papakating Watershed, and on the Wallkill River downstream of the confluence of Papakating Creek, respectively.

The Papakating Creek Watershed is comprised of seven HUC 14 drainage units. However, only one HUC 14 (02020007020070) is of importance for this TMDL. The shaded rows in the Table 3 depict the impaired segments for both watersheds. Refer to Figure 2 shown previously for delineations of the HUC-14 watersheds that are impaired by arsenic.

Table 3. Wallkill River and Papakating Creek Watersheds 1995-97 Land Use/Land Cover (by HUC 14) Total Area = 96,538 acre (150.8 square miles)

HUC14	Water Quality Stations[1]	Area of Land Use within each HUC14 (acre)					
		Agriculture	Barren	Forest	Urban	Water	Wetlands
7010010		86.2	9.7	3,867.5	1,859.8	993.2	525.5
7010020		192.9	0.7	2,796.7	690.3	98.7	816.5
7010030		3.2		3,333.8	447.2	323.9	481.2
7010040	2-WAL-1, 2-WAL-2	1,685.6	168.3	3,982.6	1,560.1	191.3	1,445.0
7010050		383.0		2,253.4	283.4	72.8	511.5
7010060		1,218.5	50.5	1,973.3	308.5	24.5	568.4
7010070	2-WAL-2, 2-WAL-3, 2-WAL-4	1,136.3	249.6	2,563.0	872.8	56.7	967.6
7020010		1,081.2	4.0	1,503.8	215.4	13.2	443.8
7020020		1,492.7	5.3	1,262.3	336.2	30.0	687.5
7020030		1,530.6	47.4	943.2	181.6	11.2	308.8
7020040		1,189.7	8.7	1,695.1	362.9	21.2	542.4
7020050		1,113.2	1.0	1,536.1	361.6	77.1	452.3
7020060		3,124.4	22.2	6,051.8	1,228.2	198.1	2,216.5
7020070	2-PAP-1	2,588.9	5.7	3,482.1	799.8	165.7	1,456.3
7030010	2-WAL-4	1,488.9	31.2	2,081.6	789.3	125.2	1,343.4
7030020		2,025.5	5.0	1,643.9	244.8	37.2	1,438.7
7030030	2-WAL-5	561.9	3.9	1,187.8	261.6	89.9	1,219.6
7030040	2-WAL-5	672.1	0.5	1,613.6	264.8	49.6	1,504.0
Grand Total		**21,575**	**614**	**43,772**	**11,068**	**2,580**	**16,929**

[1] Water quality monitoring site located within the specified HUC14. Water quality monitoring stations 2-WAL-2, 2-WAL-4, and 2-WAL-5 are located at the intersection of two HUC14s.

Data Sources

The Department's Geographic Information System (GIS) was used extensively to describe the WMA 2 watershed characteristics. In concert with USEPA's November 2001 listing guidance, the Department is using Reach File 3 (RF3) in the 2002 *Integrated List of Waterbodies* to represent rivers and streams. The following is general information regarding the data used to describe the watershed management area:

- Land use/Land cover information was taken from the 1995/1997 Land Use/Land cover Updated for New Jersey DEP, published 12/01/2000 by Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA), delineated by watershed management area.

- 2004 Assessed Rivers coverage, NJDEP, Watershed Assessment Group, unpublished coverage.

- County Boundaries: Published 11/01/1998 by the NJDEP, Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA), "NJDEP County Boundaries for the State of New Jersey." Online at: http://www.state.nj.us/dep/gis/digidownload/zips/statewide/stco.zip

- Detailed stream coverage (RF3) by County: Published 11/01/1998 by the NJDEP, Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA). "Hydrography of Monmouth County, New Jersey (1:24000)." Online at: http://www.state.nj.us/dep/gis/digidownload/zips/strm/

- NJDEP 14 Digit Hydrologic Unit Code delineations (DEPHUC14), published 4/5/2000 by New Jersey Department of Environmental Protection, New Jersey Geological Survey (NJGS) Online at: http://www.state.nj.us/dep/gis/digidownload/zips/statewide/dephuc14.zip

- NJPDES Surface Water Discharges in New Jersey, (1:12,000), published 02/02/2002 by Division of Water Quality (DWQ), Bureau of Point Source Permitting - Region 1 (PSPR1).

- NJDEP Existing Water Quality Stations in New Jersey, published 5/12/2003, NJDEP, Division of Land Use Management (LUM), Water Monitoring and Standards, Bureau of Freshwater Biological Monitoring (BFBM), http://www.state.nj.us/dep/gis/digidownload/zips/statewide/ewqpoi.zip

- NJDEP Ambient Stream Quality Monitoring Sites, published 5/30/2001, NJDEP , Bureau of Freshwater Biological Monitoring (BFBM), http://www.state.nj.us/dep/gis/digidownload/zips/statewide/swpts01.zip

- The spatial extent of impaired segments associated with each monitoring site were established using the methodologies described in the December 2002, *Integrated Water Quality Monitoring and Assessment Methods* report prepared pursuant to Section 303(d) of the Federal Clean Water Act, which can be accessed through the Department's website at http://www.state.nj.us/dep/wmm/sgwet/wat/integratedlist/2004methodsdoc.pdf

5.0 Applicable Surface Water Quality Standards

Arsenic criteria have been established to protect aquatic life and human health. The applicable surface water quality criteria for arsenic under N.J.A.C. 7:9B-1.14(c)12 of the New Jersey Surface Water Quality Standards (SWQS) for the Wallkill River and Papakating Creek Watersheds include:

i. None, either alone or in combination with other substances, in such concentrations as to affect humans or be detrimental to the natural aquatic biota, produce undesirable aquatic life, or which would render the waters unsuitable for the designated uses. (All Classifications)

ii. None which would cause standards for drinking water to be exceeded after appropriate treatment. (FW2 Classification)

iii. Toxic substances shall not be present in concentrations that cause acute or chronic toxicity to aquatic biota, or bioaccumulate within an organism to concentrations that exert a toxic effect on that organism or render it unfit for consumption. (All Classifications)

iv. The concentrations of nonpersistent toxic substances in the State's waters shall not exceed one-twentieth (0.05) of the acute definitive LC_{50} or EC_{50} value, as determined by appropriate bioassays conducted in accordance with N.J.A.C. 7:18.

v. The concentration of persistent toxic substances in the State's waters shall not exceed one-hundreth (0.01) of the acute definitive LC_{50} or EC_{50} as determined by appropriate bioassys conducted in accordance with N.J.A.C. 7:18.

N.J.A.C. 7:9B-1.14(c)13.ix. presents the numerical criteria for all Fresh Water 2 (FW2) waters:

Arsenic (ug/l, Total Recoverable):

(1) 0.0170 (hc)

Criteria followed by an (hc) are carcinogenic effect-based human health criteria as a 70-year average with no frequency of exceedance at or above the design flow specified in section N.J.A.C. 7:9B-1.5(c)2 and are based on a risk level of one-in-one-million.

