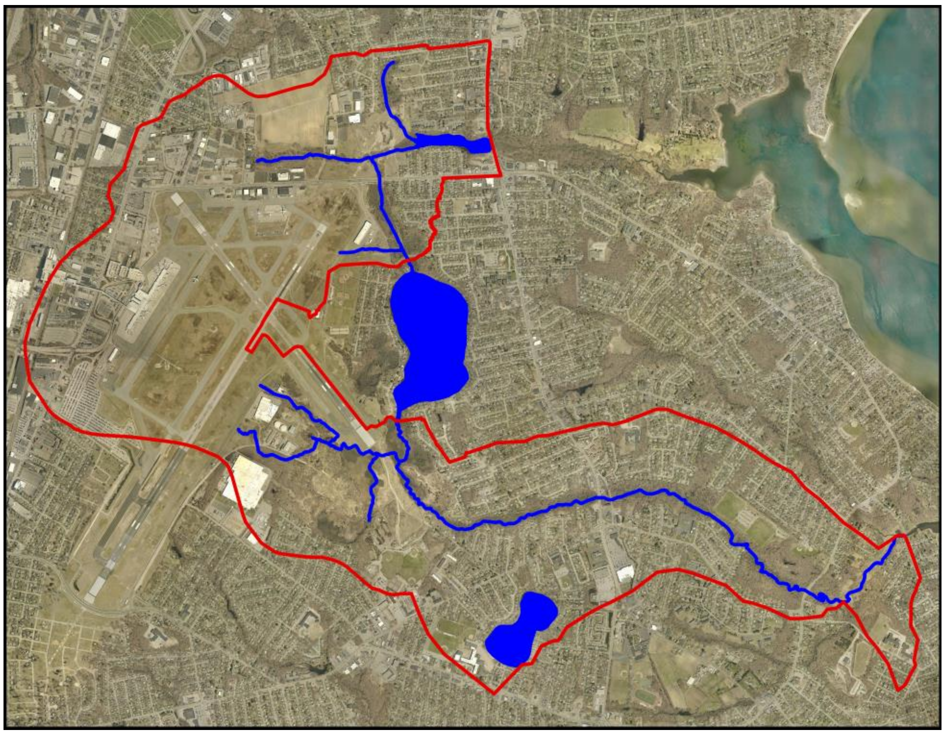
TOTAL MAXIMUM DAILY LOAD ANALYSIS FOR BUCKEYE BROOK AND TRIBUTARIES TO WARWICK POND

FINAL REPORT
NOVEMBER 2021

303(d) listings addressed in this study:
Buckeye Brook and Unnamed Tributaries (RI0007024R-01):
Benthic-Macroinvertebrate Bioassessments, Dissolved Oxygen, Total Iron, Dissolved Cadmium, Copper, and Lead
Tributaries to Warwick Pond (RI0007024R-05):
Benthic-Macroinvertebrate Bioassessments, Total Iron, Dissolved Cadmium



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Best Management Practice (BMP). Schedules of activities, prohibitions of practices, maintenance procedures, and other management practice to prevent or reduce the pollution of and impacts upon waters of the State. BMPs also include treatment requirements, operating procedures, and practices to control site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage.

Bypass. The intentional diversion of waste streams from any portion of a treatment facility.

Clean Water Act (CWA). The Federal Water Pollution Control Act 33 U.S.C. § 1251 *et seq.*

Code of Federal Regulations (CFR). Document that codifies all rules of the executive departments and agencies of the federal government. It is divided into fifty volumes, known as titles. Title 40 of the CFR (referenced as 40 CFR) lists all environmental regulations.

Designated uses are those uses specified in water quality standards for each waterbody or segment whether or not they are being attained. In no case shall assimilation or transport of pollutants be considered a designated use.

Load allocation. means the portion of a receiving water's loading capacity that is allocated to its nonpoint sources and natural background

Loading capacity means the maximum amount of loading that a surface water can receive without violating water quality standards.

Margin of Safety (MOS). Because there are uncertainties in data and TMDL analysis, it is possible that the specified reductions in a TMDL may not be adequate to allow water quality to meet standards. To account for this uncertainty, an additional reduction beyond the required numeric concentration is specified. This can be achieved using conservative assumptions, an explicitly allocated reduction, such as a level 10% below the standard, or a combination of both techniques.

Mixing zone. A limited area or volume in the immediate vicinity of a discharge where mixing occurs, and the receiving surface water quality is not required to meet applicable standards or criteria provided that the minimum conditions described in §§ 1.10(B)(5) and (6) of the Rhode Island Water Quality Regulations.

Natural background conditions are all prevailing dynamic environmental conditions in a waterbody or segment thereof, other than those human-made or human-induced.

Nonpoint Source (NPS). Any discharge of pollutants that does not meet the definition of Point Source in section 502(14) of the Clean Water Act, 33 U.S.C. § 1362 and the State of Rhode Island Water Quality Regulations. Such sources are diffuse, and often associated with land-use practices, and carry pollutants to the waters of the State, including but not limited to, non-channelized land runoff, drainage, or snowmelt; atmospheric deposition; precipitation; and seepage.

Point source means any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation or vessel, or other floating craft, from which pollutants are or may be discharged. This term does not include return flows from irrigated agriculture.

Primary contact recreational activities are those activities in which there is prolonged and intimate contact by the human body with the water, involving considerable risk of ingesting water, such as swimming, diving, water skiing and surfing.

Rhode Island Geographic Information System (RIGIS). A consortium of government and private organizations employing computer and communications technology to manage and use a collective database of comprehensive geographically related information.

Rhode Island Pollutant Discharge Elimination System (RIPDES). The Rhode Island system for issuing, modifying, revoking, reissuing, terminating, monitoring and enforcing point source discharge permits and imposing and enforcing pretreatment requirements pursuant to R.I. Gen. Laws Chapter 46-12 and the federal Clean Water Act.

Runoff means water that drains from an area as surface flow.

Secondary contact recreational activities are those activities in which there is minimal contact by the human body with the water, and the probability of ingestion of the water is minimal, such as boating and fishing.

Storm water means precipitation-induced runoff.

Surface waters are any waters of the state that is not groundwater.

Total Maximum Daily Load (TMDL). The amount of a pollutant that may be discharged into a waterbody and still maintain water quality standards. The TMDL is the sum of the individual wasteload allocations for point sources and the load allocations for nonpoint sources and natural background taking into account a margin of safety.

Wasteload allocation means the portion of a receiving water's loading capacity that is allocated to its point sources of pollution.

Water quality criteria means the elements of the State water quality standards, expressed as constituent concentrations, levels, or narrative statements, representing a quality of water that supports a particular use.

Water quality standard means provisions of State or Federal law, which consist of designated use(s) and water quality criteria for the waters of the State. Water Quality Standards also consist of an antidegradation policy.

1.0 INTRODUCTION

1.1 Purpose

The State of Rhode Island Department of Environmental Management (RIDEM) has identified water quality impairments in Buckeye Brook and the Tributaries to Warwick Pond. Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require States to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are not meeting designated uses. As confirmed by the 2008 benthic macroinvertebrate bioassessments (RIDEM, 2008) that included assessment of both habitat and biological condition, RIDEM finds that Buckeye Brook and Tributaries to Warwick Pond do not support aquatic life uses and are considered impaired for fish and wildlife habitat.

A TMDL is a tool for implementing state water quality standards and is based on the relationship between pollution sources in the watershed and water quality in the affected waterbody. The TMDL establishes the allowable pollutant loading to a waterbody and provides the basis for states to establish water quality-based controls. The TMDL provides a framework for identifying specific actions needed to reach water quality standards. The goal of the TMDL process is to reduce pollutant loadings to a waterbody to improve water quality to the point where state water quality standards are met.

One of the major components of a TMDL is to establish instream numeric endpoints, which are used to evaluate the attainment of acceptable water quality. Instream numeric endpoints represent the water quality goals that are to be achieved by implementing the load or pollutant reductions specified in the TMDL. The endpoints allow for a comparison between current instream water quality conditions and those conditions that are expected to restore beneficial uses. The endpoints are usually based on either the narrative or numeric criteria documented in Rhode Island's Water Quality Regulations as the state water quality standards (RIDEM, 2018a).

The requirements of the TMDL process helped determine the scope of the Buckeye Brook Watershed study (as defined here to be inclusive of the Tributaries to Warwick Pond). The goal of this sampling was to characterize water quality of these brooks and to provide a more robust dataset for use in developing a TMDL that would address this impairment.

Since 1998, Buckeye Brook has been on the State of Rhode Island's 303(d) list as being impaired, because it does not support fish and wildlife habitat (Aquatic Life Use) based upon Benthic-Macroinvertebrate Bioassessments (RIDEM, 2008). Earlier 303(d) lists also identified Buckeye Brook as being impaired, because it does not support Primary Contact Recreation (Swimming/Recreation Uses) based upon pathogen data. RIDEM completed a water quality investigation and TMDL addressing pathogen impairments within the watershed, which was approved by US EPA in December 2008. Since a TMDL has been completed addressing the pathogen related impairments, that impairment listing was removed from the 303(d) list (also referred to as Category 5 waters in the state's Integrated Report) and placed in Category 4A in the Integrated Report (impairments for which a TMDL has been completed). Also in 2008, this TMDL project was commenced with goals to: further characterize the biological condition impairment of Buckeye Brook and Tributaries to Warwick Pond; document water quality conditions; identify potential contributing pollution sources or stressors; and develop a TMDL to address the fish and wildlife habitat impairment.

Aquatic Life Use in Buckeye Brook was first listed as impaired in 1998 based upon macroinvertebrate sampling conducted by RIDEM's contractor, Roger Williams University. Subsequent sampling conducted by ESS, Inc. as part of RIDEM's Wadeable Stream Biomonitoring and Habitat Assessment Program, confirmed Buckeye Brook's impairment (ESS, 2002). Samples were collected annually at a station located at Old Warwick Avenue in Warwick, Rhode Island 2002-2005.

Possible stressors contributing to the observed impairments at this location include runoff from nearby roads in this highly urbanized watershed, runoff from T.F. Green Airport (including use of propylene glycol as a de-icing agent during the winter months), and runoff and/or groundwater leachate from a landfill (Truk-Away Landfill) located in the easternmost section of the airport property – along the western bank of Buckeye Brook.

1.2 Study Area

The focus of the TMDL study was the portion of the watershed that includes the mainstem stream system for Buckeye Brook as well as the Tributaries to Warwick Pond located in the northern part of the watershed above Warwick Pond. Prior to the 2014 Integrated Reporting cycle, the Tributaries to Warwick Pond were included as part of the Buckeye Brook waterbody assessment unit ID. The new listings show a separate waterbody ID for the stream system north of Warwick Pond. As a result of RIDEM creating this separate waterbody ID for the upstream tributaries, the watershed for Buckeye Brook assessment unit is redefined as the drainage area that extends from the exit of Warwick Pond to where the brook crosses under Tidewater Drive as it empties into Old Mill Creek. The field work for the data report covered approximately 55 percent of the full watershed for the areas surrounding T.F. Green Airport and Warwick Pond. Figure 1.1 shows the two areas of the watershed where the field work for this TMDL was conducted and Table 1.1 shows the waterbody IDs with their water quality classifications in the 303(d) listings addressed in this TMDL.

Table 1.1 Applicable Waterbodies in the Buckeye Brook Watershed

Waterbody ID Number	Waterbody Description	Water Quality Classification	Water Quality Impairment
R10007024R-01	Buckeye Brook assessment unit, Warwick, RI	B	Benthic-Macroinvertebrate Bioassessments, total Fe, dissolved Cd, Cu, and Pb and Dissolved Oxygen
RI00007024R-05	Tributaries to Warwick Pond assessment unit	B	Benthic-Macroinvertebrate Bioassessments, dissolved Cd, and total Fe

1.3 Pollutants of Concern

The goal of the RIDEM 2008 field work for the current study was to identify the source or sources that contribute to the aquatic life use (macroinvertebrate biodiversity) impairment in the Buckeye Brook Watershed.

Analysis of the data collected during the field work portion of the study has identified exceedances (violations) of numerous water quality criteria: dissolved oxygen, total iron and dissolved cadmium, copper, and lead as assigned to each segment in Table 1.1. A weight of evidence approach suggests that these pollutants along with hydrologic impacts associated with stormwater runoff from the highly urbanized watershed are contributing to the benthic macroinvertebrate bioassessments impairment.

Stormwater runoff can transport a complex array of pollutants to waterbodies, and, as a result, aquatic life communities may be subjected to many stressors associated with stormwater runoff. These stressors are related either directly or indirectly to stormwater runoff volumes and include increased watershed pollutant load (e.g., sediment), increased pollutant load from in-stream sources (e.g., bank erosion), habitat degradation (e.g. siltation, scour, over-widening of stream channel), washout of biota, and reduced groundwater recharge resulting in the loss of habitat due to reductions in stream base flows. The stressors associated with stormwater runoff may act individually or cumulatively to degrade the overall biological community in a stream to a point where aquatic life uses are not fully supported.

Impervious cover can be directly related to the amount of human disturbance occurring within a watershed and how it relates to the overall health of aquatic communities. Certain studies have documented aquatic life use impairments in relation to the extent of impervious surfaces in the watershed and have used impervious cover (IC) as a surrogate for stormwater related impacts to aquatic life (Maine IC TMDL, 2012).

Higher concentrations of copper (Cu) are usually from anthropogenic sources such as WWTF, industrial facilities, and urban runoff. These sources include corrosion of brass and copper pipes by acidic waters, industrial effluents and fallout, sewage treatment plant effluents, and the use of copper compounds as aquatic plant controls.

Cadmium (Cd) is a soft, bluish-white metal and is used in batteries (especially rechargeable nickel-cadmium batteries). As a result of its low coefficient of friction and its high fatigue resistance, cadmium is used in alloys for bearings.

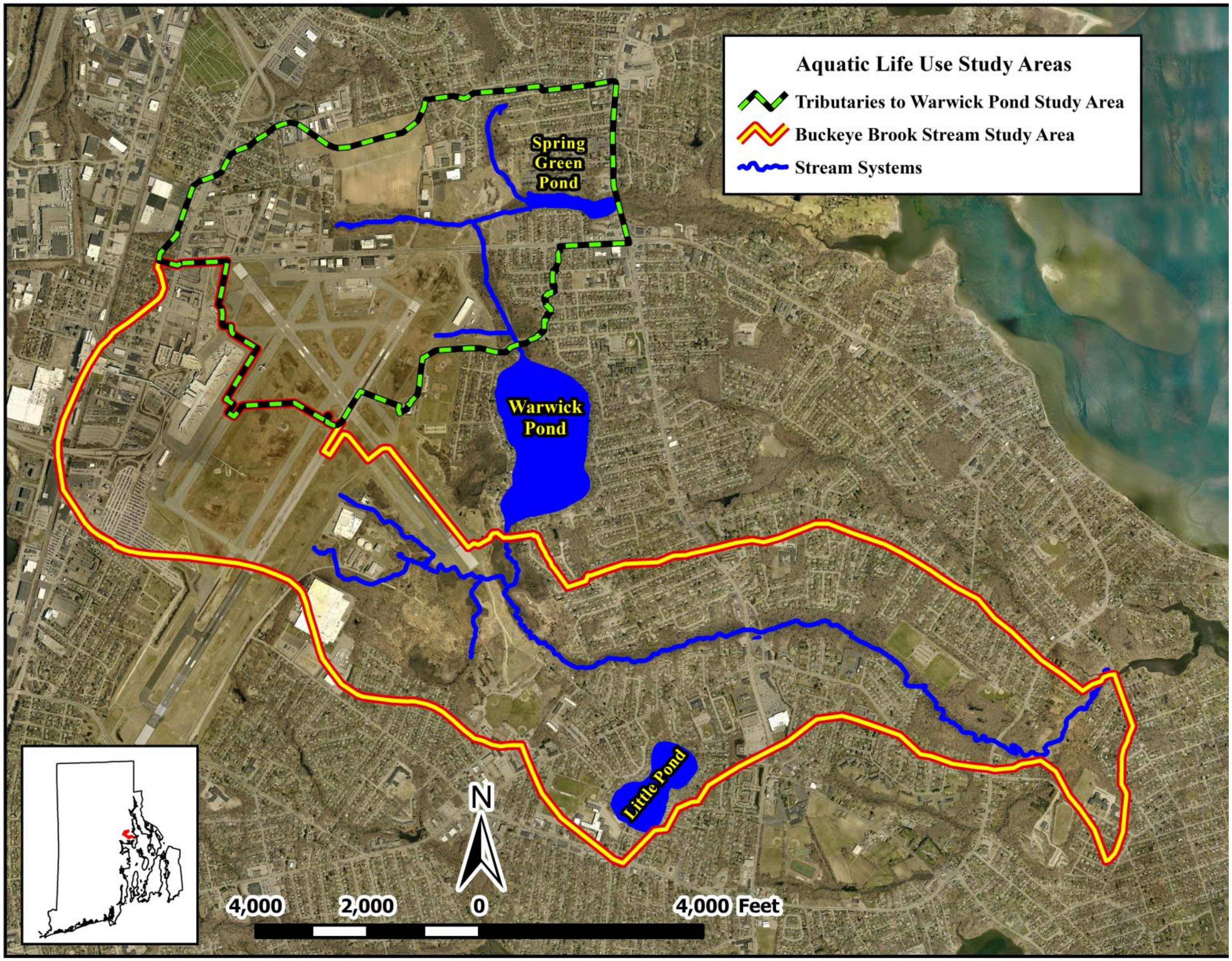


Figure 1.1 Biodiversity TMDL Study Areas

Lead (Pb) is a highly toxic metal whose widespread use has caused extensive environmental contamination and health problems in many parts of the world. Lead is a bright silvery metal, slightly bluish in a dry atmosphere. It begins to tarnish on contact with air, thereby forming a complex mixture of compounds, depending on the given conditions. Human activities such as mining, manufacturing and fossil fuel burning has resulted in the accumulation of lead and its compounds in the environment, including air, water, and soil. Lead has been used for the production of batteries, fertilizers, pesticides, metal products such as ammunitions, solder and pipes. The highly toxic nature of has resulted in the reduction or elimination of lead in products such as paints and gasoline. The main sources of lead exposure are lead based paints, gasoline, cosmetics, toys, household dust, contaminated soil, and industrial emissions.

Iron (Fe) in water can be precipitated as a hydroxide $Fe(OH)_3$ or as ferric oxide (Fe_2O_3) which forms a gel or floc that, when suspended in water, may be detrimental to fishes and other aquatic life. They can settle to form flocculent materials that cover stream bottom, thereby destroying bottom-dwelling invertebrates, plants, or incubating fish eggs.

The amount of Dissolved Oxygen (DO) in the water column is indicative of the aesthetic qualities of the water as well as an important gage of existing water quality and the ability of a water body to support a well-balanced aquatic fauna. For freshwater aquatic life, the minimum criterion for warmwater fisheries is dissolved oxygen content of not less than 60% saturation, based on a daily average, and an instantaneous DO of 5.0 mg/L, except as natural occurs. The seven day mean water column dissolved oxygen concentration shall not be less than 6mg/L (RIDEM, 2018a).

Potential sources of contaminants include stormwater discharges from T.F. Green Airport and Truk-Away landfill as well as runoff from the highly urbanized watershed. Stormwater outfalls from T.F. Green Airport (PVD) discharge to the Tributaries of Warwick Pond above Lakeshore Drive and into Buckeye Brook between the exit of Warwick Pond and Warwick Avenue. Historically, during winter de-icing operations RIAC has implemented manual practices to collect stormwater contaminated with de-icing and anti-icing chemicals and the stormwater discharging from several outfalls on the airport property has contained varying amounts of propylene glycol, the major constituent in aircraft deicing fluid (ADF). During the course of this study, the RI Airport Corporation had begun implementation of structural controls to reduce propylene glycol being discharged. One concern of this study was the effects of the biological oxygen demand caused by the breakdown of deicing and anti-icing compounds.

Truk-Away Landfill is another potential source of pollutants to the brook. The landfill is located southwest of the approach end of Runway 34. Landfill operations were ceased in 1977, but the landfill was never properly capped, and the potential exists for waste material to be in the stream that meanders along the southern edge of the landfill and to ultimately end up in Buckeye Brook. The stream has very low flows and it joins with the flow from Outfall 08 prior to the confluence with Buckeye Brook. Previous site investigations have identified environmental concerns such as volatile organic compounds (VOCs), presence of light non-aqueous phase liquid (LNAPL), and polychlorinated biphenyls (PCBs) in groundwater and elevated levels of methane and VOCs in soil gas.

As will be discussed in detail in the following sections, the sampling completed as part of this study has identified exceedances (violations) of numerous water quality criteria: dissolved oxygen, total iron, and dissolved cadmium, copper, and lead. Dissolved copper and lead and dissolved oxygen impairments apply to Buckeye Brook only.