The impaired segments covered under this TMDL are all classified FW2. The designated uses, both existing and potential, that have been established by the Department for such waters are as stated below:

In all FW2 waters, the designated uses are (N.J.A.C. 7:9B-1.12):

1. Maintenance, migration and propagation of the natural and established aquatic biota;
2. Primary and secondary contact recreation;
3. Industrial and agricultural water supply;
4. 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
5. Any other reasonable uses.

6.0 Water Quality Data and Source Assessment

Water Quality Data

The six segments were listed based on arsenic data collected through the ambient stream monitoring network at eight stations since the late 1970s (see Table 4 and Appendix D). The 2002 listings were also based on the 1998 303(d) Evaluation Monitoring. The 303(d) Evaluation Monitoring, also called 303(d) Reconnaissance Monitoring, was initiated in 1998 to provide high quality, current data regarding concentrations of total recoverable and dissolved metals in waterbodies included on the 1998 303(d) List for metals. Sites were sampled three times during stable baseflow, often for three consecutive days. All sites in a Watershed Management Area were sampled on the same day. Total recoverable and dissolved fraction metals samples were collected using modified Clean Methods techniques. Sediment samples were also collected as part of this program.

Table 4. Water Quality Monitoring Sites and Data Supporting Arsenic TMDLs. Microgram per liter = µg/l; cubic feet per second = cfs; and Estimated value = E.

Station Name	Station #	Average Total Recoverable Arsenic (µg/l)	Sampling Period	Sampling Count	Drainage Area (mi^2)[1]	75% Flow Duration (cfs)[2]
Walkill River near Franklin	01367700 (WAL-1)	4.10	10/79-7/99	18	29.4	11.3E
Walkill River at Scott Rd in Franklin	01367715 (WAL-2)	4.34	7/99-8/01	5	40.6	15.7E
Walkill River at Rt 94 in Hamburg	01367729 (WAL-3)	1.40	7/13/99-7/15/99	3	43E	16.6E

Walkill River near Sussex	01367770 (WAL-4)	2.15	9/78-8/00	26	60.8	23.4E
Walkill River near Unionville	01368000 (WAL-5)	1.46	6/76-8/02	18	140	54.0
Papakating Creek at Sussex	01367910	1.19	10/77-7/99	26	58E	22.4E

[1] U.S. Geological Survey, "Low-Flow Characteristics and Flow Duration of New Jersey Streams," U.S. Geological Survey Open-File Report 81-1110. Estimated drainage areas were derived from Geographic Information System data.
[2] Estimated flow values were calculated using a weighted drainage area.

Source Assessment

Based on an analysis of land use and stream hydrography, several potential sources of arsenic have been identified, all of which are nonpoint in nature. Sources may include leaching of naturally occurring mineralogy; legacy effects of mining operations; and agricultural use of pesticides.

Point Sources

Potential point sources were considered and determined not to be sources of arsenic. There are a total of 11 individual NJPDES-permitted discharges to surface water (DSWs) that discharge either directly into the Papakating Creek and Wallkill River mainstem or one of its tributaries. Figure 4 depicts the impaired sites and associated DSWs.

None of the discharges is required to monitor for arsenic in the effluent. Per routine, in order to determine sludge disposal suitability, the municipal dischargers do have a requirement to monitor for arsenic in residuals. Wastewater characterization reports were completed for the Sussex-Wallkill STP and the Sparta High School STPs. No arsenic was detected in the effluent. It is assumed that any arsenic present is removed in the treatment process. However, it should be noted that the detection limit is considerably higher than the SWQS for arsenic. Table 5 lists the treatment works that discharge to surface waters in both watersheds.

Table 5. Treatment Works that Discharge to Surface Waters in the Wallkill River and Papakating Creek Watersheds

Facility Name	NJPDES #	Outfall Location	Antideg Designation of receiving waters	Trout Designation of receiving waters	Monitors for Arsenic as a permit requirement
Ames Rubber Corp.	0085561	Wallkill R. via wetlands	C2	NT	No
Ames Rubber Corp.	0000141	Wallkill R. via ditch	C2	NT	No
County Concrete	0119130	Papakating Creek via storm sewer	C2	NT	No
Sussex County MUA-Upper Wallkill	0053350	Wallkill River	C2	NT	Yes
Accurate Forming Division	0002275	Wallkill River	C2	NT	No
Southdown Inc.	0035564	Wallkill River	C2	NT	No
Sparta Township High School	0027073 0027081	Wallkill R. via unnamed tributary	C2	NT	Yes
Tri-County Water Cond. Co.	0033472	Wallkill River	C2	NT	No
Sparta Plaza	0027057	Wallkill River via unnamed tributary	C2	NT	Yes
Morris Lake WTP	0136603	Morris Lake	C2	NT	Application Pending
Regency at Sussex Apts.	0029041	Wallkill River via Layton Road Brook	C2	NT	Yes
Highpoint Regional HS	0031585	Papakating Creek	C2	NT	Yes

IMI = Industrial Minor
IMJ = Industrial Major
MMI = Municipal Minor

Stormwater discharges permitted through NJPDES are also considered point sources. The Department does not yet have the data to actually delineate the drainage area subject to NJPDES regulation. Instead, land use can be used to estimate areas that are regulated. It is assumed that residential, urban, commercial and industrial land uses are likely to be served by MS4s. These land uses are not expected to generate arsenic loads, based on the source assessment to date. Therefore, stormwater point sources are deemed negligible. This demarcation based on land use source categories is not perfect, but it represents the best estimate defined as narrowly as data allow.