This TMDL establishes numeric water quality targets for total iron and dissolved copper, cadmium, and lead. Dissolved copper and lead numeric water quality targets apply to Buckeye Brook only. The TMDL must ensure that the water quality criteria for dissolved oxygen are also met. As will be discussed in greater detail, controls of propylene glycol discharges and reductions in total iron levels are expected to prevent dissolved oxygen violations. With the expected reduction of total iron and propylene glycol levels in the water column, which cause the dissolved oxygen sags, dissolved oxygen should return to above criteria levels. Benthic macroinvertebrate bioassessments targets are comprised of the narrative criteria in the RIDEM (2018a) Water Quality Regulations.

This TMDL establishes that the subwatersheds influencing the impairments of Buckeye Brook and Tributaries to Warwick Pond addressed by this TMDL are the following: Spring Green Pond (RI0007024L-03), Unnamed Tributary To Spring Green Pond (RI0007024R-10), Tributaries to Warwick Pond (RI0007024R-05), Warwick Pond (RI0007024L-02), and Buckeye Brook (RI0007024R-01). Uncontrolled stormwater and other pollutant sources must be addressed by the appropriate entity in each subwatershed.

1.4 Priority Ranking

Buckeye Brook and the Tributaries to Warwick Pond are Category 5 waterbodies on the RIDEM 303(d) List of Impaired Waters for Benthic-Macroinvertebrate Bioassessments; the Buckeye Brook impairment was first placed on the list for this impairment in 1998. This Category constitutes the 303(d) List of waters impaired or threatened by a pollutant(s) for which one or more TMDL(s) are needed. Further impairments resulting from this study were added to the 303(d) List.

1.5 Applicable Water Quality Standards

As stated in 40 CFR 131.2, "[water quality] standards serve the dual purposes of 1) establishing the water quality goals for a specific waterbody and 2) serving as the regulatory basis for the establishment of water-quality based treatment controls and strategies beyond the technology-based levels of treatment required by section 301(b) and 306 of the Act." The primary aim of a TMDL is to bring a waterbody back into compliance with applicable water quality regulations.

Therefore, it is important to know exactly which regulations apply to the waterbody for which a TMDL is developed. The regulations, which are specifically applicable to the impairments that caused Buckeye Brook and its tributaries and Tributaries to Warwick Pond to be listed on the State's 303(d) list, are described below.

1.5.1 Waterbody Class and Designated Use

§ 1.9 of the Water Quality Regulations (RIDEM, 2018a) describes the water use classification. All surface waters shall be assigned to a class that is defined by the designated uses, which are the most sensitive, and therefore, governing water uses which it is intended to protect. Surface waters may be suitable for other beneficial uses but shall be regulated to protect and enhance the designated uses. In no case shall waste assimilation or waste transport be considered a designated use.

§ 1.9 (E)(3) of the Water Quality Regulations (RIDEM, 2018a) states that all freshwaters hydrologically connected to and upstream of Class B, B1, SB, SB1, C, or SC waters shall be Class B unless otherwise identified in § 1.25 of the Water Quality Regulations. Buckeye Brook and Tributaries to Warwick Pond are listed as Class B.

The following excerpt from § 1.9(B)(3) of the Water Quality Regulations (RIDEM, 2018a) describes Class B freshwaters and their designated uses:

> *These waters are designated for fish and wildlife habitat and primary and secondary contact recreational activities. They shall be suitable for compatible industrial processes and cooling, hydropower, aqua cultural uses, navigation, and irrigation and other agricultural uses. These waters shall have good aesthetic value.*

1.5.2 Numeric Water Quality Criteria

The water quality standards for aquatic life criteria for toxics, including dissolved metals, set forth in § 1.26(D) of the Water Quality Regulations (RIDEM, 2018a) state that “to protect aquatic life, the one-hour average concentration of a pollutant should not exceed the acute criteria more than once every three years on the average. The four-day average concentration of a pollutant should not exceed the chronic criteria more than once every three years on the average. These aquatic life criteria shall be achieved in all waters, except mixing zones, regardless of the waters’ classification.

Hardness is a measure of the concentration of cations in solution (Minton, 2002), with hardness usually measured as calcium carbonate ($CaCO_3$) equivalents in mg/l. An increase in hardness decreases the toxicity of metals because calcium and magnesium cations compete with the metal ions for complexing sites, allowing fewer metal complexes to form and therefore resulting in a lower level of toxicity (Minton, 2002).

The chronic and acute freshwater criteria of metals apply to the dissolved form and are calculated using water hardness (in mg/l as CaCO3) based on equations in §§ 1.26(K) of Rhode Island’s Water Quality Regulations (RIDEM, 2018a) shown below in Table 1.2. The criterion for total iron is not dependent upon the hardness of the water sample but is a single chronic value of 1000 µg/L for all conditions.

§§ 1.10(C) and 1.26(D)(4) of Rhode Island’s Water Quality Regulations (RIDEM, 2018a) denote that acute and chronic aquatic life criteria for freshwaters shall not be exceeded at or above the lowest average 7 consecutive day low flow with an average recurrence frequency of once in 10 years (7Q10). U.S. Geologic Survey (USGS) gages located near Tributaries to Warwick Pond and Buckeye Brook were reviewed, and conditions prior to sampling dates were above 7Q10.

Table 1.2 Applicable Freshwater Criteria Equations

Parameter	**ACUTE (µg/L)** $CF \times e^{(m_a[\ln Hardness] + b_a)}$			**CHRONIC (µg/L)** $CF \times e^{(m_c[\ln Hardness] + b_c)}$		
	CF =	m_a	b_a	CF =	m_c	b_c
Cadmium (Cd)	@*	1.0166	-3.924	@*	0.7409	-4.719
Copper (Cu)	0.96	0.9422	-1.700	0.96	0.8545	-1.702
Lead (Pb)	#*	1.273	-1.46	#*	1.273	-4.705
Zinc (Zn)	0.978	0.8473	0.884	0.986	0.8473	0.884

@ = Cadmium Conversion Factors: Acute CF= 1.136673 – [(ln H) x 0.041838]; Chronic CF= 1.101672 – [(ln H) x 0.041838]

= Lead Conversion Factors: Acute and Chronic CF= 1.46203 – [(ln H) x 0.145712]

*When an ambient hardness of <25mg/l is used to establish for lead or cadmium, the CF should not exceed one.

One exceedance of the chronic criteria is acceptable, given that the State's Water Quality Regulations stipulate "the four-day average concentration of a pollutant should not exceed the chronic criteria more than once every three years on the average". However, more than one exceedance would constitute a violation of chronic criteria resulting in the waterbody being listed as impaired for the specific constituent. Similarly, one exceedance of the acute criteria is acceptable, given that the State's Water Quality Regulations (WQRs) stipulate "the one-hour average concentration of a pollutant should not exceed the acute criteria more than once every three years on the average". However, more than one exceedance would constitute a violation of acute criteria which would require that the waterbody be added to the list of impaired waters.

In some instances, a single exceedance of the criteria may be viewed as non-compliance with the standards if there is strong evidence that the criteria could be exceeded again within a three-year period. More specifically, one exceedance may be considered a violation of criteria where RIDEM has knowledge of an actual or potential upstream pollution source or where the exceedance occurred during a wet weather event, and it is considered likely that the condition would reoccur, and the criteria would be exceeded again within a three-year period.

In dry weather, hardness values ranged from 30.4 to 59.4 mg/L, with the landfill stream reaching a high of 98 mg/L. Wet weather values ranged from an observed low of 15 mg/L during Wet Weather 1 at the airport outfall OF08 to a high of 98 mg/L observed at the landfill stream station. The resulting range of numeric water quality concentration criteria for dissolved cadmium (Cd), copper (Cu), lead (Pb), and zinc (Zn) are shown in Table 1.3, and the data tables and criteria evaluations are in Appendix A.

Table 1.3 Range of Water Quality Criteria Utilized for the Buckeye Brook TMDL

Hardness as $CaCO_3$ (mg/L)	Cadmium (µg/L)		Copper (µg/L)		Lead (µg/L)		Zinc (µg/L)	
	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute	Chronic
15	0.31	0.07	2.25	1.77	7.30	0.28	23.5	23.7
30	0.62	0.11	4.32	3.20	17.0	0.66	42.2	42.6
60	1.23	0.17	8.31	5.79	36.9	1.44	76.0	76.6
90	1.82	0.23	12.2	8.18	57.6	2.24	107.2	108.0
100	2.01	0.25	13.4	8.96	64.6	2.52	117.2	118.1

The criterion for total iron is not dependent upon the hardness of the water sample but is a single chronic value of 1000 µg/L for all conditions. The target criteria concentrations for dissolved copper, cadmium, lead, and zinc were calculated using the observed hardness values of the field samples. RIDEM evaluated hardness value distributions during both dry and wet weather conditions, as follows:

For TMDL assessments, dry weather acute and chronic criteria calculations used the average hardness of all stations by survey for each designated waterbody segment. In addition to the two dry weather surveys, the prestorm samples (12/9/2008, 2/1/2011) for the two wet weather events were evaluated as being dry weather samples. The stations used for the Tributaries to Warwick Pond were BB00 and BB02, while the Buckeye Brook segment averaged the hardness values from BB03, BB04, BB05A, OF08, TA0, and AP01. The resultant criteria were compared against the observed dissolved metal concentration collected at each sample location for each survey date to determine if an exceedance occurred.

The criteria for the wet weather surveys were calculated as follows:

1. Acute criteria: For each wet weather survey, the observed hardness values from all the stations in a waterbody segment for each run were averaged together to get an average hardness for that run. The averaged hardness values for each run were used to calculate the acute criteria for the segment using the equations in Table 1.2. The acute criteria associated with the waterbody segment were then compared against the observed dissolved metal concentration at each station to determine if criteria were exceeded. This procedure was followed for each wet weather run for each storm. The first wet weather event used Runs 1 (12/10/2008) and 2 (12/11/2008) as wet weather samples. The second wet weather event used Runs 1 (2/3/2011), 2 (2/6/2011), and 3 (2/8/2011) as wet weather samples.

2. Chronic criteria:
    a. Wet Weather 1 averaged Runs 1 (12/10/2008) and 2 (12/11/2008) samples to calculate the average hardness and averaged observed concentrations for each station. The hardness was then averaged by segment, and the resulting hardness concentration was used to calculate the chronic criteria for each station sampled during the storm event. The calculated criteria were compared

against the averaged observed concentration for each sampling station to determine if an exceedance occurred.

b. Wet Weather 2 was conducted over a 6-day period from February 3rd to February 8th, 2011 and Runs 1 (2/3/2011), 2 (2/6/2011), and 3 (2/8/2011) samples were used as follows since the temporal spacing of the samples did not allow for the averaging of all three samples for each station to calculate the chronic criteria. Instead, the hardness values were averaged for Runs 1 (2/3/2011) and 2 (2/6/2011) samples and for Runs 2 (2/6/2011) and 3 (2/8/2011) samples. This resulted in two averaged hardness values for each station for the storm. The hardness was then averaged by segment, and these resulting values were used to calculate the criteria for each pair of samples collected. The observed dissolved metals concentrations for Runs 1 (2/3/2011) and 2 (2/6/2011) and for Runs 2 (2/6/2011) and 3 (2/8/2011) were averaged together for each sampling station. The calculated criteria were compared to the averaged observed metals concentrations by station to determine if there was an exceedance of the criteria.

This TMDL finds that a combination of stressors is contributing to the observed biodiversity impairments in Buckeye Brook and the Tributaries to Warwick Pond. The uncontrolled discharge of stormwater and hydrologic alterations associated with the highly urbanized watersheds, violations of ambient water quality criteria for various metals, discharge of propylene glycol (occurring prior to and at the time of sampling in 2008 – 2011), extensive growth of iron fixing bacteria on substrates downstream of the airport outfalls and the Truk-Away Landfill are all believed to be stressors contributing to the observed biodiversity impairments. This TMDL establishes numeric water quality targets for dissolved cadmium and total iron for Tributaries to Warwick Pond and numeric water quality targets for dissolved copper, cadmium, and lead and total iron for Buckeye Brook. This TMDL also establishes the numeric criteria targets of dissolved oxygen and narrative criteria targets in the RI Water Quality Regulations (RIDEM, 2018a) are required to support aquatic life, which are expected to be achieved through reduction of metals, propylene glycol, and stormwater.

A stormwater permit (RIPDES RI0021598) issued by RIDEM to the RI Airport Corporation in July 2012 requires the collection and treatment of propylene glycol-impacted stormwater and discharge to the City of Warwick's sanitary sewer system. These permit requirements strictly control the discharge of propylene glycol to Buckeye Brook and the Tributaries to Warwick Pond. The permit contains terms and conditions, including narrative/numeric effluent discharge limits based on technology-based effluent limitations and water quality-based effluent limitations as well as special conditions such as supplemental controls and Best Management Practices that may be needed to ensure that the goals of the CWA are met.

The TMDL must ensure that the water quality criteria for dissolved oxygen are also met. Based on historical monitoring of in-stream dissolved oxygen levels, RIDEM has determined that implementation of new aircraft/airfield source water contamination prevention measures at T.F. Green Airport (including construction of propylene glycol treatment and diversion structures completed in the fall of 2014) will prevent violations of in-stream DO criteria associated with propylene glycol discharges. A review of the monitoring reports required by the permit from the 2012 through the 2017 deicing seasons shows that the deicing management system that became operational at T.F. Green Airport in October 2014 has markedly improved the propylene glycol collection efficiencies and reduced propylene glycol concentrations in stormwater. Monitoring of deicing events for the 2014-2015 through 2016-2017 seasons after the facility became operational finds an average propylene glycol collection efficiency of 65%. These results show a marked improvement from propylene glycol collection efficiencies reported prior to the facility becoming operational which averaged 39% for the 2011-2012 through 2013-2014 seasons. It also compares favorably with the expected collection efficiency of 60% reported in the 2012 RIPDES Permit Fact Sheet.

Concentrations of propylene glycol in stormwater discharged from the airport's outfalls reflect improvements made to their deicing management system. Comparing outfall monitoring results from pre- and post- facility operations finds Outfalls 002 and 003 which discharge to Tributaries to Warwick Pond had an average decrease of propylene glycol concentrations of 69%, whereas Outfall 008 had a 97% reduction. Comparing stream monitoring results for the same periods finds propylene glycol concentrations have decreased from an average of 14 mg/L before the facility was operational to below detection (<10 mg/L) for deicing events after the facility was operational. In-stream concentrations of COD and BOD for the same period finds average decreases of 77% and 82%, respectively. Appendix C contains the results of deicing event monitoring of the outfalls and stream stations as well as the propylene glycol collection efficiencies. This TMDL also requires reductions in iron levels to meet water quality standards and in turn prevent the dissolved oxygen violations observed in the summer months associated with their growth.

Among the physical, chemical and biological criteria set forth in § 1.10(B)(1) of RI's Water Quality Regulations are that waters shall be free of pollutants in concentrations or combinations or from anthropogenic activities that adversely affect the physical, chemical, or biological integrity of habitat (RIDEM, 2018a). Mitigation of the hydrologic alterations and pollutant loads associated the discharge of uncontrolled runoff from the highly impervious watersheds are addressed by stormwater control requirements placed on both the Rhode Island Department of Transportation and the City of Warwick to implement the Buckeye Brook Bacteria TMDL. Both MS4 operators are required to undertake structural improvements to eliminate or treat impervious cover to act as if it were eliminated to achieve a 10% impervious cover. The activities undertaken by the MS4 operators for the bacteria TMDL will have benefits for the biodiversity impairment. This TMDL does not establish separate targets to address hydrologic alterations.

2.0 DESCRIPTION OF THE STUDY AREA

2.1 Project Stream Systems

There are two primary waterbody segments in this study: Tributaries to Warwick Pond and Buckeye Brook. Buckeye Brook flows in a southeast direction from the southernmost point of Warwick Pond into Old Mill Creek, which is south of Conimicut Point, and ultimately

Narragansett Bay. Buckeye Brook water body segment has three tributaries, Lockwood, Warner, and Knowles (Parsonage) Brooks. Except for Warner Brook, none were included in the biodiversity study for this TMDL. A station on Warner Brook was established to document water quality conditions in a highly urbanized sub-watershed not influenced by either TF Green Airport or the landfill. Results from this station are presented in the Final Data Report; however, they are not included here, because the station is not within the two study areas that are the focus of this TMDL.

The Tributaries to Warwick Pond are made up of a small stream system north of the airport that empties into Spring Green Pond and the outlet of the pond joins another first order stream that drains an agricultural area located north of Airport Road. Table 1.1 lists the applicable waterbodies in this TMDL, and Figure 1.1 shows the hydrologic boundaries of the stream systems.

The two watersheds are highly urbanized and encompass the majority of the area that is the site of Rhode Island's primary airport, T.F. Green. The tributaries north of Warwick Pond have a drainage area of 1.2 mi^2 and the Buckeye Brook watershed drainage area is 2.55 mi^2.

As part of the Airport Safety Improvement Program, an Engineered Materials Arrestor System (EMAS) safety over-run was constructed at the approach end of runway 34. The tributary stream that receives the discharges from outfalls 008 and 009 was diverted around a cofferdam for the project. After completion, the re-routed stream bed remained as a permanent change.
Another part of the T.F. Green airport improvement programs was the relocation of the Winslow Park athletic fields to a site that is adjacent to the maintenance building on the north-eastern side of the airport property. The project is complete and open for operation. Rain gardens and infiltration ponds were constructed in this area to handle the storm water runoff for the new fields.

The tributary reach that flows along the east side of the airport property between Airport Road and Lake Shore Drive was redesigned to make a meandering stream system in this area and the culverts under the drive were replaced with larger conduits to compensate for the increased storm water flows observed at Airport Road and Outfalls 002 and 003 during some wet weather events, and to provide enhanced accessibility for the annual alewife passage to upstream spawning areas. The old system with the smaller culverts under the drive could not handle some of the larger storm water flows, resulting in a flooded road crossing. The replacement with larger culverts and the channel modifications up-stream of Lake Shore Drive will reduce the velocity of the flows and eliminate the flooding issues associated with the increased storm water flows.

The perimeter road and other low berms were removed as well as the airport chain link fence to allow more freedom of movement within the wetland area by native animals. Construction for these improvements started in July 2015 and was completed by September of the same year. The US Army Corps of Engineers report dated January 3, 2017 stated that performance standards are being met at all mitigation sites that no additional remedial actions were recommended at this time.

2.2 Watershed History

The recorded history of Warwick and the Buckeye Brook watershed area began with the arrival of the Europeans in 1636. The attractions of the region to colonists were: the natural resources afforded by the geographic and topographic diversity that allowed settlers to hunt, fish, and farm in abundance. The lowland and central portions of Warwick, in which the study areas are found, is generally composed of glacial outwash soils. These soils are well sorted, well drained, sandy, and loosely packed. They are especially amenable to farming and building construction.

Hillsgrove State Airport (now T.F. Green Airport) was constructed in 1931. In the same year, Warwick transformed from a town to a city, complete with a mayor-city council form of government. The post WWII era brought a rash of newcomers and development to the area, filling the area with gas stations, restaurants, and the necessary municipal developments to support the expanding population. As transportation in the area gradually improved, many residents began to transform their summer houses along the coast into year-round residences. In spite of this development, a few areas have managed to remain as open green space. The entire study area, situated among the residential developments, industrial parks, and the airport, has continued to provide a habitat for a diversity of wildlife. Buckeye Brook itself remains one of the only undimmed herring runs left in the region.

2.3 Water Quality History

RIDEM's Baseline Monitoring Program had a biological sampling station on the main stem of Buckeye Brook at the Old Warwick Road crossing. The ESS Group conducted several biological surveys at this site starting in 2003 (ESS, 2004, ESS, 2005), with the last one occurring in 2008. Because the monitoring at this locale was strictly biological, only field water quality measurements are collected that included dissolved oxygen, temperature, and specific conductivity. Chemistry and pathogen sampling was not conducted for these surveys. This location has been rated as moderately impaired for fish and wildlife habitat.

University of Rhode Island's Watershed Watch and the Buckeye Brook Coalition have performed volunteer monitoring on the brook and its tributaries since 2008, collecting grab samples twice a month from April through October. Two main stem stations were monitored by the Watershed Watch volunteers in Warwick, RI. One was located at the end of Novelty Road, and the other was at the entrance to Old Mill Creek at Tidewater Drive. Constituents sampled included enterococci, chloride, pH, dissolved nitrogen-nitrate, dissolved nitrogen-ammonia, dissolved ortho-phosphate, total nitrogen, and total phosphorus.