Figure 4. Discharges to Surface Water within the Wallkill River Watershed

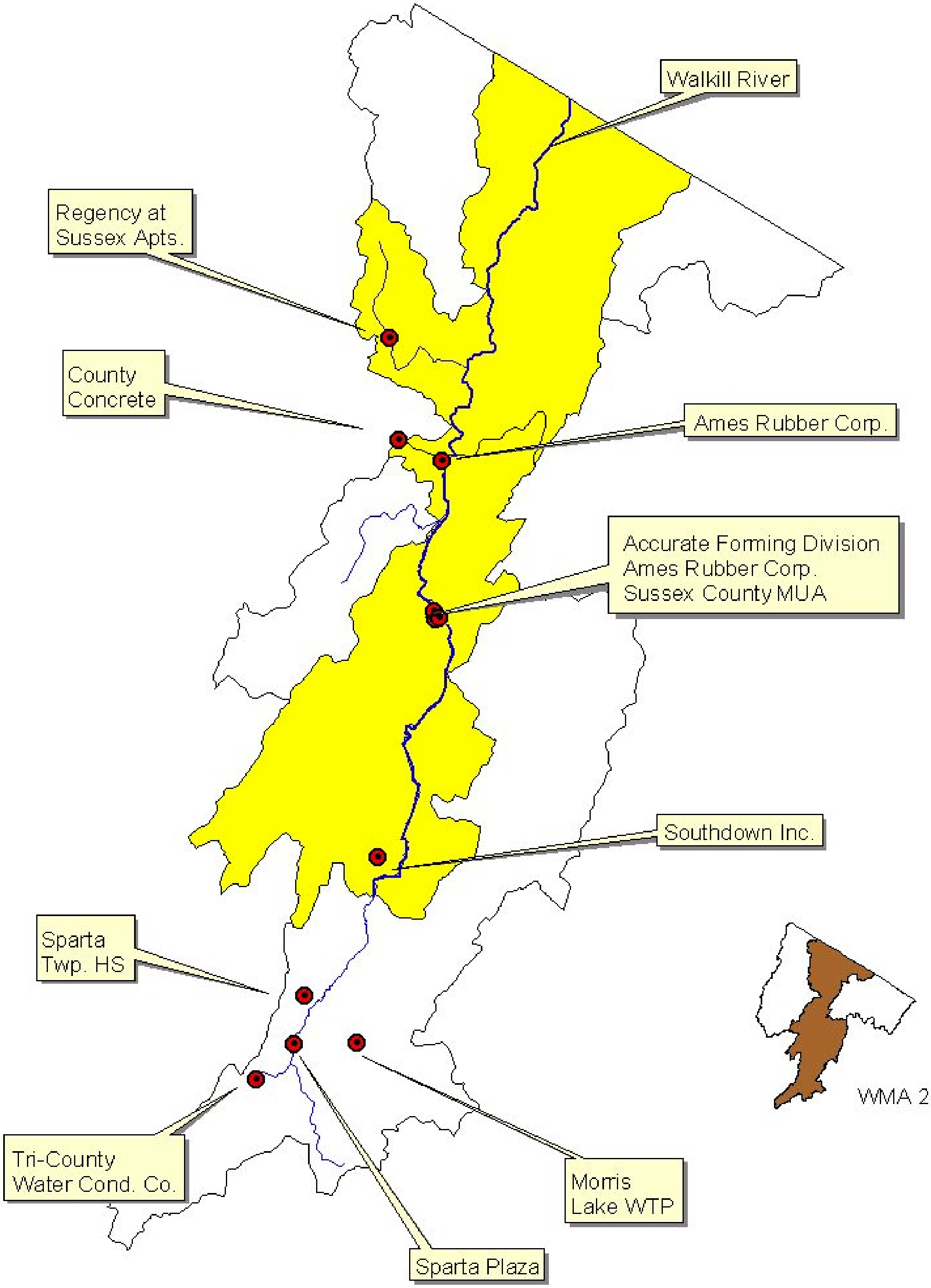
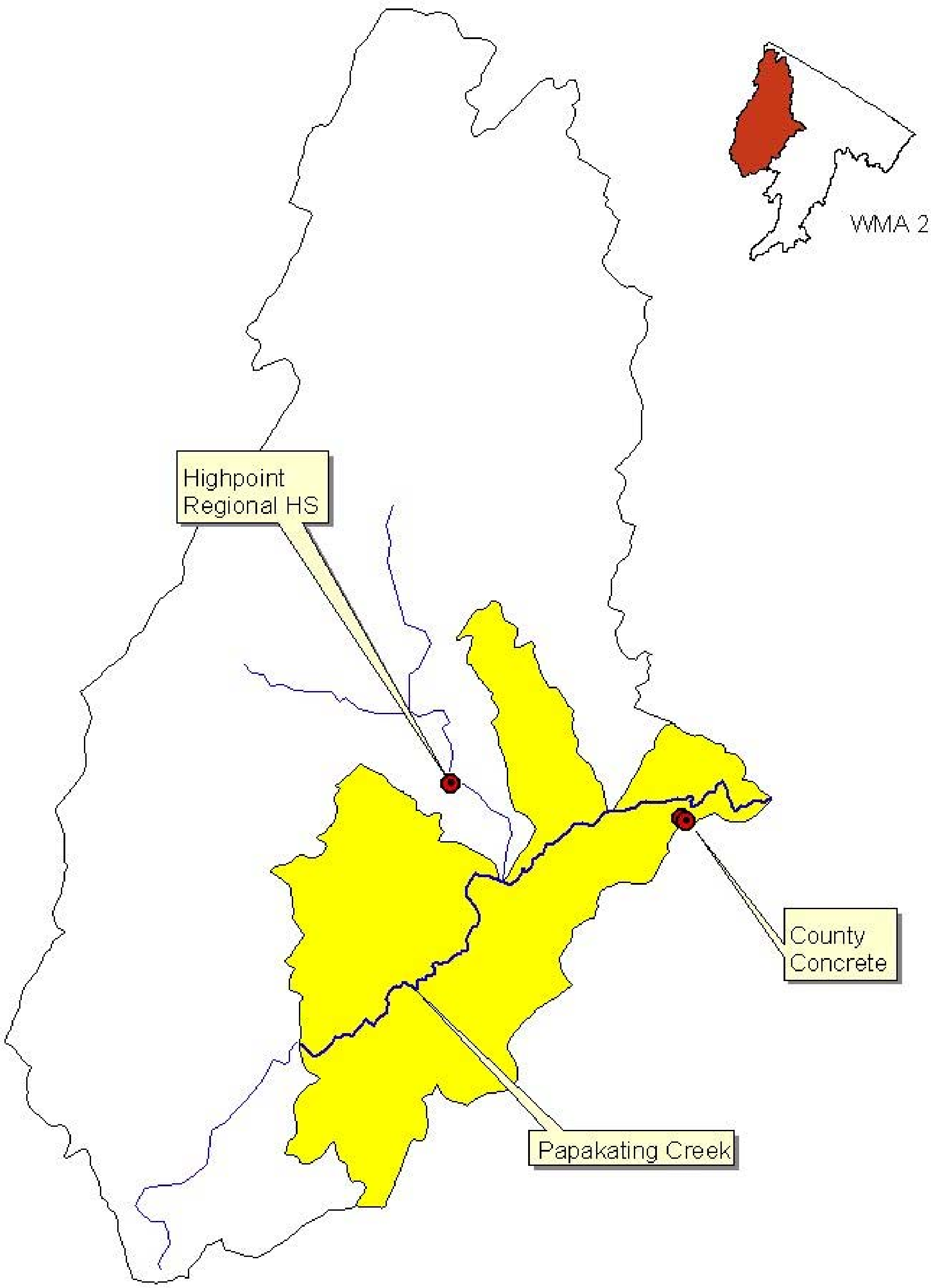


Figure 5. Discharges to Surface Water within the Papakating Creek Watershed



Nonpoint Sources

A preliminary assessment of the data suggests arsenic loading is widespread throughout the Wallkill River corridor, possibly emanating from natural sources as well as historical mining activities. Historic pesticide uses are also suspected as sources that may be contributing to the elevated arsenic levels, particularly in the Papakating Creek Watershed. The following is a discussion of potential sources of arsenic to the impaired segments.

Natural Sources—Leaching of rock formations

Based on information developed about the Franklin and Sterling Hill Mines by Palache, 1935, arsenic is found in the rock strata of the basin associated with zinc, sulfur, iron and manganese. Assessments of the formations of this area have been formally conducted since 1929. Almost all arsenic bearing minerals are secondary, occurring in veins and fissures due to hydrothermal deposition. Arsenic is found in the formations characteristic of the Wallkill Basin, particularly in those areas around Franklin where elevated levels were detected. In some cases, the samples were hydrated, which indicates contact with water. For leaching to occur, the proper conditions must be present and are discussed below. A more detailed discussion on the geology may be found in Appendix B.

At neutral pH, most of the arsenic found in ground water is either inorganic arsenic (III), uncharged arsenious acid, or inorganic arsenic (V), in the form of arsenic acid (with a charge of -1 or-2). The chemistry of arsenic (V) in the system allows it to bind to the surface of soil particles, removing it from the water column. Arsenic is sensitive to oxidation-reduction (redox) reactions. Arsenic adsorption and desorption are influenced by changes in pH, occurrence of redox reactions and the presence of competing anions (commonly sulfide).

There is a pH dependency for arsenic adsorption. As the pH is raised, the compounds will tend to become more negatively charged and water becomes more basic, releasing $^-$ OH ions, which interact with the ion exchange sites effectively neutralizing them. Hence, soil binding sites are affected by increasing pH. While arsenates (H_2As0_4- or $HAs0_4$2-) tend to bind in pH 6 to 7.77, pH above this level affects the binding site generally iron or aluminum. The ground water aquifers within the Wallkill Basin, in particular the limestone formation, already tend toward basic levels due to the rock composition increasing the likelihood of an elevated pH. The reduction of arsenate to arsenite can effectively mobilize arsenic (Manning and Goldberg, 1997).

As water moves through the ground water system over time, it causes not only the dissolution of the rock but will mobilize elements including the arsenic component. The leaching of arsenic allows release to the environment. Based on analysis of pH data for the region, the median pH of the Wallkill Basin is 8.00 or higher allowing the possibility for arsenic mobility. Studies by Hinkle and Polette, 1999 in the Willamette Basin in Oregon demonstrate the presence of arsenic due to leaching at pH values 8 or greater.

The presence of other anions, in particular, sulfides, for binding would limit this mobility. Based on monitoring data, for most stations, sulfide is not present or present at low values (0.5 mg/l).

Mining

From a geologic perspective, natural processes that took place before the Paleozoic era resulted in an abundance of iron- and zinc-containing mineral deposits that were later discovered circa 1640 in the towns of Franklin (Mine Hill area) and Ogdensburg (Sterling Hill area) in Sussex County and circa 1790 in West Milford, which is located in the upper portion of Passaic County. The Franklin and Sterling Hill locations are world famous. These deposits later served as sources of valuable ore in the development of thriving iron- and zinc-mining operations. Department staff and the Wallkill Technical Advisory Committee performed a search for mine slag piles, which could be leaching arsenic into the environment. However, none were located or documented. Through communication with staff of the Sterling Hill and Franklin mines, it was learned that slag piles would have not been present due to the fact that materials were taken to another site in Pennsylvania for processing and not processed on site. Therefore, legacy mining activity would be the result of general unearthing of the arsenic bearing materials as opposed to concentrated slag pile erosion. A more detailed discussion of area mining is presented in Appendix C.

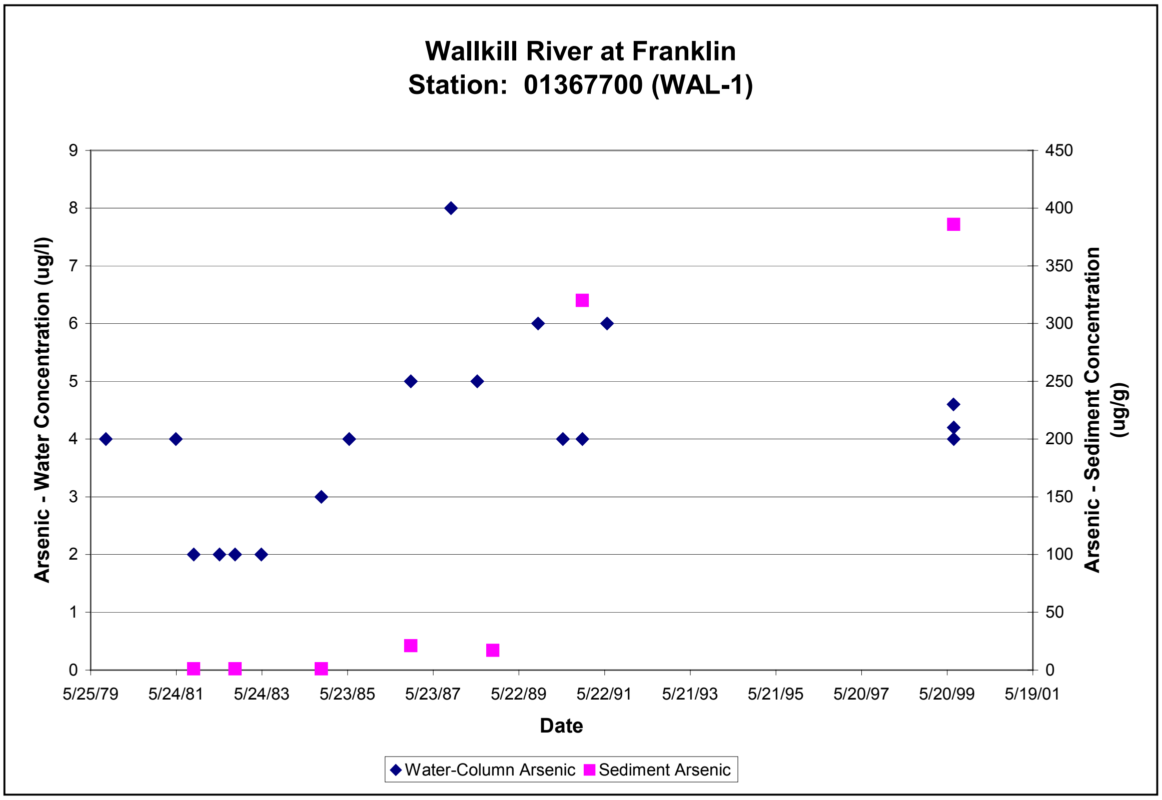
Agricultural Use in Pesticides

The Wallkill Basin has traditionally been an area of agriculture, particularly dairy farming, corn and vegetable farming. Orchard production is found in parts of the basin. Arsenical pesticides have been known, historically, to be used in connection with the orchard industry. However, agricultural land use of this type has not been located in geographic proximity to the points in question in the mainstem Wallkill River. Further investigation of this potential source is required.

There are numerous impoundments of various sizes in the Wallkill Basin that have undergone dredging. Heavier elements such as iron, manganese and arsenic tend to accumulate in sediments. When sediments are disturbed, the metals can become temporarily re-suspended. Spikes seen in water and sediment arsenic concentrations in Figure 6 correspond to the approximate time of the dam replacement at Franklin Pond.

This suggests arsenic from the various sources may be accumulating in sediments and especially in impoundments.