URI Watershed Watch in cooperation with the RI Airport Corporation and the Buckeye Brook Coalition added a winter sampling program in 2012 – 2013. Dissolved oxygen and temperature were measured at six locations within the watershed. The sampling period was once a month from July 2012 to January 2013, with four chlorophyll *a* samples collected from August to November. Four stations were on the mainstem of Buckeye Brook and two were on Spring Green Pond and Warwick Pond. The four main stem stations for Buckeye Brook were located at Lakeshore Drive, Warwick Avenue, Novelty Road, and Tidewater Drive. A second winter sampling effort is scheduled to commence in November 2013 at the same six stations. The constituents being sampled include propylene glycol, total dissolved solids, dissolved oxygen, and temperature.

The watersheds are dominated by the presence of Rhode Island's major airport, T. F. Green. During the winter months, aircraft de-icing and anti-icing operations are conducted; historically, the excess propylene glycol runoff would flow into the stream systems at two primary locations. One site discharges to the tributary stream segment of Warwick Pond above Lake Shore Drive, and the other site, which is the largest outfall from the airport, discharges to Buckeye Brook, downstream of the outflow from Warwick Pond. The presence of compounds used in anti-icing and de-icing operations (propylene glycol) was detected in the brook downstream of Warwick Pond during winter surveys conducted on behalf of the Rhode Island Airport Corporation (RIAC) in the winter of 2000-2001.

On September1, 2012, a new RIPDES permit for T.F. Green was issued that required RIAC to develop and implement BMPs to promote source reduction and pollution prevention that will be protective of freshwater quality standards and criteria in receiving waters to include dissolved oxygen, aquatic toxicity, foaming, nuisance odors and nuisance bacteria growth. A system went operational in October 2014 and is designed to divert concentrations of propylene glycol when thresholds in the permit are exceeded.

Additionally, the Truk-Away Landfill, located to the west of Buckeye Brook, operated as a solid waste landfill between 1970 and 1977. Initially, a site inspection was performed in 1993 by CDM Federal Programs Corporation (CDM, 1993), and several monitoring wells on the landfill property were sampled by Lincoln Environmental for RIDEM in December 2004 (Lincoln Environmental, 2005). Several other investigations and evaluations of the site have taken place in the interim. Table 2.1 lists historic monitoring conducted in the Buckeye Brook watershed.

Table 2.1 Historic Monitoring Conducted in Buckeye Brook Watershed

Primary Organization	Sample Location	Time Period	Analyte
U.S. Environmental Protection Agency (USEPA)	Main area of Truk-Away Landfill	1993	Soil and Leachates
RI Dept. of Environmental Management (RIDEM)	Buckeye Bk at Old Warwick Avenue Bridge crossing	2002-2005	Biological Assessment
RI Dept. of Environmental Management (RIDEM)	Truk-Away Landfill groundwater from monitoring wells	2005	VOCs
RI Dept. of Environmental Management (RIDEM)	Buckeye Bk, Warner Bk, Lockwood Bk, Knowles Bk, Old Mill Creek, Tributaries to Warwick Pond	2006	Field measurements (Dissolved Oxygen, Temperature, Specific Conductivity), Fecal Coliform, Enterococci
Watershed Watch, URI	Buckeye Bk, Lockwood Bk, Warner Bk	2004 -2012	Fecal Coliform, Enterococci, Dissolved Nitrates, Dissolved Ammonia, Dissolved Orthophosphate, Total Nitrogen, Total Phosphorus, pH, Chlorides
Watershed Watch, URI	Buckeye Bk, Spring Green Pond, Warwick Pond	Winter 2012-13	Propylene Glycol, Dissolved Oxygen, Total Dissolved Solids (TDS), Temperature
Truk-Away Landfill Joint Defense Group	Truk-Away Landfill	August 2019 Winter 2020-21	Documented in Site Investigation Work Plan and Supplemental Site Investigation Report

2.4 Impervious Cover as Predictor of Biodiversity Impacts

The watershed's impervious cover (IC) is considered separate from the rest of the land use categories and is often considered a standalone value that directly relates to the health of a waterbody (Center for Watershed Protection, 2003). The percentage of impervious cover increases as the urbanization of a watershed progresses over time. Impacts due to increased imperviousness can manifest in many areas other than water quality. Hydrologic impacts such as decreased groundwater recharge, lower base flows and increased runoff can also cause changes in stream morphology. Altered morphology can result in a flashier, less stable stream that degrades the quality of habitats for aquatic life. Elevated pollutant loads, temperatures, as well as increased sediment transport are some of the water quality impacts associated with high IC watersheds. All this together can impact not only aquatic life but degrade the waterbody's recreational potential. Figure 2.1 shows the impacts associated with impervious cover.

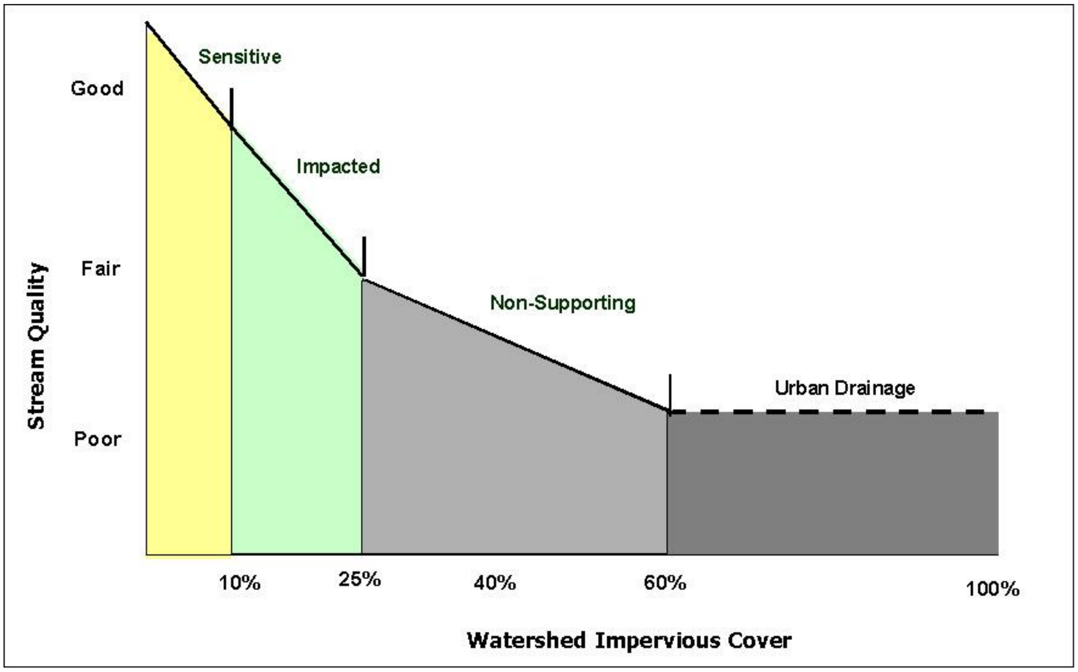


Figure 2.1 Watershed Impervious Cover versus Stream Quality (EPA/ENSR, 2005)

3.0 RIDEM AQUATIC LIFE USE STRESSOR STUDY

In 1998, the state's Integrated Water Quality Monitoring and Assessment Report 305(b) and 303(d) list identified Buckeye Brook (at that time, inclusive of the Tributaries to Warwick Pond) as non-supporting for fish and wildlife habitat. The cause of the impairment is attributed to the poor comparability of bioassessment metrics evaluating these brooks' benthic-macroinvertebrate community and habitat to a reference site. The Rhode Island Department of Environmental Management conducted a sampling project to characterize the geographic extent and severity of the Buckeye Brook Aquatic Life Use (AQLU) impairment and to identify potential causes and/or pollution sources contributing to the impairment. Water quality and/or benthic biological samples were collected from nine sites in the Buckeye Brook watershed over the course of four surveys from July 2008 through February 2011 that consisted of four dry weather and two wet weather surveys, one of which was during a winter icing event.

3.1 Methodology

3.1.1 Stations

Eight stations were selected in the two watersheds for the surveys. Three stations were located on airport property, two on tributaries to Warwick Pond and three on the Buckeye Brook stream system. A ninth station for Adamsville Brook in Adamsville, RI was used as a biological reference site by the ESS Group, Inc. Table 3.1 lists the stations as well as their location, description, type of sampling conducted, and the reasoning or purpose of the selection.

Figure 3.1 shows the location of the sampling stations within the watershed, and Figure 3.2 is a more detailed view of the stations sampled in and adjacent to T.F. Green Airport property.

3.1.2 Parameters

Samples were collected for water quality, with biological and toxicity sampling conducted during the second dry weather survey. Toxicity testing was also conducted during the second wet weather survey under icing conditions. The water quality samples were analyzed for dissolved trace metals that included Arsenic (As), Copper (Cu), Cadmium (Cd), Manganese (Mn), Lead (Pb) and Zinc (Zn) as well as Total Iron (Fe). Other constituents included Hardness as $CaCO_3$, five-day Biological Oxygen Demand (BOD_5), Chloride (Cl), Ammonia-Nitrogen (NH_3-N), Nitrate+Nitrite-Nitrogen (NO_2+NO_3-N), Total Kjeldahl Nitrogen (TKN), Total Phosphorus (TP), Total Suspended Solids (TSS), Total Organic Carbon (TOC), pH, and Propylene Glycol. All water quality and toxicity samples were collected by RIDEM staff.

The water quality analyses, with some exceptions were conducted at the RI State Health Laboratories in Providence, RI. ESS Laboratories in Cranston, RI conducted the NH_3-N, TKN, TOC and Propylene Glycol analysis. Field measurements consisting of dissolved oxygen (D.O.), temperature in degrees centigrade (° C), and specific conductance in microsiemens per centimeter (µS/cm) were measured by RIDEM staff in the field using an YSI-85 meter. Field data was collected during all sampling events. All constituents listed were analyzed for all surveys except for TOC, which was only analyzed for the second dry weather survey when biological sampling was conducted, and Propylene Glycol, which was analyzed for the wet surveys only. The toxicity samples collected by RIDEM staff were delivered to the EPA Region 1 Laboratory at Chelmsford, MA where the toxicity testing was conducted by the laboratory staff. A Two Species – 7 Day Chronic Toxicity Test was done for *Ceriodaphnia dubia* (daphnid) and the *Pimephales promelas* (fathead minnow). Toxicity sampling was conducted during the first dry weather survey and during the second wet weather survey under icing conditions. Toxicity sampling runs were conducted every other day to collect water to replenish the specimen tank. The Quality Assurance Project Plan (QAPP) is available on the RIDEM website at: http://www.dem.ri.gov/pubs/qapp/buckbio.pdf

Table 3.1 Biodiversity Sampling Station Locations and Description

Station ID	Location	Description	Type	Purpose
BB00	Unidentified tribs to Warwick Pond above Airport Road	In-stream: Upstream of Airport Road culvert	Water Quality, Biological, CPOM, FPOM, TOC	Background sample of stream away from airport and landfill influence
BB02	Warwick Pond Tributary @ Lakeshore Drive	In-Stream, Downstream of culverts under Lakeshore Dr.	Water Quality, Toxicity, Biological, CPOM, FPOM, TOC	Brackets airport Outfalls 002 and 003 with background site BB00
BB03	Buckeye Brook @ Lakeshore Drive	In-stream, Exit of Warwick Pond	Water Quality, Toxicity	Separates Warwick Pond from confluence of airport Outfalls 008 and 009 with Buckeye Bk
BB04	Buckeye Brook @ Rufus Road	In-stream: Downstream of confluence of Buckeye Brook and airport outfall flows	Water Quality, Toxicity, Biological, CPOM, FPOM, TOC	Samples the brook after the confluence of all airport outfalls and the landfill
BB05A	Buckeye Brook downstream of Old Warwick Avenue	In-stream and approximately 1000 ft downstream of the ESS Biological Monitoring Site	Water Quality, Toxicity, Biological, CPOM, FPOM, TOC	To compare the 2008-09 monitoring results to the ESS biomonitoring at BB05 located at Old Warwick Avenue where several stormwater outfalls are located (RIDOT; City of Warwick)
OF08	Discharge point of outfall 008	TF Green Airport Outfall 008 discharge	Water Quality, Habitat Assessment, Toxicity	Isolates Outfall 008 flows from landfill influence
TA01	Stream from Truk-Away Landfill	In-stream, prior to confluence with stream from Outfall 008	Water Quality, Habitat Assessment, Toxicity	Isolates landfill stream from outfall stream coming from airport
AP01	Confluence of channels downstream of outfall 008 and landfill	In-stream, prior to discharge into Buckeye Brook upstream of airport service road.	Biological, CPOM, FPOM, TOC	Evaluates biological community in stream downstream of landfill and airport and other upstream areas
Adamsville Brook	@ USGS Gage off Route 81 in Little Compton, RI	In-stream sampling	Macroinvertebrate	Biological Reference Site

Brown shade indicates Buckeye Brook stations on not on the Buckeye Brook mainstem. This theme will be carried throughout the document.

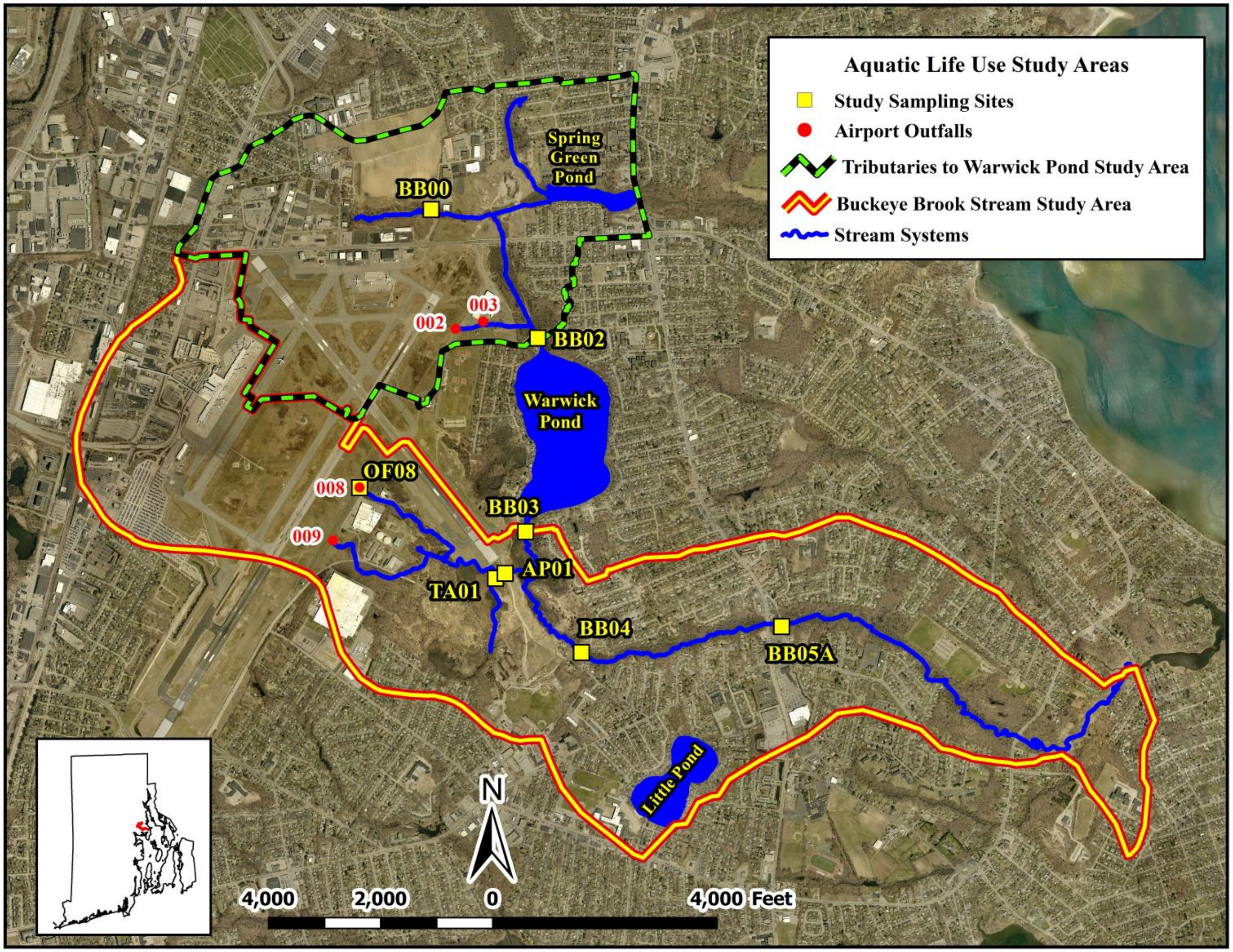


Figure 3.1 Sampling Sites for Aquatic Life Use Stressor Study

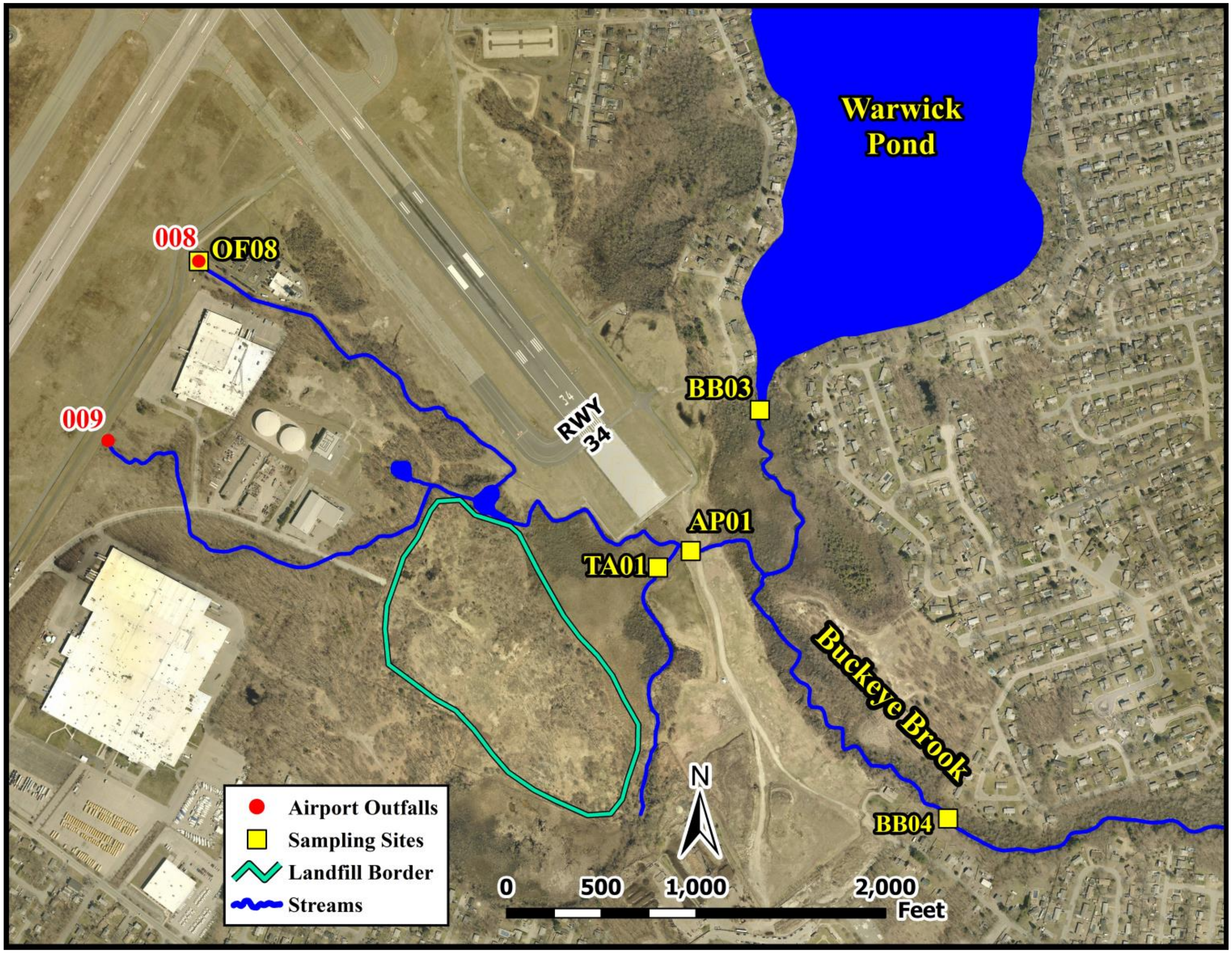


Figure 3.2 Buckeye Brook Tributary and Mainstem Sampling Sites

Biological sampling was done by ESS Group, Inc. and accompanied by RIDEM staff during the second dry weather survey. The station at BB03, Warwick Pond exit, was not evaluated by the ESS Group because the stream bottom at this location was not conducive for the type of biological protocols that were being conducted at the other stations. The ESS Group recommended that this station be eliminated due to the substrate type and lack of riffles. The biological survey included a combination of any or all of the following: Macroinvertebrate sampling, Periphyton sampling, Stream Habitat Assessments, CPOM (coarse particulate organic matter >1mm), and FPOM (fine particulate organic matter, less than 1mm and more than .05 mm).