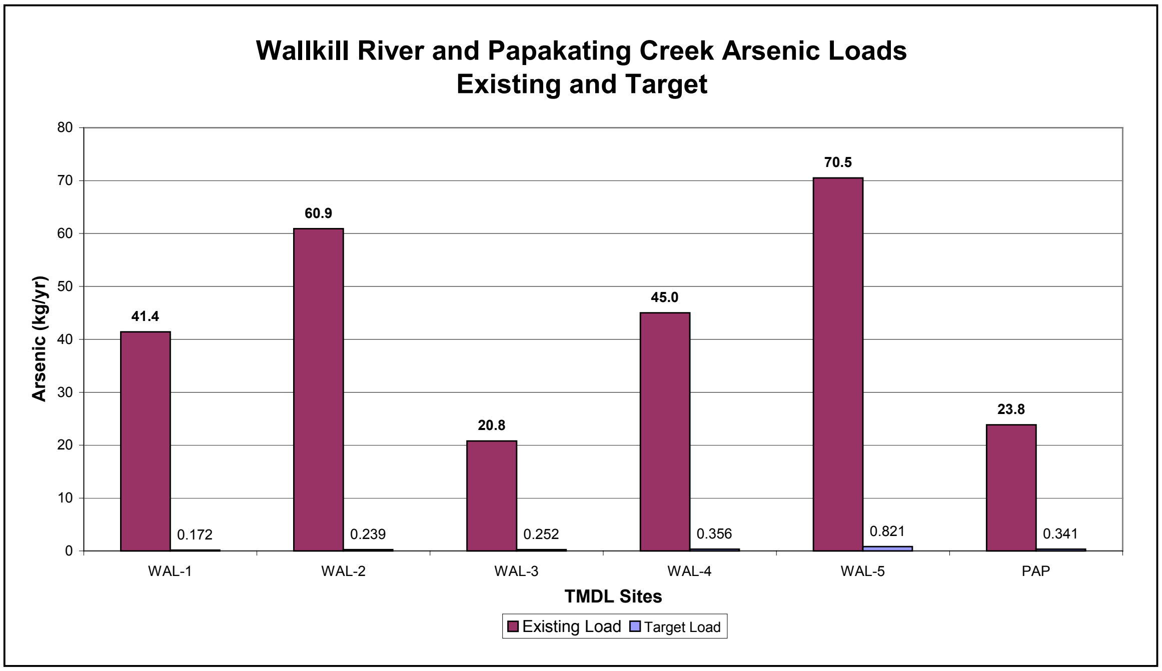
Figure 6. Arsenic Water and Sediment Concentrations vs. Date for Wallkill River at Franklin



7.0 TMDL Calculations

The TMDLs will be expressed in terms of the loading capacity of the stream segments at a 75 percent duration design flow (i.e., flow which is exceeded 75 percent of the time) as specified in section N.J.A.C. 7:9B-1.5(c)2. The existing loading was calculated using the average of available concentration data for each impaired segment, multiplied by the 75 percent flow duration for that segment. An average concentration was used in accordance with N.J.A.C. 7:9B-1.14(c)13. The loading capacity was determined by multiplying the 75 percent flow duration for each segment by the SWQS of 0.017 µg/l. The loading values are depicted in Figure 8. The available data suggest that all of the load is contributed by nonpoint sources. Therefore, the WLA for arsenic is zero. It is not possible at this point to differentiate the existing or future loads between types of nonpoint sources. This differentiation will be the outcome of the in-depth study of arsenic sources described under the Implementation section.

Figure 7. Relative difference between existing and target arsenic loading, using a 75% flow duration.



Seasonal Variation, Critical Conditions, Load Allocation, Reserve Capacity and Margin of Safety

A TMDL must account for critical conditions and seasonal variations. Available data, see Appendix D, were analyzed and it was determined that no seasonal pattern of variation was apparent. The critical condition was taken as the average concentration at a 75 percent flow duration. Since the annual loading capacity was based on an established ambient water quality standard, no Margin of Safety (MOS) is necessary to define variability of the set target concentration. A MOS of 5 percent was applied to offset marginal variability associated with the flow measurements. Load allocations were determined by multiplying the Loading Capacity (TMDL) identified in Table 6 by 0.95, which represents the Loading Capacity minus the MOS.

Table 6. Wasteload and Load reductions with a 5 percent margin of safety.

Station number	Loading Capacity (kg/yr)	MOS (5%, kg/yr)	Load Allocation (kg/yr)	Wasteload Allocation (kg/yr)
WAL-1	0.172	0.009	0.163	0
WAL-2	0.239	0.012	0.227	0
WAL-3	0.252	0.013	0.239	0
WAL-4	0.356	0.018	0.338	0
WAL-5	0.821	0.041	0.780	0
PAP-1	0.341	0.017	0.324	0

No allowance for reserve capacity was included because existing sources are natural or the result of historical anthropogenic activities. Use of arsenical pesticides is no longer allowed and mining has been discontinued.

8.0 Implementation Plan

A combination of best management practices (BMPs) and further investigation to pinpoint sources will be used to implement these TMDLs. Because natural sources of arsenic are present, a possible outcome could be a finding that the SWQS cannot be achieved. In this case, a site specific criterion reflecting natural conditions will be defined and loading capacity calculated relative to this criterion. Loading reductions attributed to anthropogenic sources may still be required.

Management measures are "economically achievable measures for the control of the addition of pollutants from existing and new categories and classes of nonpoint and stormwater sources of pollution, which reflect the greatest degree of pollutant reduction achievable through the application of the best available nonpoint and stormwater source pollution control practices, technologies, processes, citing criteria, operating methods, or other alternatives" (USEPA, 1993). The Department will address the sources of impairment, using regulatory and non-regulatory tools, through systematic source assessment, matching management strategies to sources, selecting responsible entities and aligning available resources to effect implementation. The WMA 2 PAC/TAC has been an active participant in watershed management initiatives and will be included in the refinement of source identification and implementation plan.

Since 1998, 319(h) funds have provided approximately 3 million annually to the Department, most of which approximately is passed through in the form of grants. Priority is given to funding projects that address TMDL implementation, development of stormwater management plans and projects that address impaired waterbodies.

One project currently underway, funded through a 319(h) grant awarded to North Jersey Resource Conservation and Development Council, is A *Watershed Management Agriculture Control and Management Implementation Program* which will use the following BMPs:

- Nutrient Management Systems
- Integrated Crop Management
- Grazing Systems
- Transition to Organic and Organic Management Practices
- Soil Management Testing

If agricultural sources are identified, several programs are available to assist farmers in the development and implementation of conservation management plans and best management practices. The Natural Resource Conservation Service is the primary source of assistance for landowners in the development of resource management pertaining to soil conservation, water quality improvement, wildlife habitat enhancement, and irrigation water management. The USDA Farm Services Agency performs most of the funding assistance. All agricultural technical assistance is coordinated through the locally led Soil Conservation Districts. The funding programs include:

- **The Environmental Quality Incentive Program (EQIP)** is designed to provide technical, financial, and educational assistance to farmers/producers for conservation practices that address natural resource concerns, such as water quality. Practices under this program include integrated crop management, grazing land management, well sealing, erosion control systems, agri-chemical handling facilities, vegetative filter strips/riparian buffers, animal waste management facilities and irrigation systems.