3.1.3 Land Use

The land use in the study area (RIGIS, 2011) is 43% residential (75% of this value, or 32% of the total land use is medium to high density residential), 19.7% forest and wetland, 16.1% airport, 11.4% commercial-industrial, 5.2% open, 3.3% agricultural, and 2.2% institutional. Figure 3.3 shows a map of the land use for the entire study area. Table 3.2 shows the drainage area associated with each station as well as the acres of impervious cover within each station. Stations BB06 through BB08 were used in the Buckeye Brook Pathogen TMDL field study and are included in this table even though they were not sampled as part of the biodiversity field work.

The watershed's impervious cover (IC) is considered in addition to the land use categories, as studies show that it directly relates to the health of a waterbody (Center for Watershed Protection, 2003). The land use for the study area (RIGIS, 2011) shows that 78.2% of the area can be classified as urban. The remaining 21.8% of the area falls under the general land use categories for agriculture, forest, wetland, and water. A breakdown of the urban development land use shows that the impervious cover (IC) within the study area is significant at 42.1%.

3.2 Dry Weather Surveys

The first dry weather survey was on July 16, 2008 where single grab samples were collected at eight stations for water quality analysis. Station AP01 was not sampled for the first dry weather survey since it was located downstream of Stations OF08 and TA01 and represented the total of these latter two stations. This survey was the first toxicity sampling event for the watershed and water samples were collected and transported to EPA Region 1 Laboratory at Chelmsford, MA for toxicity tests. The first set of toxicity samples were collected along with the water chemistry samples on July 16th, and additional toxicity water samples only were collected on July 18th and July 21st that were used to replenish the water for the 2-species toxicity test. Table 3.3 shows the dates of the biodiversity dry weather surveys and the type of sampling that took place during those events. The first sampling events for both wet weather events were also added to Table 3.3, because those sampling events were conducted prior to the start of each storm and were under dry conditions. The dates of the two wet events are discussed in the wet weather section.

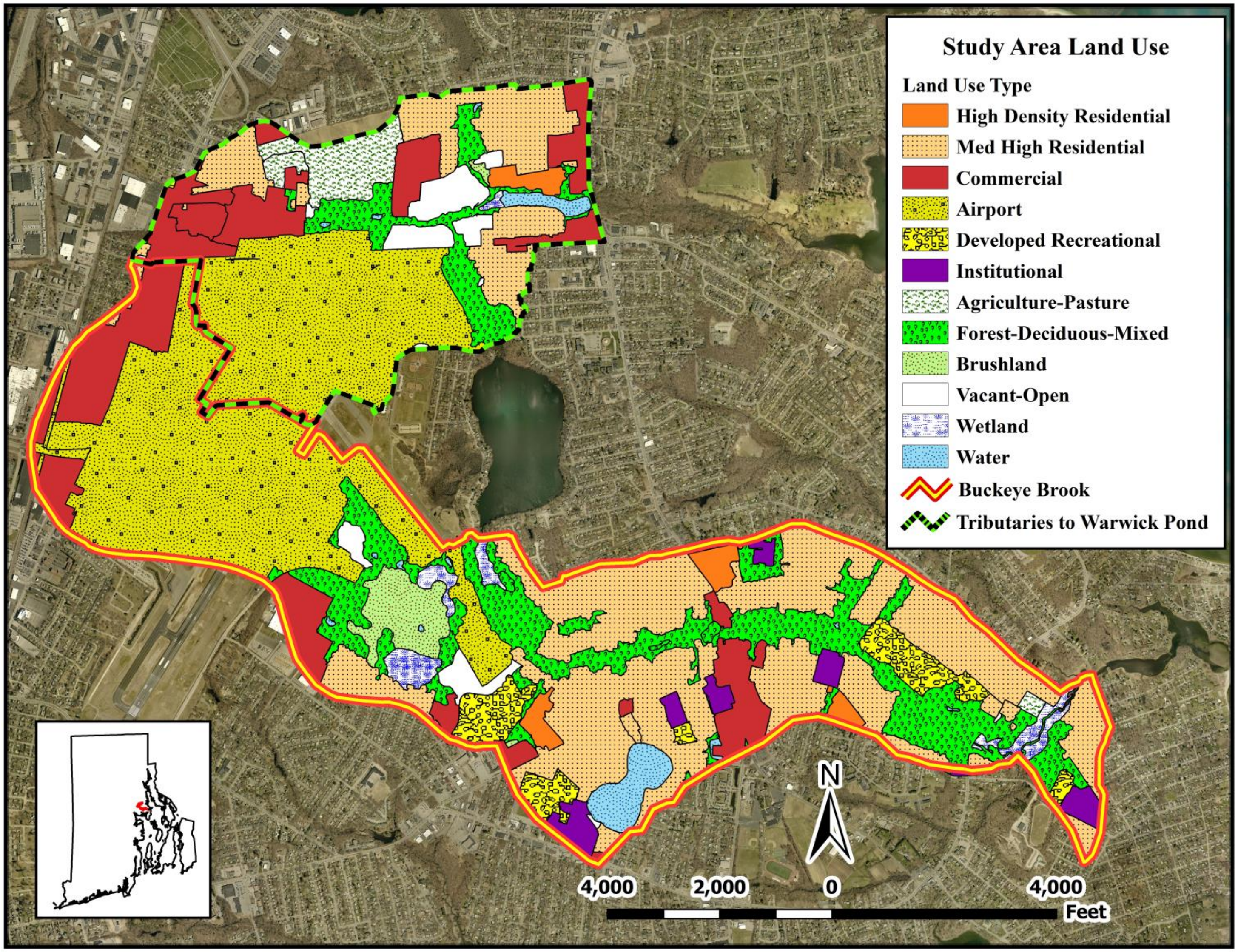


Figure 3.3 Biodiversity Study Area Land Use

Table 3.2 Study Site Land Use, Drainage Area (Acres) and Impervious Cover Percentages

Land Use Type	Tributaries to Warwick Pond			Buckeye Brook				
	BB00	BB02	Sub-Total	BB04	BB05	BB06*	BB07-08*	Sub-Total
Residential	27.6	122.5	150.1	54.26	146.52	228.25	105.77	534.8
Commercial	28.5	32.1	60.5	80.8	10.0	63.3	10.2	164.3
Industrial	44.5	19.4	63.9	34.1				34.1
Airport/Transportation	23.6	252.0	275.6	422.0	4.7	0.3		427.0
Developed Recreational	0.4		0.4	24.7		40.1	10.6	75.4
Pasture and Cropland	51.3	0.1	51.4					
Mixed Forest	22.7	49.2	71.9	103.1	35.0	60.7	64.8	263.7
Brushland		1.6	1.6	43.4				43.4
Vacant/Urban Open	1.2	39.9	41.1	18.3		0.5	3.2	22.0
Wetland		1.6	1.6	22.5			13.6	36.1
Water	0.6	9.2	9.8	1.4		29.3	0.2	30.9
Impervious Cover Percentages for Study Areas								
Total Station Drainage Area	200.4	527.5	727.9	804.7	196.2	422.4	208.4	1631.7
Impervious Cover	100.6	227.0	327.6	351.7	86.3	172.9	55.6	666.5
Percentage Impervious Cover	50.2%	43.0%	**45.0%**	43.7%	44.0%	40.9%	26.7%	**40.8%**

*BB06, 07 & 08 were stations for the 2008 Buckeye Brook Bacteria TMDL. BB06 at end of Novelty Rd; BB07 at West Shore Rd; BB08 at Tidewater Dr.

ESS Group, Inc. accompanied RIDEM personnel for the second dry weather survey on September 10, 2008 and collected biodiversity samples for selected stations as noted in Table 3.3. During the second dry survey, grab samples were collected for water quality chemical analysis from all stations except BB03. As previously explained, Station BB03 at the exit of Warwick Pond was not evaluated by the ESS Group because the stream bed characteristics at this location were not conducive for the type of biological protocols being conducted for the other stations. The sandy substrate, lack of riffles, and the absence of biological diversity were some of the reasons that this station was not a viable candidate for biodiversity sampling.

Table 3.3 Dry Weather Sampling Dates and Sample Type

Station	BB00	BB02	BB03	BB04	BB05A	OF08	TA01	AP01
DW1 July 16-21, 2008	**Chem**	**Chem, Tox**	**Chem, Tox**	**Chem, Tox**	**Chem, Tox**	**Chem, Tox**	**Chem, Tox**	**NS**
DW2 September 10, 2008**	**Chem, Bio**	**Chem, Bio**	**NS**	**Chem, Bio**	**Chem, Bio**	**Bio**	**Bio**	**Chem, Bio**
DW3 December 9, 2008	**Chem**	**Chem**	**Chem**	**Chem**	**Chem**	**Chem**	**Chem**	**NS**
DW4 February 1, 2011	**Chem, Tox**	**Chem, Tox**	**Chem, Tox**	**Chem, Tox**	**Chem**	**Chem, Tox**	**Chem, Tox**	**NS**

Notes: Chem – Water Quality Chemistry samples; Tox – Toxicity samples; Bio – Biodiversity samples; NS – Not Sampled
**This sampling date has been determined to have been influenced by precipitation.

3.3 Wet Weather Surveys

Two wet weather studies were conducted, the first from December 10-11, 2008 and a second from February 3-8, 2011. The first wet survey in December 2008 was during a rainfall event with an average high temperature of 53°F (11.7°C) and a total precipitation of 2.27 inches recorded at T.F. Green Airport. The survey consisted of two runs, the first run on December 10th and one more survey run on the consecutive day of December 11th. A third run was planned on December 12th; however, between the end of the December 11th run until the planned start of the last run, 3.56 inches of rainfall was recorded at T.F. Green Airport, and it was decided to terminate the survey at two wet weather sampling runs. During this event, the samples were analyzed for water chemistry only. A total of eight stations were sampled during the first wet weather event. AP01 was not sampled as it was downstream of TA01 and outfall OF08 and represented the total of the two upstream stations. Table 3.4 shows the dates of the wet weather surveys and the type of sampling conducted.

The second wet weather survey was a winter survey in February 3-8, 2011. The purpose of this survey was to collect water quality and toxicity samples during a winter storm when de-icing and anti-icing solutions were being applied to departing aircraft at T.F. Green Airport. The winter survey proved to be a difficult storm to capture due to the constraints imposed by the EPA laboratory for sample drop-off times and dates when the lab would be available to provide the toxicity analysis. Additionally, the unpredictability of the weather patterns to provide a discrete storm that provided a worst-case scenario to collect runoff from deicing operations was also a challenge. For these reasons, the second wet weather survey was not completed until February of 2011. During this survey, approximately 6 inches of snowfall was recorded at the airport and the average temperature ranged from 20° (-6.7°C) to 38°F (3.3°C). The survey consisted of three runs, Run 1 on February 3rd, Run 2 on February 6th, and Run 3 on February 8, 2011.

Table 3.4 Wet Weather Sampling Stations Dates and Sample Type

Station	BB00	BB02	BB03	BB04	BB05A	OF08	TA01	AP01
WW1 **December 10-11, 2008**	**Chem**	**Chem**	**Chem**	**Chem**	**Chem**	**Chem**	**Chem**	**NS**
WW2 **February 3-8, 2011**	**Chem, Tox**	**Chem, Tox**	**Chem, Tox**	**Chem, Tox**	**Chem**	**Chem, Tox**	**Chem, Tox**	**NS**

Notes: Chem – Water Quality Chemistry samples; Tox – Toxicity samples; NS – Not Sampled

Two stations sampled during the first toxicity survey were swapped for the winter survey at the suggestion of the EPA laboratory staff. Station BB05A was not sampled for toxicity and Station BB00 was added. As show in Figure 3.1, BB05A was located downstream of Station BB04, and any suspected pollutants being discharged from the airport stations would be in the sample collected at BB04. Station BB00 also provided another station that would not have been directly influenced by airport de-icing operations or by runoff from the landfill. Its location north of Warwick Pond in a wetland area served as neutral background sampling location for the toxicity analysis being conducted by the EPA laboratory in Chelmsford, MA.

3.4 Rhode Island Airport Corporation (RIAC) February 2011 Wet Weather Sampling

The February 2011 storm was also sampled by RIAC to fulfill their permit requirement. RIAC's RIPDES Permit (RI0021598) requires that they annually conduct wet weather monitoring during a frozen precipitation event (i.e. snow, sleet, freezing rain) during the deicing season (October 1 – March 31) at the T.F. Green Airport while aircraft deicing was occurring. Locations to be sampled included the stormwater outfalls that discharge to the Buckeye Brook stream system both above and below Warwick Pond. These include airport outfalls 002, 003, and 008 (RIDEM station OF08). Receiving water at the airport's four sample sites included the Tributaries to Warwick Pond at the pond's inlet (BB02), the exit of Warwick Pond (BB03), Buckeye Brook at West Shore Road, and Buckeye Brook at Tidewater Drive. Only stations that overlap with stations sampled for this TMDL study are included on site maps in this document.

Flows from airport outfalls 002 and 003 entered the tributary stream approximately 200 feet above Warwick Pond inlet (BB02), while the flow from airport outfall 008 (OF08) entered Buckeye Brook approximately 0.25 miles downstream of the exit of Warwick Pond (BB03). The next two sampling stations are located at West Shore Road and Tidewater Drive, 1.8 miles and 2.4 miles downstream respectively from the confluence where the flows from the airport outfall 008 and the landfill meet Buckeye Brook. After the January 2012 winter monitoring event, the sampling site at Tidewater Drive was dropped and the Rufus Road station (BB04) was added to provide a sampling site closer to the confluence of the brook and the airport discharge.

Constituents sampled at the airport outfalls by RIAC that were common to the RIDEM study included Arsenic, Copper, Iron, Manganese, Zinc, BOD_5, TOC, TSS, and propylene glycol. The receiving waters were sampled for dissolved oxygen, pH, temperature, BOD_5, TSS, chloride, and propylene glycol. The sampling frequency for the airport outfalls (002, 003, and 008) was every hour for the first 12 hours of the storm, while the RIAC Buckeye Brook sites were sampled every four hours for a period of 48 hours. The RIAC sampling for the airport and stream stations commenced on February 1^{st} at 10:00am and continued until 10:54am on February 3, 2011. Although the data from the 2011 RIAC sampling event was not a part of the RIDEM field survey portion of the study, it is presented in the TMDL alongside the RIDEM data for comparison.

3.5 Results of Water Chemistry Study

This section presents the results of both the dry and wet weather surveys, including water chemistry analytical results and field measurements of dissolved oxygen, temperature, and specific conductance. Table 3.6 shows the field data collected from both the dry and wet weather surveys. Table 3.7 shows the water chemistry results for all dry weather surveys. Tables 3.8 and 3.9 show the water chemistry results for Wet Weather Survey One and Two, respectively. The tables are located at the end of this section. While the September 10, 2008 survey proceeded as a dry weather survey, 4.39" of precipitation occurred between September 6^{th} and 9^{th}, with 0.29" of precipitation on September 9^{th}. Therefore, these samples are likely influenced by precipitation. It was determined that the final assessment of trace metals would be not be affected by analysis as dry or wet weather, given that with a single sample only acute criteria would apply for wet weather. Analysis of acute criteria occurs under dry weather in the same manner as wet weather.

Dry Weather

Dissolved Oxygen (DO)

The waters of Buckeye Brook Watershed are considered Class B, warm water fish habitat waterbodies. The Rhode Island Water Quality Regulations (RIDEM, 2018a) state that these waterbodies must maintain an instantaneous minimum dissolved oxygen concentration of at least 5.0 mg/L, except as naturally occurs in addition to establishing a percent saturation and 7-day average criteria. During both dry weather surveys, the dissolved oxygen levels at four of the nine water quality stations violated the 5.0 mg/L minimum concentration and percent saturation portions of the criteria. Station BB00 is not affected by the airport discharges but had values below concentration criteria for three of the six field measurements. This station is in the middle of an urban wetland area and the low stream flow may account for the low D.O. values, as stagnant water can produce low D.O readings.

Dissolved oxygen measurements were also collected at the two stations near the discharge from the landfill and the airport. At the landfill station (TA01), dissolved oxygen values were measured during the first, third and fourth dry weather surveys with all values except the fourth survey below the instantaneous criterion, averaging 3.38 mg/L. Observed stream velocities at TA01 were very low during the survey, (estimated <0.10 ft^3/sec) which may contribute to the low D.O. values. The dissolved oxygen levels at OF08 which drains the airport tarmac were well above the criteria averaging 9.45 mg/L for dry weather; however, any oxygen demand from pollutants present at this location would be exerted further downstream.

There was a significant decrease in the dissolved oxygen levels observed between Stations BB03 (exit of Warwick Pond) and BB04 (Rufus Road). The dissolved oxygen level at BB04 was an average of 3.44 mg/L lower than the level at BB03 for the three dry weather surveys that also sampled BB03 and BB04 together. During the pathogen field surveys in 2006, the average dissolved oxygen deficit between the two stations from August to October was 2.73 mg/L. After Station TA01, with an average of 3.38 mg/L, Station BB04 had the next lowest overall dissolved oxygen level averaging 5.93 mg/L for the dry weather surveys displayed in Table 3.4. This is likely attributable to the large increase of iron concentrations at BB04 downstream of the confluence of the tributary receiving flow from OF08 and TA01, which also have high iron concentrations.

Propylene Glycol

Propylene Glycol is one of the main constituents used in Aircraft Deicing Fluids (ADFs), and concentrated glycol has a potential BOD_5 demand of 200,000 mg/L. ADFs that contain glycol are diluted with water, and the amount of dilution is dependent upon the outside air temperature at the time of application. If glycol is present in the water column, the BOD_5 values would be much lower than the above number but still significantly higher than the expected background levels usually observed in stream systems. High oxygen demand in stream systems caused by pollutants like glycol can reduce the dissolved oxygen levels within the water column to levels well below the criteria of 5.0 mg/L and would be detrimental to aquatic life forms. If high levels of glycol are in a stream system, the corresponding BOD_5 levels would likewise show an increase in samples collected at the same time and location.

Propylene glycol was sampled for during the third and fourth dry weather surveys, which were the dry weather period just prior to each of the wet surveys in 2008 and 2011. Although during the December 2008 sampling events, the temperatures were not cold enough for the use of aircraft de-icing fluid or anti-icing fluids, glycol samples were still collected for analysis. The February 2011 sampling survey did have temperatures that required the application of de-icing and anti-icing fluids.

The confluence of airport outfall 008 and Buckeye Brook is located between Station BB03 and BB04, so the downstream station BB05A was changed and BB03 added it its place to bracket the discharge from sample Station OF08. The propylene glycol concentrations were below the detection limit of 20 mg/L for all samples collected during the third and fourth dry surveys.

Five-day Biological Oxygen Demand (BOD_5)

Biological Oxygen Demand is a 5-day test procedure and indicates the amount of organic matter present in water. Dissolved Oxygen (DO) is consumed by bacteria when large amounts of organic matter from sewage or other discharges are present in the water. Therefore, a low BOD_5 is an indicator of good quality water, while a high BOD_5 indicates polluted water. Most pristine rivers may have a BOD_5 value below 1.0 mg/L. Untreated domestic sewage has a value of 300 mg/L while treated sewage may range from 10 to 40 mg/L.

The mean BOD_5 ranged from 1.0 to 9.7 mg/L at the stream stations. The station above Warwick Pond have the lowest BOD_5 concentrations for all dry surveys, while the single highest observed concentration was at OF08 for DW4 at 20.0 mg/L. The lowest BOD_5 observed was at Station BB00 with a mean observed concentration of 1.0mg/L for all dry surveys.

Hardness as $CaCO_3$

Hardness is most commonly expressed as milligrams of calcium carbonate ($CaCO_3$) equivalent per liter. Water containing calcium carbonate at concentrations below 50 mg/L is generally considered as soft; 50–150 mg/L, moderately soft to slightly hard, 150–250 mg/L, moderately hard; and more than 350 mg/L, very hard. Hardness is used to calculate dissolved metals criteria and as hardness values increase, the toxicity of metals such as cadmium and lead in the water column will decrease.

Hardness, which is used to calculate dissolved metals criteria, averaged between 44 and 55 mg/L. The Buckeye Brook stream station with the highest mainstem mean hardness concentration was 54.0 mg/L at Station BB04, which was downstream from the confluence of the airport and landfill discharges. The landfill station, TA01, had the highest mean concentration of all stations at 97.3 mg/L.

pH

The pH is the measure of how acidic or basic water is. A pH of 7.0 is considered neutral and the range goes from 0.0 to 14.0, with values less than 7.0 indicating acidity, and greater than 7.0 indicating a base. The criteria for freshwater pH values in the state is 6.5 to 9.0 or as naturally occurs.

The pH values for the stations were in the normal range for stream systems in the state, with averages between pH of 6.74 and 8.01 for all stations. BB03 had the highest observed single grab sample pH that was just above the upper limit of the 9.0 criterion. This station had a pH of 9.22 during the first dry survey. This is not considered a violation of the criterion, due to a single sample exceeding the criterion which is allowable.

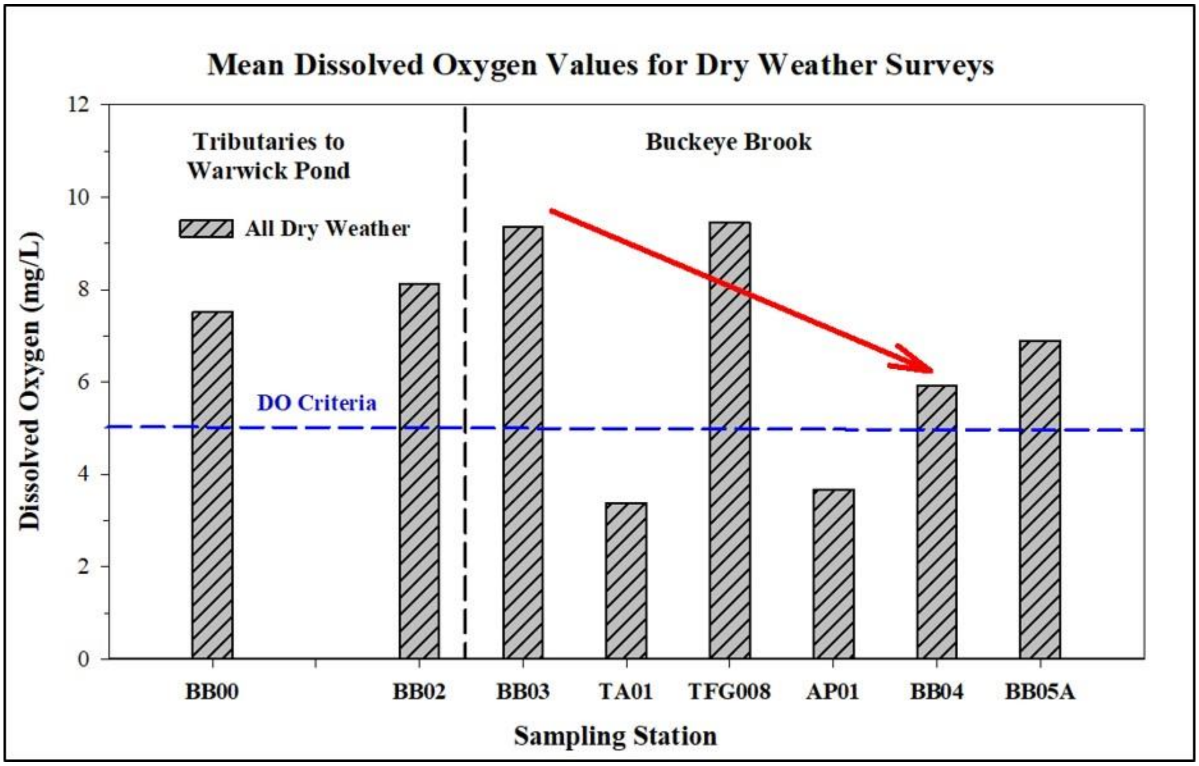


Figure 3.4 Mean Dry Weather Dissolved Oxygen Values for Watershed Survey Sites.[1]
Note: The red arrow denotes decrease in dissolved oxygen between the mainstream Buckeye Brook stations (BB03 upstream of BB04) with the stations TA01, TFG008, and AP01[2] tributary flow joining the mainstem Buckeye Brook between BB03 and BB04.

Total Suspended Solids (TSS)

Total Suspended Solids are solids in water that can be trapped by a filter. TSS measurements can be useful as an indicator of the effects of runoff from construction, agricultural practices, sewage treatment plant discharges, and other sources. TSS can include a wide variety of material, such as silt, decaying plant and animal matter, industrial wastes, and sewage. Suspended sediment can clog fish gills, reduce growth rates, decrease resistance to disease, and prevent egg and larval development. When suspended solids settle to the bottom of a water body, they can smother the eggs of fish and aquatic insects, as well as suffocate newly hatched insect larvae. Settling sediments can fill in spaces between rocks which could have been used by aquatic organisms for homes. Solids concentrations often increase sharply during rainfall, especially in developed

[1] Instantaneous criteron is displayed for informational purposes only. Procedures for assessment purposes under the Clean Water Act Section 303(d) is described in the Rhode Island Consolidated Assessment and Listing Methodology (CALM).
[2] A single dissolved oxygen value was collected at AP01.

watersheds. High concentrations of suspended solids, such as muddy runoff from a construction site, can cause many problems for stream health and aquatic life. The state does not have freshwater TSS numeric criteria for stream systems.

TSS was very low for all stream stations during the dry weather surveys, ranging between a low that was below the detection limit of 1.0 mg/L to a high of 6.0 mg/L at the stream station BB04. As expected, the highest TSS observed was at the landfill station, TA01, with a concentration of 39.0 mg/L for dry weather survey one. There is no numeric criterion for TSS in the Rhode Island Water Quality Regulations (RIDEM, 2018a).

Chlorides

Chloride concentrations of between 1.0 and 100 ppm (parts per million) are normal in freshwater. Chloride is toxic to aquatic life and impacts vegetation and wildlife. There is no natural process by which chlorides are broken down, metabolized, taken up, or removed from the environment. Chloride ions in the environment can come from sodium chloride or from other chloride salts such as potassium chloride, calcium chloride and magnesium chloride. The freshwater chloride criteria are 860 mg/L for acute and 230 mg/L for chronic.

The chloride concentrations for the stream stations averaged from 40.4 mg/L at BB03 to 86.9 mg/L at Station BB00. The mean observed chloride at the landfill (TA01) and airport stations (OF08) were 47.7 and 68.4 mg/L respectively.

Nutrients – Nitrogen and Phosphorus

Nutrients, such as nitrogen and phosphorus, are essential for plant and animal growth and nourishment, but the overabundance of certain nutrients in water can cause a number of adverse health and ecological effects.

Nitrogen is a nutrient needed for plant growth. Nitrogen can be found in several forms in freshwater systems, such as ammonia nitrogen (NH_3-N), nitrite nitrogen (NO_2-N), and nitrate nitrogen (NO_3-N). Ammonia is oxidized by organisms in the water column to nitrite and then to nitrate, which is the form of nitrogen available for plant growth. Common sources of excess nitrate reaching lakes and streams include septic systems, animal feed lots, agricultural fertilizers, manure, industrial waste waters, landfills, and garbage dumps. Currently, the state does not have a freshwater numeric criterion for surface water nitrate-nitrogen, but site-specific permit limits may be assigned based on reasonable Best Available Technologies. There are numeric criteria for ammonia nitrogen that are pH dependent. Using the state's pH criteria range, ammonia concentrations can range from 0.885 mg/L at pH 6.5 to 32.6 mg/L at pH 9.0.

Total Kjedahl Nitrogen (TKN) is the combination of both the ammonia and organic forms of nitrogen. Ammonia and organic nitrogen can enter water through sewage and runoff from land where manure has been applied or stored. Organic nitrogen is not accessible to plants for growth. Total nitrogen (TN) is the sum of all nitrogen forms. There are no State of Rhode Island numeric criteria for TKN or TN in the water quality regulations (RIDEM, 2018a).

Phosphorus (P) is generally considered to be the limiting nutrient for plant growth in freshwater with small quantities occurring naturally mainly from geological sources. A limiting nutrient controls the growth of primary producers, such as algae and aquatic plants. Phosphorus in natural waters and wastewaters is usually found in dissolved organic and inorganic forms or attached to sediment particles. High concentrations generally occur in conjunction with algal blooms. Phosphorus can build up in the sediments of a lake. When it remains in the sediments it is generally not available for use by algae; however, various chemical and biological processes can allow sediment phosphorus to be released back into the water.

In the RIDEM Water Quality Regulations (2018a), lakes, ponds, reservoirs, and kettle holes have an average Total Phosphorus (TP) criterion of 0.025 mg/L. While there aren't numeric TP criteria for stream systems, the average TP for tributaries that flow into these types of waterbodies shall not cause exceedance of this phosphorus criteria, except as naturally occurs, unless the Director determines, on a site-specific basis, that a different value for phosphorus is necessary to prevent cultural eutrophication. Additionally, for stream systems, RIDEM utilizes EPA's 1986 Quality Criteria ("Gold Book") as a component of evaluating compliance with narrative phosphorus criterion. The EPA Gold Book notes Mackenthun (1973) recommends a goal to prevent plant nuisances in streams or other flowing waters not discharging to lakes or impoundments to be less than 100µg/L total phosphorus.

Figures 3.5 through 3.8 show the dry weather concentrations for Total Kjeldahl Nitrogen (TKN) and Ammonia (NH_3-N). While there are no significant dry weather sources of nitrogen or phosphorus in the main stem portion of Buckeye Brook, the mean concentrations for the landfill TKN and NH_3-N samples were 4.29 mg/L and 3.53 mg/L respectively for the dry surveys. Mean TKN concentrations for the stream stations ranged from 0.38 mg/L at BB02 to 1.01 mg/L at BB04. The highest single grab TKN concentration was at the Truk-Away station with 7.28 mg/L at TA01 for the December 2008 DW3 survey.

Ammonia (NH_3-N) levels for all stream stations ranged from 0.13 mg/L at Stations BB02 and BB03 to a maximum of 0.85 mg/L observed at BB04 during the first and third dry surveys. Of all the stations, TA01 had the highest single grab concentration at 7.28 mg/L for the third dry weather survey. The airport outfall (OF08) had mean TKN and NH_3-N values of 0.29 mg/L and 0.09 mg/L respectively for all dry surveys. The second survey only took samples from the AP01, which was the combined flow from the airport and the landfill. TKN and NH_3-N levels at AP01 for the second dry survey were 2.07 mg/L and 1.71 mg/L respectively. The TKN and NH_3-N values for the landfill station were significantly higher than any stream station on Buckeye Brook as well as the outfall from T.F. Green. There were no exceedances of ammonia criteria, the only nutrient for which RI's Water Quality Standards (RIDEM, 2018a) establish a numeric criterion for rivers and streams.

With the exception of Truk-Away sampling station (TA01), Total Phosphorus (TP) levels were uniformly low during dry weather, with concentrations ranging from below the reporting limit of 0.02 mg/L to a high value of 0.23 mg/L for the fourth dry survey at the landfill station, TA01. The values do not exceed the numeric criterion in the RI Water Quality Standards (RIDEM, 2018a) of 0.025 mg/L in lakes and reservoirs or tributaries at the point where they enter such bodies of water causing an exceedance. The flow at station TA01 is fairly stagnant and no increases of phosphorus are evident downstream of its confluence with the mainstem of Buckeye Brook, despite exceedance of the Gold Book recommendation.