- **The Conservation Reserve Program (CRP)** is designed to provide technical and financial assistance to farmers/producers to address the agricultural impacts on water quality and to maintain and improve wildlife habitat. CRP practices include the establishment of filter strips, riparian buffers and permanent wildlife habitats. This program provides the basis for the Conservation Reserve Enhancement Program (CREP).

- **Conservation Reserve Enhancement Program (CREP)** The New Jersey Departments of Environmental Protection and Agriculture, in partnership with the Farm Service Agency and Natural Resources Conservation Service, signed a $100 million CREP agreement earlier this year. This program matches $23 million of State money with $77 million from the Commodity Credit Corp. within USDA. Through CREP, financial incentives are offered for agricultural landowners to voluntarily implement conservation practices on agricultural lands. NJ CREP will be part of the USDA's Conservation Reserve Program (CRP). There will be a ten-year enrollment period, with CREP leases ranging between 10-15 years. The State intends to augment this program to make these leases permanent easements. The enrollment of farmland into CREP in New Jersey is expected to improve stream health through the installation of water quality conservation practices on New Jersey farmland.

The Department supports further investigation into old cemeteries as a source of arsenic to ground water. In the United States, the widespread use of arsenic in embalming fluids began in the Civil war period (1860's). Arsenic was the primary embalming agent used in to preserve bodies up to 1910 when it was banned. Today, arsenic is prevalent near old cemeteries as evidence by USGS studies in Iowa. Although WMA 2 stakeholders report no anecdotal evidence of such cemeteries near the impaired segments, it would be prudent to follow through with an investigation to rule out cemeteries as a contributing source.

Determination of Concentrations and Sources of Arsenic in the Wallkill River Watershed, Northwestern New Jersey, USGS

The overall goal of this yearlong investigation is to identify sources of arsenic to the Wallkill River Watershed. This will be accomplished through the monitoring of ground water in several aquifers, surface water and soil samples. The main focus of the initial implementation plan is an in-depth investigation that will differentiate the relative sources of arsenic and determine if/where arsenic is accumulating in sediments. This will be accomplished through the monitoring of ground water in several aquifers, surface water and soil samples, including speciation between arsenic (V) and arsenic (III). Objectives of the study include:

- Determining whether arsenic (and other trace element) concentrations in surface water vary diurnally, in order to select an optimum time for sampling;
- Verifying reaches of the Wallkill River where arsenic concentrations are elevated relative to New Jersey surface-water-quality standards and determining concentrations of associated trace elements;
- Determining potential anthropogenic sources by evaluation of historic and existing land uses;
- Determining the combinations of other elements associated with arsenic that can be used as chemical fingerprints, starting with sediments, and extending the concept, if possible, to surface and ground water;
- Identifying whether domestic wells in different lithologies are tapping water with elevated concentrations of arsenic.
- Determining the speciation of arsenic in the aqueous environment, which may be either arsenic (V) or arsenic (III), the latter of which is more toxic.

Upon the completion of this investigation, the Department will be able to refine this TMDL and establish the appropriate distribution of reductions among the various sources in order to reflect the outcome of specific source contribution to arsenic impairment. Arsenic loadings will be traced to the area or specific location of the source using an arsenic-species tracking technique. Once the sources are identified, via surface water, ground water, and sediment testing, specific remediation actions will be identified.

If it is determined that natural sources of arsenic would still exceed the SWQS, a site specific criterion would be established. Management strategies may then shift to include means to address potential human health effects. These may include education projects that present the identified hazards of the local arsenic; arsenic treatment systems for individual potable water supplies; municipal ordinances to address the drilling of new wells in areas of elevated natural arsenic loads.

Upon completion of the USGS investigation, the Department will have enough data to support more complex modeling efforts, including a mass-balance modeling approach. The mass balance will allow an estimation of aeral contributions of arsenic and the amount of arsenic that is settling out in Franklin Pond, located between 2-WAL-2 and 2-WAL-3.

Upgrade Drinking Water Standard

The Department has recently proposed the strongest, most protective drinking water standard for arsenic in the nation; the new limit would be half the new federal standard. The proposed rules (36 N.J.R. 295, January 20, 2004) call for a limit of 5 parts per billion (ppb) for arsenic concentrations in drinking water, effective January 23, 2006. In February 2002, the federal government adopted a 10 ppb arsenic drinking water standard that will become effective on January 23, 2006. No other state has adopted an arsenic standard as protective as 5 ppb. The Department requires monitoring for arsenic at more than 600 public community water systems and 900 non-transient, non-community systems, which combined sere around 85% of the state's population. In addition, the new standard also would apply to private well owners regulated under New Jersey's Private Well Testing Act, requiring notification during real estate transactions. The Department in partnership with the New Jersey Corporation for Advanced Technology (NJCAT) has verified four technologies capable of removing arsenic from drinking water to levels as low as 5 ppb. The most feasible and cost effective treatment technologies currently available are 1) activate alumina adsorption, 2) coagulation/filtration, 3) granular ferric adsorption, and 4) ion exchange. Although the SWQS for arsenic is more stringent than the drinking water standard, the implementation of this rule will serve to address arsenic reduction through treatment technology.

9.0 Follow - up Monitoring

The Department's primary surface water quality monitoring program is the Bureau of Water Monitoring with the Division of Science and Research. In association with the Water Resources Division of the United States Geological Survey, the Department has cooperatively operated the Ambient Stream Monitoring Network (ASMN) in New Jersey since the 1970s. The ASMN currently includes 115 stations that are routinely monitored.

10.0 Reasonable Assurance

With the implementation of follow-up monitoring and source identification, the Department is reasonably assured that New Jersey's Surface Water Quality Standards will be attained for arsenic. Activities directed in the watersheds to reduce arsenic shall include options as described in the implementation section.

11.0 Public Participation

In accordance with the Water Quality Management Planning Rules N.J.A.C. 7:15 –7 et seq., each TMDL shall be proposed by the Department as an amendment to the appropriate areawide water quality management plan(s) in accordance with N.J.A.C. 7:15-3.4(g). N.J.A.C. 7:15-3.4(g)5 states that when the Department proposes to amend the areawide plan on its own initiative, the Department shall give public notice by publication in a newspaper of general circulation in the planning area, shall send copies of the public notice to the applicable designated planning agency, if any, and may hold a public hearing or request written statements of consent as if the Department were an applicant. The public notice shall also be published in the New Jersey Register.

As part of the public participation process for the development and implementation of the TMDLs for arsenic in the Northwest Water Region, the Department worked collaboratively with stakeholders in WMA 2 as part of the Department's ongoing watershed management efforts. The Department's watershed management process includes a comprehensive stakeholder process that includes members from major stakeholder groups (agricultural, business and industry, academia, county and municipal officials, commerce and industry, purveyors and dischargers, and environmental groups). As part of the watershed management planning process, Public advisory Committees (PACs) and Technical Advisory Committees (TACs) were created in all 20 WMAs. The PACs serve in an advisory capacity to the department, examining and commenting on a myriad of issues in the watersheds. The TACs are focused on scientific, ecological, and engineering issues relevant to the issues of the watershed, including water quality impairments and management responses to them.