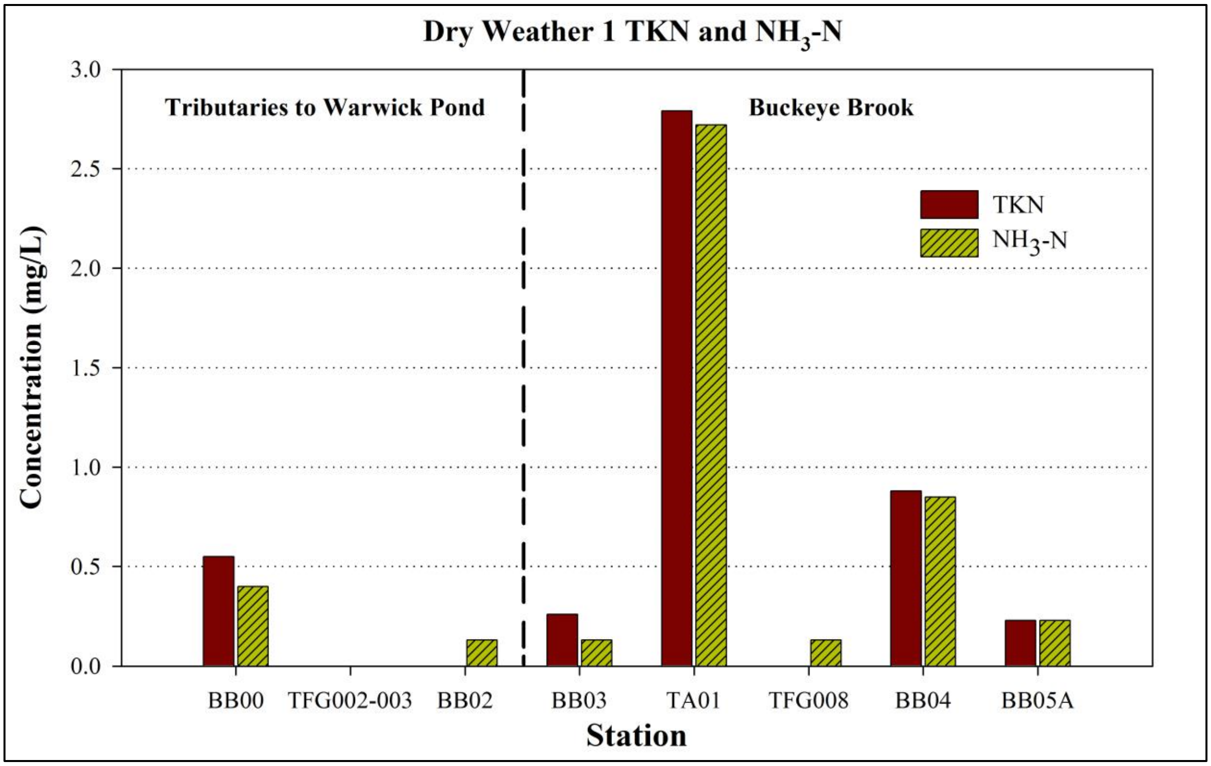


Figure 3.5 Dry Weather 1 TKN and NH_3-N Concentrations

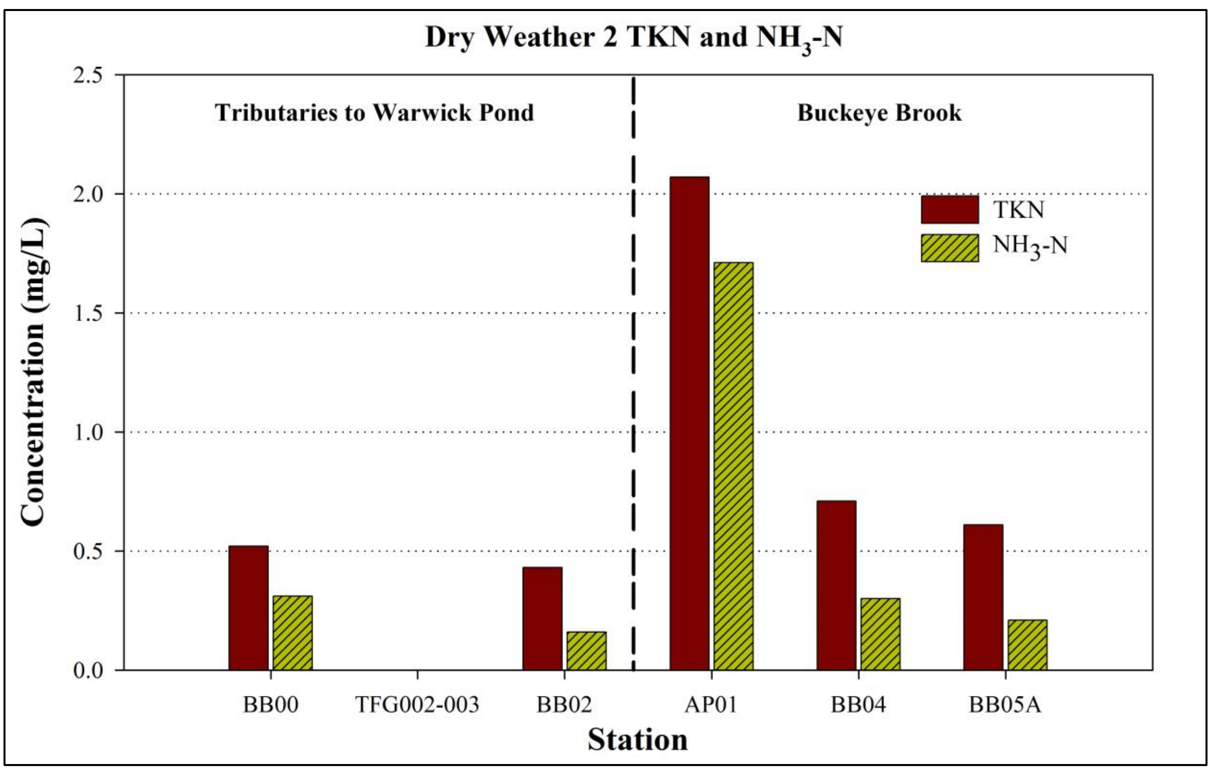


Figure 3.6 Dry Weather 2 TKN and NH_3-N Concentrations

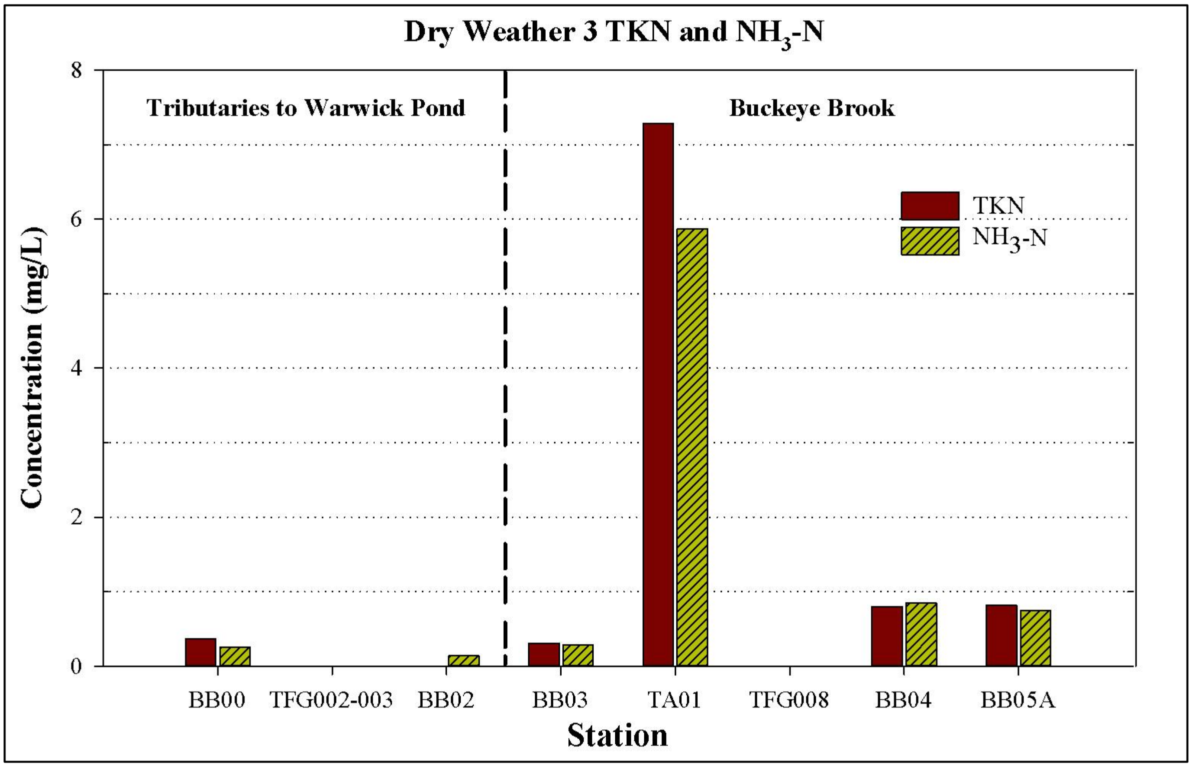


Figure 3.7 Dry Weather 3 TKN and NH_3-N Concentrations

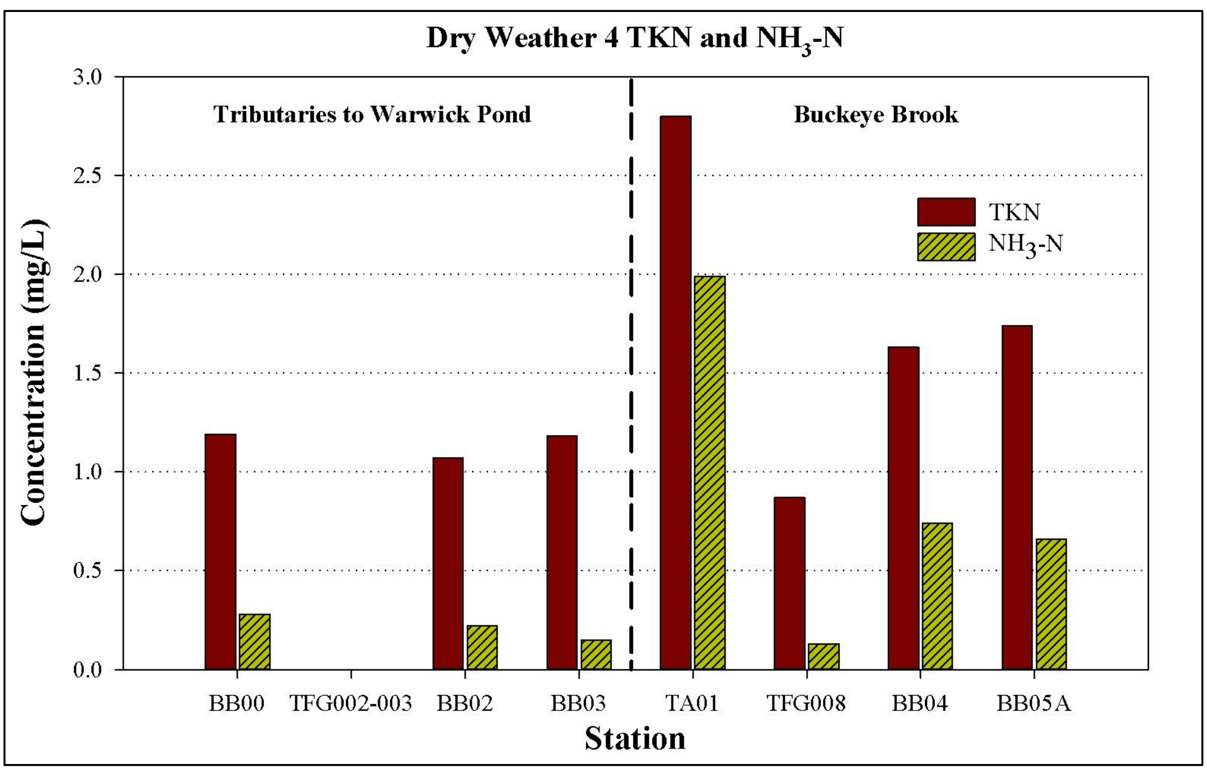


Figure 3.8 Dry Weather 4 TKN and NH_3-N Concentrations

Trace Metals
The trace metals sampled during the biodiversity field surveys were dissolved Arsenic (As), Cadmium (Cd), Copper (Cu), Lead (Pb), Manganese (Mn), and Zinc (Zn) and Total Iron (Fe). The procedure for determining the acute and chronic criteria used to assess the metals data are described in detail in Section 1.5.2 above. Since the metals criteria are dependent upon a waterbody's hardness, the concentration of a metal that exceed the criteria will vary as the hardness changes. The exception is total iron, with a chronic criteria value of 1,000 ug/L. Table 3.5 in this section shows the summary of dry weather metals exceedances. There were dry weather exceedances of the freshwater criteria for dissolved cadmium and lead and total iron.

Cadmium (Cd)
There were five exceedances of the freshwater dissolved cadmium chronic criteria during the three dry surveys. The mean cadmium concentrations for the dry surveys ranged from below the detection limit of 0.06 µg/L to 0.34 µg/L. The stream system above Warwick Pond had three exceedances of criteria. The highest observed cadmium concentration for the Warwick Pond tributaries was at BB00 at 0.40 µg/L. The Buckeye Brook watershed stations had two exceedances of criteria during the dry weather surveys. The mean observed cadmium concentrations in mainstem Buckeye Brook ranged from below the detection limit of 0.06 µg/L to 0.31 µg/L at the landfill station, TA01, which also had the highest single grab dissolved cadmium concentration of 0.58 µg/L during DW3.

Copper (Cu)
There were no dry weather exceedances of the dissolved copper acute or chronic criteria. Mean dissolved copper concentrations were identical for the Warwick Pond tributaries for the dry surveys at 1.74 and 1.17µg/L. The Buckeye Brook watershed stations mean dissolved copper ranged from 0.89 µg/L at the airport outfall station, OF08, to 2.48 µg/L at station BB05A. The maximum single grab concentration observed for dry weather at any station was at BB05A with a value of 3.24 µg/L for the first dry weather survey. Dissolved copper concentrations from both Truk-Away and the airport station were two to three times lower than values observed at the stream stations.

Lead (Pb)
There was one exceedance of the freshwater dissolved lead chronic criteria. The range of the mean dissolved lead concentrations for the Warwick Pond streams was from 0.15 to 0.12 µg/L for BB02 and BB00, respectively. Buckeye Brook stations mean concentrations ranged from a low 0.04 µg/L at OF08 to the maximum of 1.12 µg/L the landfill station, TA01. TA01 and BB04 had the maximum observed single grab concentrations of all the stations at 1.51 and 1.50 µg/L respectively.

Zinc (Zn)
No station exceeded the zinc freshwater criteria during any of the dry weather surveys. The mean dissolved zinc concentrations for the Warwick Pond tributaries were nearly identical at 19.2 and 9.1 µg/L for BB00 and BB02, respectively. The mean zinc concentrations in the Buckeye Brook watershed ranged from a low of 4.5 µg/L at BB05A to a maximum of 15.3 µg/L at TA01.

Total Iron (Fe)
The freshwater chronic criterion for total iron is 1000 µg/L. This limit was exceeded during the dry surveys at all but two stations, BB00 and BB03, with a 65% exceedance rate for dry weather. The two stations above Warwick Pond averaged total iron concentrations of 662 and 1,162 µg/L at BB00 and BB02, respectively. The mean iron concentrations for stations in Buckeye Brook watershed ranged from 309 µg/L at BB03 to a maximum of 13,285 µg/L at the landfill station, TA01. During the second dry survey, the stations OF08 and TA01 were not sampled individually because chemistry samples were only taken at stations where ESS was doing the biological sampling. Instead, AP01 was sampled during the second dry survey, which is downstream of the confluence of the discharges from TA01 and OF08, and had a total iron value of 3,008 µg/L. The maximum total iron concentration for a single grab sample at any station was 19,180 µg/L at TA01 during the third dry survey.

Arsenic (As)
The aquatic life criteria for dissolved arsenic in freshwater systems is 340 and 150 µg/L for acute and chronic criteria respectively. There were not any exceedances of either criterion at the stream stations during the dry weather surveys, with mean concentrations ranging from 0.33 µg/L at BB00 to 0.65 µg/L at BB04. The mean concentrations of arsenic for the airport and landfill stations were 0.81 and 1.30 µg/L at OF08 and TA01, respectively. The highest single grab sample concentration of 1.87 µg/L occurred at TA01 during the first dry weather survey.

Manganese (Mn)
Dissolved manganese does not have listed numeric criteria for freshwater streams in RIDEM water quality regulations. Manganese is not a naturally occurring metal but is often found in various salts and minerals and is a micro-nutrient for plants and animals. Mean dry weather concentrations for manganese at the stream stations ranged from 208 µg/L at BB03 to 767 µg/L at BB00. The airport outfall and the landfill site mean concentrations were nearly identical at 1,144 and 1,147 µg/L for OF08 and TA01, respectively. The maximum single grab concentration observed was 1,599 µg/L at the airport outfall, OF08 during the last dry survey.

Total Organic Carbon (TOC)
TOC is released from both natural and man-made sources. All aquatic life release TOC through their normal metabolism, excretion, and eventual decomposition. Soils and peat also leach TOC into water bodies. Man-made sources include sewage treatment plants, farm slurry run-off, and leachate from waste disposal landfills. TOC is broken down by aquatic micro-organisms, consuming oxygen in the process. At high TOC concentrations, so much oxygen in the water may be used up that fish and other aquatic animals cannot survive. There are no criteria for TOC, but levels can range from 7.0 mg/L in pristine streams to over 1000 mg/L in polluted systems.

TOC samples were collected during the second dry survey at the stations visited by the ESS Group during their biology field sampling of Buckeye Brook. TOC is often a source of food for benthic organisms; however, high levels of sediment TOC can result in significant changes in a benthic community structure and the predominance of pollution-tolerant species. The TOC values ranged from a low of 580 mg/L at BB02 to a high of 17,000 mg/L at AP01, which represents the combined flows from airport outfall OF08 and the landfill, TA01. BB00, chosen because it is not influenced by airport run-off, had a TOC level of 1,900 mg/L. BB00 is located in the wetland area that is northwest of the intersection of Commerce Drive and Airport Road.

3.5.1 Wet Weather

Two wet weather surveys were conducted for the biodiversity field program. The first survey, which consisted of two consecutive sampling days, was to capture a storm event that would generate run-off for the watershed but one that did not require the airport to commence de-icing operations. The second wet survey was under icing conditions where the airport had commenced de-icing of aircraft and had intermittent rain/sleet as well as snow during the first day of sampling and totaled three sampling runs for the event. The same constituents that were sampled for the dry surveys were also collected during the wet weather surveys with the exception of TOC, which was dropped. However, propylene glycol was added to the constituent list to determine if significant amounts were being discharged to Buckeye Brook during storm events.

Dissolved Oxygen

The dissolved oxygen levels for both wet weather events were well above instantaneous criteria for all the Buckeye Brook stream stations. The DO levels were slightly below criteria during both wet weather events for the landfill station (TA01), with the lowest observed value at 4.84 mg/L occurring during Run 2 for Storm 2 and averaging 4.98 mg/L for both wet weather events. It is not unusual for dissolved oxygen levels in stagnant water or streams experiencing extremely low flow conditions to be below criteria. The lower values observed at the landfill station during the wet weather events were not considered significant as the stream flow was so low as to be nearly undetectable. The other station located on airport property, outfall OF08, had dissolved oxygen values that were well above the 5.0 mg/L criterion, averaging 10.47 mg/L for all wet weather runs.

As with the dry surveys, there was a DO sag observed between Stations BB03 and BB04 for both storm events. Comparing observed dissolved oxygen values between the two stations for Wet Weather 1, the mean DO deficit or drop between the stations was -4.67 mg/L. This drop is significant considering the distance between these two stations is approximately 0.64 miles (1 km), which is short considering how much DO concentrations decreased between stations BB03 and BB04. This again can be attributed to high iron concentrations downstream of the confluence of the OF08 and TA01 stations.

The second wet weather also had significant DO sags that ranged between -2.77 mg/L for Run 3 to -4.77 mg/L for Run 2. Figure 3.9 is a plot of the instantaneous dissolved oxygen concentrations for Stations BB03 and BB04 for both dry and wet weather surveys and shows the sag in DO levels that occurred between the two Buckeye Brook stations. The same increase of total iron concentrations is also apparent during the second wet weather event, but high BOD and associated detection of propylene glycol likely also influences this dramatic decrease in dissolved oxygen concentration over a small distance.

Propylene Glycol

Propylene Glycol is one of the main constituents used in Aircraft Deicing Fluids (ADFs), and concentrated glycol has a potential BOD_5 demand of 200,000 mg/L. ADFs that contain glycol are diluted with water, and the amount of dilution is dependent upon the outside air temperature at the time of application. If glycol is present in the water column, the BOD_5 values would be much lower than the above number but still significantly higher than the expected background levels usually observed in stream systems. High oxygen demand in stream systems caused by pollutants like propylene glycol can reduce the dissolved oxygen levels within the water column to levels well below the criteria of 5.0 mg/L and would be detrimental to aquatic life forms. If high levels of propylene glycol are in a stream system, the corresponding BOD_5 levels would likewise show an increase in samples collected at the same time and location.

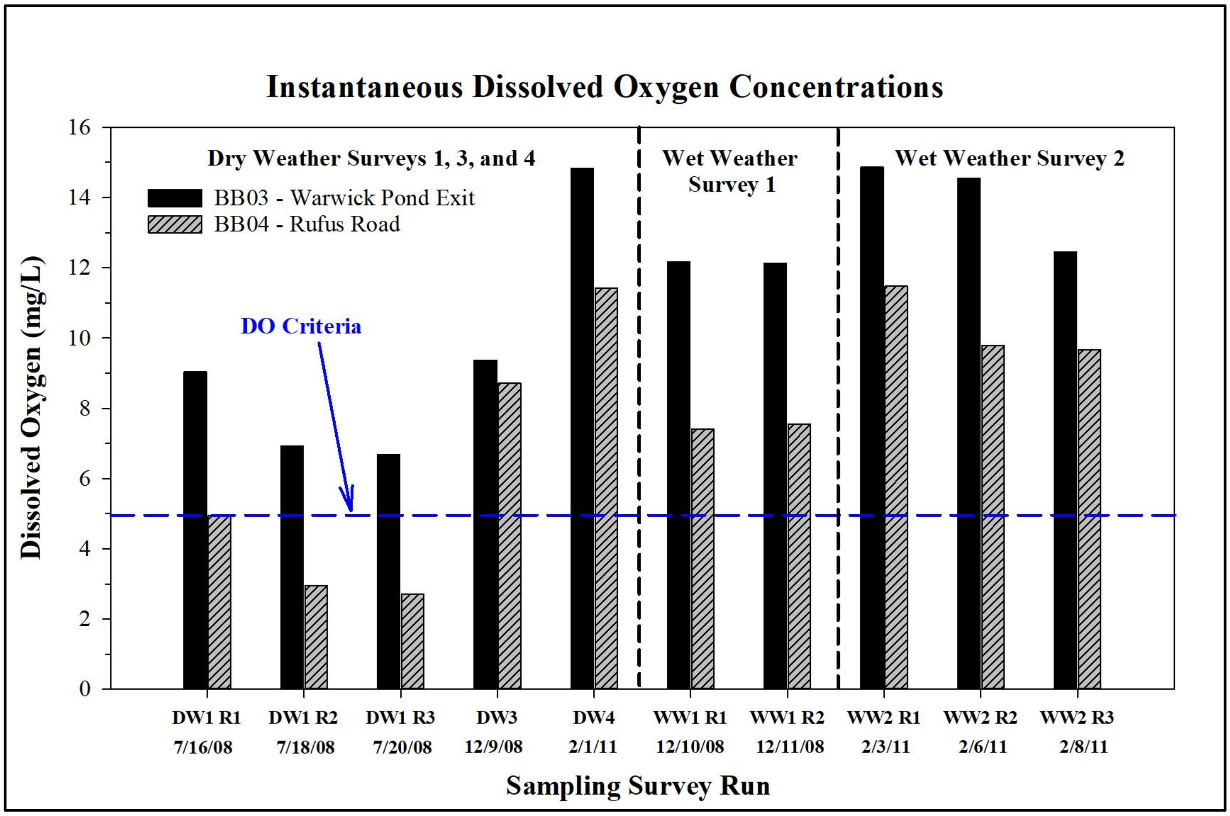


Figure 3.9 Instantaneous Dissolved Oxygen Values for RIDEM Stations BB03 and BB04

Although propylene glycol samples were collected during both wet weather events, active aircraft deicing operations occurred only during the second storm event in 2011. Wet weather samples from five stations were analyzed for propylene glycol for each storm.

One station, BB05A was dropped for the second storm and BB03 added in its place. The EPA lab that was doing the toxicity testing felt that the influence the road runoff from Warwick Avenue and Old Warwick Avenue could possibly mask potential toxic constituents that could have come from upstream sources such as the landfill or the airport.

BB00 was selected as a background station that would allow a comparison for a station that would not be likely to have any propylene glycol in the samples. BB02 is the inlet of Warwick Pond and receives stormwater discharges from those outfalls draining the aircraft parking area for cargo operations. BB03 and BB04 bracketed the confluence of the flows discharging from the main airport outfall (OF08) with Buckeye Brook. OF08 is the primary outfall for the aircraft parking area of the main airport passenger terminal and the largest contributor of stormwater to the lower segment of Buckeye Brook.

During Storm 1 in 2008, no de-icing activities occurred, and no propylene glycol was detected at any of the sampled stations. During Storm 2, in February 2011, de-icing activities did occur, and three of the five stations had detectable levels of propylene glycol. The mean values ranged from 15 mg/L at Station BB04 to 79 mg/L at the airport outfall, Station OF08. BB02, which receives the discharge from the airport outfalls draining the maintenance and air cargo areas, had a mean propylene glycol value of 45 mg/L. The highest single value of 105 mg/L was collected on the last run of the storm event at OF08, five days after the winter storm began. The higher propylene glycol concentrations at OF08 coincide with the higher BOD_5 observed at that station during the second storm.

As stated previously, RIAC is required to sample the airport outfalls and several stations along the mainstem of Buckeye Brook during a de-icing event, and coincidentally also sampled during the February 2011 survey. The stream stations were sampled every four hours for a period of 48 hours after the start of the storm. The Buckeye Brook stations sampled as part of the RIAC monitoring requirements included BB02, West Shore Road, and Tidewater Drive. Figures 3.10 and 3.11 show how the concentrations of propylene glycol changed over the 48-hour sampling period for this storm. The time of travel for propylene glycol from the airport cargo parking area outfalls 002 and 003 appears to be approximately 24 hours after the storm event starts, and 36 hours for the increased propylene glycol concentrations to travel from airport outfall 008 (OF08) to West Shore Road and Tidewater Drive. The maximum observed concentrations of propylene glycol were 210 mg/L at BB02 and 290 mg/L at West Shore Road and Tidewater Drive. This data was collected prior to full operation of the propylene glycol diversion system in October 2014.

Higher concentrations of propylene glycol will cause an increase in the demand for dissolved oxygen, resulting in higher BOD_5 demands, decreasing the amount of dissolved oxygen available for aquatic life in the water column. The water temperature also affects the amount of DO in the water, such that the observed levels of DO in the winter are much higher than those seen during the hotter months. Although the propylene glycol levels were higher in the stream system during the second storm, there was no impact on the DO levels in the water because of the cold temperatures. The DO values from the airport data during this period never dropped below 9.1 mg/L at any of the stream stations that were sampled by the airport. Therefore, while the glycol levels were much higher, they were not considered to be significant levels to impact the aquatic life in these stream systems.

Five-day Biological Oxygen Demand (BOD_5)

The five-day biological oxygen demand (BOD_5) for all stations was slightly higher for the first wet survey, as compared to dry weather, with mean values ranging from 2.0 mg/L at Stations BB00 to 7.0 mg/L at BB04, and the landfill station (TA01) and airport outfall (OF08) stations at 3.5 and 6.0 mg/L respectively. The BOD_5 concentrations for the second storm during which de-icing activities occurred were two to three times higher than the values observed during storm one. Station BB00 was not influenced by airport de-icing operations had a mean value of 1.3 mg/L. The mean BOD_5 values for the stream stations that receive the discharges from those areas on the airport property where de-icing operations are conducted were significantly greater with BB02 at 14.7 mg/L and BB04 at 15.0 mg/L. The landfill station, TA01 averaged 7.3 mg/L for the winter event while the airport outfall OF08, matched BB04 with a mean of 15.0 mg/L.

As with propylene glycol, the BOD_5 signal appears to lag the start of the storm by 24 to 32 hours at the Warwick Pond tributary and Buckeye Brook stream sites sampled by the airport, with maximum concentrations ranging from 160 mg/L at BB02 to 62 mg/L and 74 mg/L at West Shore Road and Tidewater Drive respectively. The level of BOD_5 demand in the water column at BB02 is very high as it corresponds to the propylene glycol value of 210 mg/L. Most pristine rivers may have a BOD_5 value below 1.0 mg/L. Untreated domestic sewage has a value of 300 mg/L while treated sewage may range from 10 to 40 mg/L.

The dissolved oxygen levels dropped downstream, but concentrations and percent saturation did not violate water quality criteria. As noted earlier, this is attributed to winter temperatures observed in the water column averaged 32°F (0°C) to 37°F (2.8°C). The DO at BB02 never dropped below 10 mg/L, with the lowest observed values at West Shore Road and Tidewater Drive being 9.6 mg/L and 9.1 mg/L respectively.

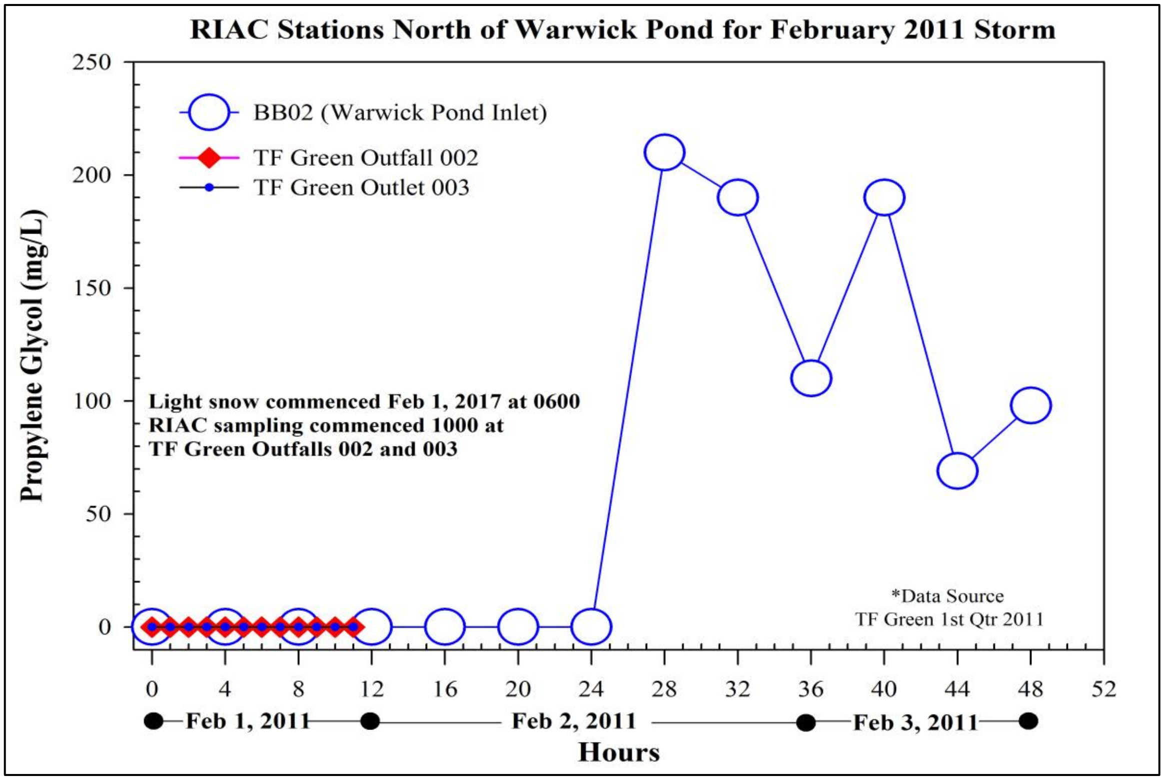


Figure 3.10 Storm 2 Propylene Glycol Concentrations for Warwick Pond Tributary Stations

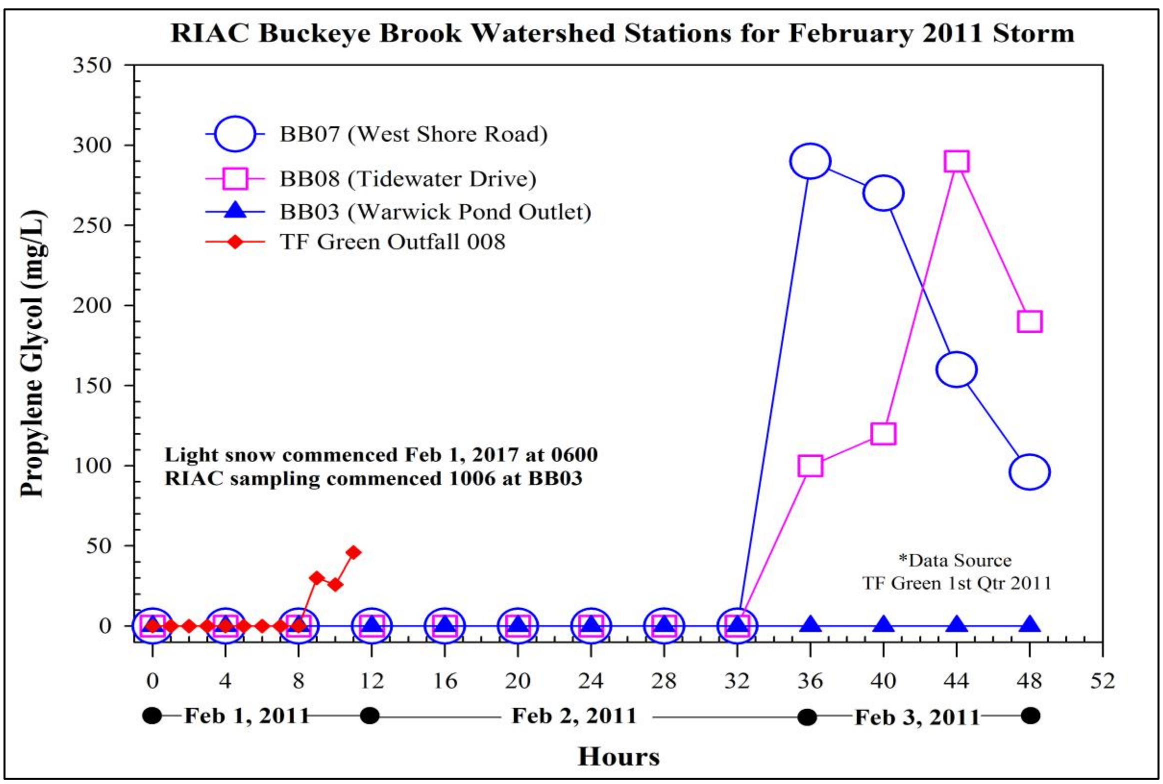


Figure 3.11 Storm 2 Propylene Glycol Concentrations for Buckeye Brook Watershed Stations

Hardness as $CaCO_3$

The hardness values observed during both storms were similar to the dry weather values. The stream stations averaged between 28.0 mg/L at BB02 for the first wet weather event to 52.7 mg/L at BB03 for the second storm. The highest observed value was the Run 1 sample from BB03 at 79.2 mg/L for the second wet survey, while outfall OF08 had the lowest hardness for either storm at 15 mg/L for both runs during Storm 1. As explained previously, hardness is used to calculate the criteria for dissolved metals using EPA formulas shown in Table 1.2, and as hardness increases, the toxicity of metals decreases.

pH

As with the dry surveys, pH was consistent across all stations, averaging from 6.34 to 7.38 for the two storms. The lowest single grab value of 6.15 occurred at Station BB00 during Storm 2, while the highest pH of 7.46 was observed at Station BB03 during Storm 1.

Total Suspended Solids (TSS)

TSS values were very low for the first storm in December 2008. The mean TSS values for the stream stations were between 5.0 to 8.5 mg/L, while the airport outfall OF08 and Truk-Away TA01 stations recorded mean values of 8.5 and 24.5 mg/L, respectively. The second wet weather event had slightly higher TSS levels for the stream stations, averaging between 1.0 mg/L at BB03 to 16.3 mg/L at BB00. Several samples had values below the reporting limit of 1.0 mg/L, but the lowest reported value was at station BB02 and BB03 with a value of 2.0 mg/L. BB00 had the highest TSS value for any stream station at 28.0 mg/L during Run 3 of the second storm. The landfill station, TA01 had the highest reported values for the second storm, averaging 17.0 mg/L, and had the highest single grab TSS value at 30.0 mg/L during Run 3.

Chlorides

The chloride values for the first storm, when no de-icing occurred, were very similar to the dry weather values, with the lowest mean value of 30.6 mg/L at Station BB04, and the high storm mean of 66.2 mg/L occurring at BB00. The second storm was much different, with some mean values for the stream stations three times higher than the averages from Storm 1, though no exceedances of the chloride criteria were observed at any stream station. The acute and chronic criteria for chloride in surface water are 860 mg/L and 230 mg/L respectively. T.F. Green outfall OF08 had the highest average with a mean value at 275.0 mg/L and the highest observed chloride concentration of 544 mg/L for Run 3. This is not considered a violation of the criterion, due to a single sample exceeding the criterion is allowable once every three years. This outfall drains the main terminal aircraft parking area, but no chloride-based deicers are applied to the tarmac. This location also receives contribution from the Long Term Parking area, and the high concentrations may be attributed to the deicing material applied to the parking lot area in this location or influence from surface runoff from surrounding roads and parking areas. BB02, which receives stormwater from the integrated cargo tarmac, also had high chloride values, averaging 175.7 mg/L, which was the highest of the stream stations.

Nutrients - Nitrogen and Phosphorus

Buckeye Brook stream concentrations for individual nitrogen forms (TKN, NH_3, and NO_3) were lower during the first storm, and depending upon the nitrogen form, were two to three times higher during the second storm event. Comparing the total nitrogen values for the stations (the sum of the TKN and nitrate concentrations), stream stations averaged from 0.42 to 1.13 mg/L for Storm 1, and from 1.53 to 2.55 mg/L for Storm 2. Between the landfill and airport outfall stations, TA01 had the highest mean concentrations for total nitrogen for either storm. OF08 averaged 0.31 mg/L for WW1 and 1.57mg/L for WW2. TA01 had much higher mean total nitrogen concentrations with 18.3 and 2.70 mg/L for Storms 1 and 2, respectively. The mean total nitrogen concentrations for the two stations above Warwick Pond were sixty percent higher as the observed mean at Station BB03 (Warwick Pond exit) during the second storm.

The Total Kjeldahl Nitrogen (TKN) values at the Buckeye Brook stations were two to three times higher for Storm 2 while the ammonia levels were similar for both storms. Mean TKN concentrations for these stations ranged from below detection (0.20 mg/L) at BB00 and BB02 for Storm 1 to a high average of 1.78 mg/L at BB04 for Storm 2. TA01 mean TKN concentrations were the highest observed for either storm during the first wet event, with an average of 18.2 mg/L for Storm 1 and 2.62 mg/L for the second event. The mean TKN values for the stream stations above Warwick Pond (BB00 and BB02) were forty percent lower than the overall mean concentrations for the Buckeye Brook stream stations BB04 and BB05A, both of which are located below the confluence of Buckeye Brook with the landfill discharges from TA01 indicating the possible influence of the landfill runoff on the water quality of the brook.

The TKN value at the airport outfall (OF08) was below the detection limit of 0.20 mg/L for Wet Weather 1, and generally lower than other sampling locations for Wet Weather 2, averaging 1.12 mg/L for the storm.

Ammonia (NH_3-N) mean concentrations were similar for both storm events at the Warwick Pond tributary and Buckeye Brook stations. The ammonia concentrations at the stream stations for the first wet event between 0.13 mg/L at BB02 to 0.83 mg/L at BB04. Station TA01 had the highest mean ammonia concentrations for either storm, averaging 2.90 mg/L for Storm 1 and 1.32 mg/L for Storm 2. There were no exceedances of ammonia criteria for either wet weather event.

Nitrate (NO_3-N) concentrations during wet weather were consistent for all the stations and comparable to observed dry weather values. The landfill and airport stations were below 0.5 mg/L for both storms, averaging between 0.10 mg/L for TA01 to 0.44 mg/L for outfall OF08.

The Total Phosphorus (TP) values were very low for all stream stations for both wet weather events. The average TP concentration range for both storms was 0.01 to 0.06 mg/L. The highest observed values occurred at the landfill station. TA01 mean TP concentrations were 0.58 mg/L for the first storm, and 0.28 mg/L for Storm 2. The airport outfall station (OF08) was slightly elevated during Storm 1 with a mean TP concentration of 0.09 mg/L, while the observed mean for WW2 was 0.03 mg/L.

Trace Metals

For the wet weather surveys, the acute and chronic criteria were calculated using the procedure explained in Section 1.5.2 of this document and using the formulas in Table 1.2. The water quality standards include duration considerations of a one-hour averaging period for the acute criteria, and a four-day averaging period for the chronic criteria. Grab samples are considered to be sufficient to assess the acute criteria.

To determine the acute criteria, which is a one-hour average, the hardness values for all stations within a waterbody segment were averaged for each sample run in a storm event. This average was used to calculate the acute criteria and that criteria was compared against each sample value for all stations and all runs in the storm.

The chronic criteria must be representative of conditions, including hydraulic conditions during a four-day averaging period. For the chronic criteria calculations, the hardness values and the observed metals were averaged for all runs for each station for a wet weather event described as the following: Storm 1 averaged the two sampling events for each station for the storm. Storm 2 was sampled over a period of days that exceeded the four-day average. Storm 2 averaged the hardness values from each station for Run 1 (2/3/11) and Run 2 (2/6/11), and then for Run 2 (2/6/11) and Run 3 (2/8/11). The same procedure was done to average each station's metal samples. The hardness was then averaged by segment with a final single hardness for Storm 1 and two final average hardness for Storm 2. The average hardness was used to calculate the chronic criteria values for the segment. The chronic criteria were then compared against each station's averaged metal concentration to determine of there was an exceedance. Appendix A contains the tables that show these calculations and comparison to criteria, and Table 3.5 shows trace metals criteria exceedances that occurred during the biodiversity surveys. These are discussed in the section below.

Cadmium (Cd)
There were five exceedances of the dissolved cadmium freshwater chronic criteria for the two wet weather events. The stations above Warwick Pond had three exceedances of the chronic criteria while in the Buckeye Brook watershed, OF08 and BB05A, each had one chronic exceedance. BB00 had chronic criteria exceedances in both wet weather events, with dissolved cadmium concentrations averaging 0.17 µg/L for Storm 1, and 0.15 µg/L for Storm 2. This station is in a wetland area, so the cadmium values observed were not expected. This station was considered an ambient background station; however, the area is bordered by major thoroughfares, RI Army National Guard facilities, parking areas for business activities as well as agriculture fields that may have contributed to the elevated levels of cadmium. Station BB02 had one exceedance of chronic cadmium criteria, with dissolved cadmium averages of and 0.13 µg/L for Storms 1 and 2.

Copper (Cu)
BB02 was the only station to exceed the dissolved copper chronic criteria during the second storm event. BB05A was the only station to exceed both the acute and chronic dissolved copper criteria, which occurred during the second storm. This station averaged 1.60 µg/L for Storm 1 and 3.92 µg/L for Storm 2. BB05A with a single grab concentration of 8.48 µg/L for Run 1 (2/3/11) during Storm 2 had the highest observed dissolved copper concentration of any station sampled during the wet weather surveys.

Lead (Pb)
There were two exceedances of the freshwater chronic criteria for dissolved lead. The airport outfall OF08 had one exceedance of the chronic lead criteria during the second wet event, averaging 0.64 µg/L for Storm 1 and 0.98 µg/L for Storm 2. The landfill station, TA01 had a single exceedance of the chronic lead criteria during Storm 1, with mean dissolved

concentrations of 1.32 and 0.26 µg/L for Storm 1 and Storm 2, respectively. TA01 had the highest single grab value for dissolved lead during Storm 1 at 1.70 µg/L, while the dissolved lead concentration of 2.62 µg/L at outfall OF08 was the maximum value for Storm 2. There were no exceedances of dissolved lead chronic criteria at any Buckeye Brook mainstem stream stations during either wet weather sampling surveys.

Zinc (Zn)
There were no exceedance of the freshwater dissolved zinc chronic criteria. The mean wet weather zinc concentrations for all stations sampled were three times higher during Storm 1, with the highest zinc concentration occurring at OF08 with a mean value of 29.84 µg/L. There were no wet weather exceedances of dissolved zinc criteria at any Buckeye Brook mainstem stream station.

Total Iron (Fe)
Total iron had numerous exceedances of the criterion during both storm events, with 89% of the samples collected exceeding the 1000 µg/L limit. The landfill and airport stations both exceeded the criterion for every sample collected, with TA01 having the highest mean iron concentrations for both storms with levels of 11,819 and 3,306 µg/L during Storm 1 and 2 respectively. The tributary station to Warwick Pond, BB02 and the Buckeye Brook stations BB04 and BB05A also exceeded criterion for all samples collected, with BB04 averaging the highest for the stream stations with total iron concentrations of 2,836 µg/L during Storm 1 and 2,172 µg/L for Storm 2. The influence of the high levels coming from the landfill and airport stations are the most likely reasons for the high iron concentrations observed at Stations BB04 and BB05A.

Table 3.5 Dry and Wet Weather Trace Metal Criteria Exceedances

Station	Cadmium						Copper					
	DW1	DW2	DW3	DW4	WW1	WW2	DW1	DW2	DW3	DW4	WW1	WW2
Tributaries to Warwick Pond (RI0007024R-05)												
BB00			C	C	C	C						
BB02			C		C							C
Buckeye Brook (RI0007024R-01)												
BB03												
BB04												
BB05A			C		C							A,C
TA01			C									
OF08					C							
AP01												

Station	Lead						Zinc					
	DW1	DW2	DW3	DW4	WW1	WW2	DW1	DW2	DW3	DW4	WW1	WW2
Tributaries to Warwick Pond (RI0007024R-05)												
BB00												
BB02												
Buckeye Brook (RI0007024R-01)												
BB03												
BB04												
BB05A												
TA01			C		C							
OF08						C						
AP01												

Station	Iron					
	DW1	DW2	DW3	DW4	WW1	WW2
Tributaries to Warwick Pond (RI0007024R-05)						
BB00						C
BB02			C	C	C	2C
Buckeye Brook (RI0007024R-01)						
BB03						C
BB04	C	C	C	C	C	2C
BB05A	C	C	C	C	C	2C
TA01	C		C	C	C	2C
OF08	C		C	C	C	2C
AP01		C				

A= Acute Criteria Exceeded; C = Chronic Criteria Exceeded; DW1- 07/16-20/08; DW2-09/10/08; DW3-12/09/08; DW4 - 02/01/11; WW1-12/09-11/08; WW2-02/02-08/11
OF08 is an outfall and considered representative of an instream monitoring station.

Arsenic (As)

There were no exceedances of the freshwater criteria for arsenic at any station during wet weather events. The mean arsenic values for the wet surveys ranged from 0.30 µg/L at both BB00 and BB04 during the second storm to 1.15 µg/L at TA01 for Storm 1. Overall, the arsenic concentrations were slightly higher for Storm 1 when compared to the second wet event. Overall, TA01 had the highest mean arsenic concentration of all sampling stations at 0.79 µg/L for all wet events. Station BB03 had the highest overall mean wet weather concentration for the stream stations at 0.63 µg/L.

Manganese (Mn)

Numeric freshwater criteria for dissolved manganese in streams or lakes in the RIDEM regulations has not been established. The highest mean value for the Warwick Pond stream stations was observed at BB00 with an overall wet weather mean of 693 µg/L with BB02 having the highest single grab value of 1,169 µg/L observed during Run 1 of Storm 2. The highest mean concentration for all wet weather samples from the Buckeye Brook stations was at the landfill station, TA01 with 683 µg/L. Similar to BB02, the highest Buckeye Brook grab concentration was during the first run of Storm 2 at TA01, with a concentration of 1,012 µg/L.

Table 3.6 Field Data Summaries

Dissolved Oxygen (mg/L)

Survey Type	DW1*			DW2	DW3	DW4	WW1		WW2			Mean
Station	7/16/08	7/18/08	7/21/08	9/10/08	12/9/08	2/1/11	12/10/08	12/11/08	2/3/11	2/6/11	2/8/11	
BB00	4.24	4.58	5.18	4.52	9.75	16.85	8.11	9.23	12.32	11.52	10.38	8.79
BB02	7.55	7.33	7.07	6.41	9.45	10.93	7.63	9.58	10.87	11.14	10.24	8.93
BB03	9.03	6.93	6.67	NS	9.37	14.84	12.17	12.12	14.87	14.55	12.44	11.30
TA01	3.41	2.55	3.05	NS	1.38	6.53	4.93	5.05	4.93	4.84	5.13	4.18
OF08	9.29	8.9	8.85	NS	7.2	13	9.02	10.45	9.94	12.03	10.91	9.96
AP01	NS	NS	NS	3.68	NS	NS	NS	NS	NS	NS	NS	3.68
BB04	4.95	2.95	2.7	4.83	8.71	11.42	7.41	7.55	11.47	9.78	9.67	7.40
BB05A	5.39	4.82	4.8	6.01	10.24	10.12	7.27	8.57	11.3	9.84	10.91	8.12

Temperature (°C)

Survey Type	DW1*			DW2	DW3	DW4	WW1		WW2			Mean
Station	7/16/08	7/18/08	7/21/08	9/10/08	12/9/08	2/1/11	12/10/08	12/11/08	2/3/11	2/6/11	2/8/11	
BB00	18.6	20.1	22.0	16.0	2.6	0.4	11.2	7.1	1.6	1.9	3.4	9.5
BB02	21.3	27.3	27.8	17.6	4.6	0.8	11.7	8.0	3.1	4.0	4.3	11.9
BB03	29.2	18.3	20.0	NS	2.8	2.1	5.2	5.0	2.2	2.6	2.6	9.0
TA01	17.5	17.9	18.9	NS	0.9	0.3	6.9	5.1	1.0	0.7	0.8	7.0
OF08	14.7	14.7	15.0	NS	11.2	7.8	13.09	8.0	7.5	4.7	6.1	10.3
AP01	NS	NS	NS	16.7	NS	NS	NS	NS	NS	NS	NS	16.7
BB04	26.5	23.2	24.5	21.0	2.7	0.9	8.7	6.4	2.5	2.3	2.9	11.1
BB05A	24.5	23.2	24.6	19.8	2.5	0.1	9.5	6.5	0.3	1.5	2.3	10.4

Specific Conductance (µS/cm)

Survey Type	DW1*			DW2	DW3	DW4	WW1		WW2			Mean
Station	7/16/08	7/18/08	7/21/08	9/10/08	12/9/08	2/1/11	12/10/08	12/11/08	2/3/11	2/6/11	2/8/11	
BB00	359	395	386	370	399	444	366	378	501	378	390	397
BB02	301	270	271	262	286	370	339	505	693	505	882	426
BB03	272	304	300	NS	218	219	218	214	210	214	195	236
TA01	416	417	415	NS	472	86	265	284	353	448	482	364
OF08	322	337	338	NS	268	333	207	91	624	456	1920	490
AP01	NS	NS	NS	277	NS	NS	NS	NS	NS	NS	NS	277
BB04	346	356	360	245	284	295	331	491	605	491	450	387
BB05A	344	343	349	241	279	308	292	688	760	688	498	435

NS = Not Sampled

*One chemistry sample was collected for DW1 on 7/16/2008. Toxicity testing required field visits, and field data was collected at time of field visit.