The Department shared the Department's TMDL process through various presentations and discussions with the WMA 2 TAC members over the past several years. Presentations included: *Introduction to TMDLs*, February 28, 2002; *Assessment and Technical Approach Paper for the Wallkill River Watershed*, March 28, 2003; 2002 *Integrated List and Methodology*, June 27, 2003; *Data and Input on Source Identification for 28 Fecal TMDLs in Northwest Water Region*, October 24, 2002. More recently, presentations were made on the proposed Papakating Phosphorus TMDL document and Arsenic Methodology to the TAC on February 26, 2004. In addition to the presentations, subsequent discussions on both the TMDL and USGS study have been held with the TAC who has been instrumental in providing comments and suggestions to the Department throughout the TMDL development process.

Additional input was received through Rutgers New Jersey EcoComplex (NJEC). The Department contracted with the NJEC in August 2001. The NJEC consists of a nine member review panel of New Jersey university professors whose role is to provide comments on the Department's technical approaches for the development of TMDLs and other management strategies. An overview of the Wallkill River arsenic impairments was presented to the panel on January 30, 2004. Several approaches were subsequently discussed with NJEC before the present methodology was found to be acceptable to address the impairments.

A Public Notice for the proposed TMDL and public hearing was published in the July 19, 2004 edition of the New Jersey Register. The public hearing was held on August 24, 2004.

Amendment Process

In accordance with N.J.A.C. 7:15-7.2(g), these TMDLs are proposed by the Department as an amendment to the Sussex County Water Quality Management Plan (WQMP).

Notice proposing these TMDLs was published July 19, 2004 in the New Jersey Register and in newspapers of general circulation in the affected area in order to provide the public an opportunity to review the TMDLs and submit comments. In addition, a public hearing was held on August 24, 2004 at the Franklin Borough Hall. Sussex County is the designated planning agency for the Sussex County WQMP; notice of the proposal and hearing was provided to affected municipalities as well as the County.

All comments received during the public notice period and at any public hearings will become part of the record for these TMDLs. All comments have been considered in the establishment of these TMDLs, in preparation for submittal to EPA Region 2 for approval. Upon approval, the TMDLs will be adopted as amendments to the Sussex County WQMP.

Appendix A. References

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Appendix B. Summary of Natural Arsenic in the Wallkill River Basin

The information below is summarized from the USGS report by Palache, 1935.

In the Wallkill Basin, arsenides are rare, except for loellingite, which is locally abundant in the black-willemite zone at Sterling Hill. A suite of nickel arsenides is seen once in a highly localized formation at Franklin. Domeykite, a copper arsenide, and cuprostibite, a copper antimonide, have been found in willemite and may have been locally abundant in tiny grains. Arsenic is also locally abundant in the nickel-arsenide assemblage and in apatite-group minerals, both from Franklin.

Arsenopyrite can locally be a major component in the Franklin Marble and in loellingite in the ore bodies of these deposits. Six manganese arsenosilicates, with arsenic in varying oxidation states, are found locally. Arsenic is present in small quantities in secondary arsenates of Mn and other cations in secondary veins at Sterling Hill. The following are the primary rock types in which arsenic is found.

Willemite

Minor elements: Cu,As,Ge,Be,Mn,Ca,Al
Trace elements: Fe,Pb,Ag,Bi,B,Cr,Ti,Mg,Ni

Manganpyrosmalite

Minor elements: Fe,Zn,Ca,Na,As,Al,Mg
Trace elements: Sr,Ba,Ti,B,Ni,Y,Cu,Be,Ag,Pb

Tephroite

Minor elements: Al,Ca,Fe
Trace elements: Cr,Ba,Sr,As,Ni,Y,Cu,As,Pb,Be

Other arsenic bearing compounds, including magnussonite, nelenite, and schallerite, exist as vein-filling arsenites. Pyrobelonite and descloizite are the only known local vanadate minerals and there are three anomalous and aberrant phosphates: meta-ankoleite, newberyite, and niahite.

Few zinc arsenates (koettigite, legrandite, and adamite) are found in the Franklin and Sterling Hill deposits. The rare arsenates of copper are known only from Sterling Hill, and the arsenates of Mg are more common at Sterling Hill than at Franklin, consistent with the greater amount of Mg there. The locally dominant group is the manganese arsenates. Parker and Troy (1982) were the first to discuss a chemical partitioning of the Sterling Hill arsenates. Those with Zn and Fe^{3+} occur primarily in the black-willemite ore, and those with Mn and Mg occur primarily in the red-willemite ore. Some arsenates of Ca and Mg are post-mining minerals.

The majority of the Sterling Hill arsenates are associated with zincite-bearing ore, the red-willemite ore of Parker and Troy (1982), in which no arsenic-bearing primary mineral is found; arsenic may have been introduced to this ore from the black-willemite zone, the enclosing marble, or some other source. The arsenates of Mn and Mg found in this red- willemite ore likely are of higher temperature of formation than those found in the black-willemite ore and are not hydrated thus indicating no potential interaction with ground water during formation.

A suite of significant Sterling Hill arsenates was found in the black-willemite zone. The species are principally arsenates of Zn or of Zn and Fe^{3+}, and many are hydrated. Iron and Arsenic are likely derived from locally abundant loellingite. The abundance of arsenate species at Sterling Hill, relative to Franklin, is partially unexplained. The arsenates in the black-willemite ore belong uniquely to Sterling Hill; black-willemite ore is uncommon at Franklin and hosts no known arsenate minerals. Many of the Mn/Mg arsenates occur at Franklin, and many others might have occurred there, but were not found, possibly because the deposit was worked long before fine microscopes were available to collectors.

Appendix C. Mining

Early mining (from approximately the 1740s to 1882) was for iron metal. In 1870, the iron found in the zinc ores was used to make a special alloy called "spiegeleisen" (an alloy of manganese and iron); this operation continued until the 1960s. In general, iron mining and zinc mining operated side-by-side. Mining operations in Franklin were discontinued circa 1954; similar operations in Ogdensburg ended in 1985. The Ogdensburg site was reopened in 1990 as the Sterling Hill Mining Museum. Many of the mineral deposits, although relatively rich in iron, zinc and lesser amounts of manganese (all chemically bound), contained arsenic, silicon, and numerous other elements. The success and failure of the mines followed the fluctuations of boom and bust cycles beginning in the mid 1800's and ending in the early 1900's.

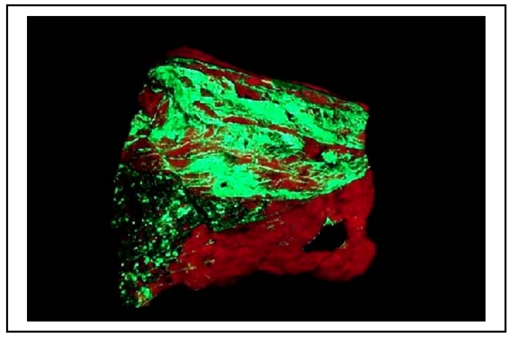
Zinc was mined in the Highlands, particularly in the Franklin and Sterling Hill area of Sussex County, up until 1986. This ore body was a major producer of zinc for a hundred and fifty years. Some of the earliest mining for zinc can be dated back to 1739 in the form of scattered pits (Jasch). One of the largest mines, at the Sterling Hill mine reached to the depth of 1850 feet at an angle of 56 degrees. By the time of the its closure in 1986, this mine had produced over twelve million tons of ore. The zinc produced in these mines was mainly used in the galvanization of iron and steel. The closure of the mine was due to the increase in transportation and production costs that made the endeavor unprofitable. In 1990 the Sterling Hill Mine was reopened as a museum to educate the public about its mining history and showcase the 70 fluorescent minerals located in the mine.

More than 340 mineral compounds/varieties have been identified, including over 70 fluorescent minerals. Key mineral deposits found and utilized either at Franklin or Sterling Hill were:

Calcite (calcium carbonate; form exhibits fluorescence when manganese is present)
Franklinite (similar to magnetite but with zinc and manganese in place of some of the iron; zinc iron manganese oxide - $(Zn, Fe, Mn)(Fe, Mn)_2O_4$))
Goethite (hydrated iron oxide – $FeO(OH)$
Hematite (ferrous oxide – Fe_2O_3, iron oxide)
Hematite-goethite (intimately associated)
Magnetite (ferric oxide – Fe_3O_4, iron oxide; magnetite is a natural magnet)
Willemite (zinc silicate – Zn_2SiO_4; exhibits fluorescence)
Willemite-franklinite-zincite (intimately associated)
Willemite-franklinite-calcite (intimately associated)
Zincite (zinc oxide)

It is a tribute to Franklin Borough to be known as the "Fluorescent Capital of the World." (Settings Report of the Wallkill Basin, 2002) Additional information may be found at: **www.mjt.nu/willcal.htm**

Figure 8. Examples of Fluorescent Minerals

Willemite & Calcite, Normal Light Franklin, New Jersey	Under Shortwave Ultraviolet Light Fluorescence
	

Appendix D. Arsenic Data for the Wallkill River and Papakating Creek

Sediment and Water-Column Arsenic Data

Site	Date	Parameter	Concentration	
WAL-1	10/1/1979	As, Total Recoverable, ug/l	4	
01367700	5/21/1981		4	
	10/20/1981		2	
	5/27/1982		2	
	10/7/1982		2	
	5/19/1983		2	
	10/11/1984		3	
	6/6/1985		4	
	11/13/1986		5	
	10/22/1987		8	
	6/1/1988		5	
	11/2/1989		6	
	5/31/1990		4	
	11/14/1990		4	
	6/13/1991		6	
	7/13/1999		4.6	Avg Conc
	7/14/1999		4	Avg Conc
	7/15/1999		4.2	Avg Conc
	10/20/1981	As, bed sediment, total, dry weight, ug/g	<1	
	10/7/1982		<1	
	10/11/1984		1	
	11/13/1986		21	
	10/12/1988		17	
	11/14/1990		320	
	7/14/1999		386	
WAL-2	7/13/1999	As, Total Recoverable, ug/l	4.2	Avg Conc
01367715	7/14/1999		3.6	Avg Conc
	7/15/1999		3.9	Avg Conc
	8/11/1999		6	
	8/7/2001		4	
	7/13/1999	As, bed sediment, total, dry weight, ug/g	4.5	
	7/14/1999		4.5	
	7/15/1999		4.5	
WAL-3	7/13/1999	As, Total Recoverable, ug/l	1.6	Avg Conc
01367729	7/14/1999		1.2	Avg Conc
	7/15/1999		1.4	Avg Conc
	7/13/1999	As, bed sediment, total, dry weight, ug/g	4.5	
	7/14/1999		4.5	

	7/15/1999		4.5
WAL-4 01367770	9/18/1978	As, Total Recoverable, ug/l	2
	10/10/1979		2
	9/23/1980		3
	5/21/1981		2
	10/20/1981		2
	9/27/1982		3
	5/19/1983		2
	6/13/1984		3
	11/14/1985		2
	6/9/1986		3
	6/11/1987		2
	6/1/1988		3
	6/20/1989		3
	5/31/1990		2
	11/14/1990		2
	5/20/1992		2
	11/16/1992		2
	5/20/1993		2
	5/26/1994		2
	10/18/1994		1
	5/30/1995		2
	10/21/1996		2
	7/13/1999		1.8 Avg Conc
	7/14/1999		1.6 Avg Conc
	7/15/1999		1.6 Avg Conc
	8/8/2000		2
	9/18/1978	As, bed sediment, total, dry weight, ug/g	<1
	9/23/1980		<1
	10/20/1981		1
	9/27/1982		1
	11/13/1986		6
	10/12/1988		5
	11/14/1990		6
	11/16/1992		1
	7/14/1999		4.5
	8/8/2000		14
WAL-5 01368000	6/3/1976	As, Total Recoverable, ug/l	<1
	9/23/1976		1
	5/12/1977		<1
	9/18/1978		2
	10/9/1991		<1
	5/20/1992		2
	11/17/1992		2
	5/19/1993		2
	10/28/1993		<1
	6/6/1994		1
	10/19/1994		1

	5/31/1995			1	
	10/23/1996			1	
	5/20/1997			<1	
	7/13/1999			2.3	Avg Conc
	7/14/1999			2	Avg Conc
	7/15/1999			1.9	Avg Conc
	8/13/2002			2	
	5/26/1976	As, bed sediment, total, dry weight, ug/g	8		
	9/23/1976		10		
	9/18/1978		.0		
	10/9/1991		8		
	11/17/1992		5		
	7/14/1999		4.5		
PAP-1	10/19/1977	As, Total Recoverable, ug/l		1	
01367909	5/31/1979			3	
01367910	5/19/1980			3	
	9/23/1980			2	
	6/25/1981			<1	
	10/15/1981			1	
	6/3/1982			1	
	10/19/1983			1	
	6/13/1984			1	
	10/16/1984			<1	
	11/19/1985			<1	
	6/4/1986			<1	
	6/10/1987			<1	
	11/17/1987			<1	
	5/16/1988			<1	
	10/25/1988			<1	
	5/16/1990			<1	
	6/11/1991			<1	
	5/20/1992			<1	
	11/19/1992			<1	
	10/17/1994			<1	
	5/23/1995			<1	
	10/21/1996			<1	
	7/13/1999			1.5	
	7/14/1999			1.2	
	7/15/1999			1.3	
	10/19/1977	As, bed sediment, total, dry weight, ug/g		4	
	10/19/1983			<1	
	11/17/1987			4	
	11/16/1989			2	
	11/19/1992			3	