Table 3.7 Buckeye Brook Chemistry Data for Dry Weather Surveys

Station	BOD5 (mg/L)					Chloride (mg/L)				
	7/16/08	9/10/08	12/9/08	2/1/11	Mean	7/16/08	9/10/08	12/9/08	2/1/11	Mean
BB00	2	1	<1.0	1	1.0	92.2	76.2	80.4	98.9	86.9
BB02	1	1	2	3	1.8	56.1	46.9	46.6	81.4	57.8
BB03	4	NS	1	1	2.0	46.9	NS	33.8	40.4	40.4
TA01	4	NS	2	2	2.7	46.2	NS	44.5	52.5	47.7
OF08	4	NS	5	20	9.7	79.0	NS	51.7	74.6	68.4
AP01	NS	1	NS	NS	1.0	NS	39.7	NS	NS	39.7
BB04	4	1	6	5	4.0	62.1	39.2	44.0	53.6	49.7
BB05A	3	1	6	4	3.5	59.2	38.6	44.7	55.3	49.5

Station	TSS (mg/L)					pH				
	7/16/08	9/10/08	12/9/08	2/1/11	Mean	7/16/08	9/10/08	12/9/08	2/1/11	Mean
BB00	0	1	<1.0	3	1.0	7.66	6.55	6.67	6.08	6.74
BB02	1	4	4	4	3.3	7.39	6.9	7.23	6.48	7.00
BB03	3	NS	2	1	2.0	9.22	NS	7.76	7.06	8.01
TA01	39	NS	5	37	27.0	7.41	NS	7.18	6.45	7.01
OF08	0	NS	<1.0	2	0.7	7.22	NS	7.21	6.93	7.12
AP01	NS	5	NS	NS	5.0	NS	7.06	NS	NS	7.06
BB04	1	4	6	2	3.3	7.33	7.01	7.05	6.76	7.04
BB05A	0	**R**	**4**	**5**	3.0	7.53	7.13	7.44	6.81	7.23

Station	Hardness (mg/L)					Total Phosphorus (mg/L)				
	7/16/08	9/10/08	12/9/08	2/1/11	Mean	7/16/08	9/10/08	12/9/08	2/1/11	Mean
BB00	R	40	51	59.4	50.1	0.03	0.03	<0.02	0.03	0.02
BB02	R	41	52	49.9	47.6	0.02	<0.02	<0.02	0.03	0.01
BB03	R	NS	51	53.7	52.4	0.02	NS	<0.02	0.03	0.02
TA01	R	NS	98	96.6	97.3	0.19	NS	0.2	0.23	0.21
OF08	R	NS	42	45.3	43.7	<0.02	NS	<0.02	0.02	0.01
AP01	NS	43	NS	NS	43.0	NS	0.09	NS	NS	0.09
BB04	R	45	58	59.1	54.0	0.03	0.03	<0.02	0.04	0.03
BB05A	R	44	57	30.4	43.8	0.03	0.03	0.03	0.04	0.03

Station	TKN (mg/L)					Ammonia-N (mg/L)				
	7/16/08	9/10/08	12/9/08	2/1/11	Mean	7/16/08	9/10/08	12/9/08	2/1/11	Mean
BB00	0.55	0.52	0.37	1.19	0.66	0.40	0.31	0.26	0.28	0.31
BB02	ND	0.43	ND	1.07	0.38	0.13	0.16	0.14	0.22	0.16
BB03	0.26	NS	0.31	1.18	0.58	0.13	NS	0.29	0.15	0.19
TA01	2.79	NS	7.28	2.80	4.29	2.72	NS	5.87	1.99	3.53
OF08	ND	NS	ND	0.87	0.29	0.13	NS	ND	0.13	0.09
AP01	NS	2.07	NS	NS	2.07	NS	1.71	NS	NS	1.71
BB04	0.88	0.71	0.80	1.63	1.01	0.85	0.30	0.85	0.74	0.69
BB05A	0.23	0.61	0.82	1.74	0.85	0.23	0.21	0.75	0.66	0.46

Station	Nitrate- N (mg/L)					Arsenic (µg/L)				
	7/16/08	9/10/08	12/9/08	2/1/11	Mean	7/16/08	9/10/08	12/9/08	2/1/11	Mean
BB00	0.78	0.82	1.53	1.65	1.20	0.38	0.29	0.50	0.14	0.33
BB02	1.90	1.16	1.59	1.79	1.61	0.27	0.42	0.46	0.21	0.34
BB03	<0.05	NS	0.34	0.35	0.23	0.66	NS	0.67	0.27	0.53
TA01	<0.05	NS	<0.05	<0.05	<0.05	1.87	NS	1.80	0.24	1.30
OF08	0.67	NS	0.79	0.53	0.66	0.39	NS	1.36	0.67	0.81
AP01	NS	0.41	NS	NS	0.41	NS	0.97	NS	NS	0.97
BB04	0.24	<0.05	0.34	0.32	0.23	0.61	0.82	0.94	0.24	0.65
BB05A	1.01	0.26	0.64	0.42	0.58	0.33	**R**	0.62	0.17	0.37

NS = Not Sampled; ND = Non-Detect; NA = Not Applicable; **R** = Rejected because data did not meet data quality objectives

Table 3.7 Buckeye Brook Chemistry Data for Dry Weather Surveys (Cont.)

Station	Cadmium (µg/L)					Copper (µg/L)				
	7/16/08	9/10/08	12/9/08	2/1/11	Mean	7/16/08	9/10/08	12/9/08	2/1/11	Mean
BB00	R	0.08	0.40	0.26	0.25	R	2.1	1.8	1.33	1.74
BB02	R	0.11	0.18	0.09	0.13	R	1.19	1.03	1.3	1.17
BB03	R	NS	0.15	<0.05	0.08	R	NS	0.98	2.94	1.96
TA01	R	NS	0.58	0.09	0.34	R	NS	2.01	1.4	1.71
OF08	R	NS	0.17	0.06	0.12	R	NS	0.74	1.03	0.89
AP01	NS	<0.06	NS	NS	<0.06	NS	1.08	NS	NS	1.08
BB04	R	<0.06	0.11	0.14	0.08	R	1.24	1.21	1.52	1.32
BB05A	R	<0.06	0.31	0.05	0.12	R	1.68	3.24	2.51	2.48

Station	Lead (µg/L)					Manganese (µg/L)				
	7/16/08	9/10/08	12/9/08	2/1/11	Mean	7/16/08	9/10/08	12/9/08	2/1/11	Mean
BB00	R	<0.07	0.27	0.09	0.12	637	732	932	768	767
BB02	R	<0.07	R	0.11	0.15	469	448	796	858	643
BB03	R	NS	0.18	0.29	0..24	12	NS	220	393	208
TA01	R	NS	1.51	0.73	1.12	988	NS	1,197	1,247	1,144
OF08	R	NS	0.08	<0.08	0.04	880	NS	962	1,599	1,147
AP01	NS	<0.07	NS	NS	<0.07	NS	505	NS	NS	505
BB04	R	0.18	0.61	1.50	0.76	335	142	321	663	365
BB05A	R	<0.07	0.66	0.37	0.34	321	203	613	724	465

Station	Total Iron (µg/L)					Zinc (µg/L)				
	7/16/08	9/10/08	12/9/08	2/1/11	Mean	7/16/08	9/10/08	12/9/08	2/1/11	Mean
BB00	732	522	654	741	662	R	28.2	24.9	4.5	19.2
BB02	648	824	1,185	1,989	1,162	R	13.9	R	<1.12	9.1
BB03	186	NS	308	432	309	R	NS	6.9	2.0	4.5
TA01	11,586	NS	19,180	9,088	13,285	R	NS	27.2	3.4	15.3
OF08	2,844	NS	4,334	3,954	3,711	R	NS	10.5	2.9	6.7
AP01	NS	3,008	NS	NS	3,008	NS	10.4	NS	NS	10.4
BB04	2,078	1,258	3,112	1,892	2,085	R	7.1	12.2	6.0	8.5
BB05A	1,347	1,439	1,112	1,010	1,227	R	7.8	9.9	4.1	7.3

Station	TOC (mg/L)			Propylene Glycol (mg/L)		
	7/16/08	9/10/08	Mean	12/9/08	2/1/11	Mean
BB00	NA	1,900		ND	ND	
BB02	NA	580		ND	ND	
BB03	NA	NS		---	ND	
TA01	NA	NS		ND	---	
OF08	NA	NS		ND	ND	
AP01	NA	17,000		NS	NS	
BB04	NA	1,700		ND	ND	
BB05A	NA	2,500		ND	ND	

NS = Not Sampled; ND = Non-Detect; NA = Not Applicable; R=Rejected because data did not meet data quality objectives

Table 3.8 Buckeye Brook Chemistry Data for Wet Weather 1 (December 10-11, 2008)

Station	BOD$_5$ (mg/L)			Chloride (mg/L)			TSS (mg/L)			pH		
	Run 1	Run 2	Mean	Run 1	Run 2	Mean	Run 1	Run 2	Mean	Run 1	Run 2	Mean
BB00	2	2	2.0	77.8	54.6	66.2	3	7	5.0	6.15	6.52	6.34
BB02	6	3	4.5	70.8	31.0	50.9	9	8	8.5	6.30	6.58	6.44
BB03	2	3	2.5	33.8	33.7	33.8	9	3	6.0	7.29	7.46	7.38
TA01	2	5	3.5	29.6	34.3	32.0	9	40	24.5	6.80	6.99	6.90
OF08	6	6	6.0	47.1	14.7	30.9	9	8	8.5	6.47	6.72	6.60
BB04	5	9	7.0	22.7	38.5	30.6	10	6	8.0	6.60	6.89	6.75
BB05A	5	7	6.0	47.6	35.8	41.7	8	9	8.5	6.90	7.18	7.04

Station	Hardness (mg/L)			Total Phosphorus(mg/L)			TKN (mg/L)			Ammonia-N (mg/L)		
	Run 1	Run 2	Mean	Run 1	Run 2	Mean	Run 1	Run 2	Mean	Run 1	Run 2	Mean
BB00	44	37	40.5	0.03	0.04	0.04	ND	ND		0.15	0.16	0.16
BB02	32	24	28.0	0.05	0.03	0.04	ND	ND		0.14	0.11	0.13
BB03	42	52	47.0	0.03	0.03	0.03	0.25	0.36	0.31	0.30	0.26	0.28
TA01	45	50	47.5	0.24	0.92	0.58	31.1	5.26	18.18	2.68	3.12	2.90
OF08	15	15	15.0	0.11	0.07	0.09	ND	ND		0.13	ND	0.07
BB04	53	45	49.0	0.03	0.04	0.04	0.96	0.66	0.81	1.02	0.64	0.83
BB05A	52	44	48.0	0.04	0.04	0.04	0.75	0.49	0.62	0.66	0.44	0.55

Station	Nitrate-N (mg/L)			Arsenic (µg/L)			Cadmium (µg/L)			Copper (µg/L)		
	Run 1	Run 2	Mean	Run 1	Run 2	Mean	Run 1	Run 2	Mean	Run 1	Run 2	Mean
BB00	1.07	0.98	1.03	0.28	0.38	0.33	0.17	0.16	0.17	2.04	2.22	2.13
BB02	0.83	<0.05	0.42	0.24	0.53	0.39	0.22	0.39	0.31	3.37	2.19	2.78
BB03	0.34	0.36	0.35	0.96	0.81	0.89	<0.06	<0.06	<0.06	0.89	0.72	0.81
TA01	0.10	0.09	0.10	0.88	1.41	1.15	0.08	0.09	0.09	1.04	1.83	1.44
OF08	0.30	0.31	0.31	0.66	0.62	0.64	0.19	0.19	0.19	4.26	2.66	3.46
BB04	0.30	0.30	0.30	0.52	0.65	0.59	<0.06	<0.06	<0.06	0.90	0.88	0.89
BB05A	0.56	0.46	0.51	0.62	0.40	0.51	0.29	<0.06	0.15	1.56	1.63	1.60

Station	Lead (µg/L)			Manganese (µg/L)			Total Iron (µg/L)			Zinc (µg/L)		
	Run 1	Run 2	Mean	Run 1	Run 2	Mean	Run 1	Run 2	Mean	Run 1	Run 2	Mean
BB00	0.30	0.49	0.40	821	598	710	897	1,082	990	25.48	27.19	26.34
BB02	0.78	0.49	0.64	382	387	385	1,377	1,419	1,398	28.71	24.48	26.60
BB03	<0.07	0.18	0.09	199	176	188	296	470	383	<6.46	<6.46	<6.46
TA01	0.94	1.70	1.32	489	389	439	4,725	18,912	11,819	9.18	21.8	15.49
OF08	1.08	0.20	0.64	228	176	202	2,049	1,726	1,888	33.51	26.17	29.84
BB04	<0.07	<0.07	<0.07	634	528	581	2,385	3,287	2,836	7.09	8.25	7.67
BB05A	0.24	0.22	0.23	365	382	374	1,991	1,423	1,707	20.64	25.43	23.04

Station	Propylene Glycol (mg/L)		
	Run 1	Run 2	Mean
BB00	ND	ND	
BB02	ND	ND	
BB03	---	---	---
TA01	---	---	---
OF08	ND	ND	
BB04	ND	ND	
BB05	ND	ND	

Sampling Dates: Run 1-12/10/08; Run 2- 12/11/08; ND = Non-Detect; R=Rejected because data did not meet data quality objectives

Table 3.9 Buckeye Brook Chemistry Data for Wet Weather 2 (February 3-8, 2011)

Station	BOD_5 (mg/L)				Chloride (mg/L)				TSS (mg/L)				pH			
	Run 1	Run 2	Run 3	Mean	Run 1	Run 2	Run 3	Mean	Run 1	Run 2	Run 3	Mean	Run 1	Run 2	Run 3	Mean
BB00	2	2	<1.0	1.3	136	91.0	88.0	105.0	13	8	28	16.3	6.38	6.18	6.58	6.38
BB02	15	15	14	14.7	175	119	233	175.7	2	3	12	5.7	6.62	6.52	7.21	6.78
BB03	1	R	<1.0	0.5	39.0	29.8	33.8	34.2	2	R	<1.0	1.0	7.31	6.81	6.89	7.00
TA01	4	14	4	7.3	49.8	81.0	89.6	73.5	14	7	30	17.0	7.27	6.48	6.78	6.84
OF08	15	15	15	15.0	168	113	544	275.0	2	1	4	2.3	6.89	6.46	6.67	6.67
BB04	15	15	15	15.0	150	106	94.6	116.9	6	<1.0	R	3.0	6.80	6.66	7.13	6.86
BB05A	15	14	11	13.3	203	156	93.6	150.9	<1.0	7	4	3.7	7.07	6.72	6.98	6.92

Station	Hardness (mg/L				Total Phosphorus (mg/L)				TKN (mg/L)				Ammonia-N (mg/L			
	Run 1	Run 2	Run 3	Mean	Run 1	Run 2	Run 3	Mean	Run 1	Run 2	Run 3	Mean	Run 1	Run 2	Run 3	Mean
BB00	52.2	32.3	43.4	42.6	0.09	0.06	0.03	0.06	1.03	1.06	1.15	1.08	0.21	0.26	0.25	0.24
BB02	41.0	28.4	34.4	34.6	0.04	0.04	0.05	0.04	1.33	1.34	1.42	1.36	0.20	0.18	0.18	0.19
BB03	79.2	43.8	35.2	52.7	<0.02	<0.02	0.03	0.01	1.22	1.21	1.16	1.20	ND	0.16	0.2	0.12
TA01	42.7	62.2	77.4	60.8	0.18	0.22	0.45	0.28	2.47	2.33	3.07	2.62	1.14	1.44	1.38	1.32
OF08	33.0	16.2	24.2	24.5	0.03	0.02	0.04	0.03	1.10	1.05	1.22	1.12	ND	0.11	ND	0.04
BB04	56.8	40.4	50.7	49.3	0.03	0.03	0.03	0.03	2.21	1.57	1.57	1.78	0.64	0.62	0.53	0.60
BB05A	59.0	36.2	44.4	46.5	0.02	0.04	0.03	0.03	1.86	1.53	1.43	1.61	0.62	0.53	0.45	0.53

Station	Nitrate-N (mg/L)				Arsenic (µg/L)				Cadmium (µg/L)				Copper (µg/L)			
	Run 1	Run 2	Run 3	Mean	Run 1	Run 2	Run 3	Mean	Run 1	Run 2	Run 3	Mean	Run 1	Run 2	Run 3	Mean
BB00	1.66	0.97	1.36	1.33	0.26	0.38	0.27	0.30	0.21	0.09	R	0.15	2.16	2.17	1.53	1.95
BB02	1.64	0.92	1.01	1.19	0.37	0.52	0.41	0.43	0.14	0.12	R	0.13	2.32	4.05	3.32	3.23
BB03	0.36	0.32	0.33	0.34	0.35	0.57	0.44	0.45	<0.05	<0.05	R	<0.05	1.05	1.63	0.81	1.16
TA01	<0.05	0.14	0.10	0.08	0.61	0.49	0.55	0.55	<0.05	<0.05	R	<0.05	1.48	1.34	1.36	1.39
OF08	0.51	0.39	0.43	0.44	0.37	0.64	0.48	0.50	0.10	<0.05	R	0.05	1.74	3.59	4.22	3.18
BB04	0.31	0.26	0.34	0.30	0.30	0.35	0.25	0.30	<0.05	<0.05	R	<0.05	1.71	2.35	1.46	1.84
BB05A	0.39	0.30	0.38	0.36	0.27	0.24	0.62	0.38	0.06	<0.05	R	0.03	8.48	2.02	1.26	3.92

Station	Lead (µg/L)				Manganese (µg/L)				Total Iron (µg/L)				Zinc (µg/L)			
	Run 1	Run 2	Run 3	Mean	Run 1	Run 2	Run 3	Mean	Run 1	Run 2	Run 3	Mean	Run 1	Run 2	Run 3	Mean
BB00	0.16	1.28	0.16	0.53	810	512	726	683	2,307	948	648	1,301	17.51	21.13	5.55	14.73
BB02	0.35	0.51	0.17	0.34	1,169	481	526	725	1,747	1,475	2,403	1,875	13.6	22.6	<1.13	12.07
BB03	0.10	0.33	<0.08	0.14	467	433	391	430	449	462	1,617	843	1.15	1.94	<1.13	1.03
TA01	0.19	0.22	0.37	0.26	1,012	689	835	845	4,976	1,250	3,693	3,306	1.44	1.91	<1.13	1.12
OF08	2.62	0.22	0.11	0.98	945	383	494	607	2,454	1,928	2,441	2,274	10.29	15.4	9.26	11.65
BB04	0.13	0.38	<0.08	0.17	713	555	550	606	3,112	1,605	1,799	2,172	<1.13	3.3	<1.13	1.10
BB05A	0.53	0.15	0.20	0.29	723	713	398	611	1,168	981	1,172	1,107	14.86	2.68	<1.13	5.85

Station	Propylene Glycol (mg/L)			
	Run 1	Run 2	Run 3	Mean
BB00	ND	ND	ND	ND
BB02	45	44	45	45
BB03	ND	ND	ND	ND
TA01	---	---	---	---
OF08	99	34	105	79
BB04	23	ND	21	15
BB05A	---	---	---	---

Sampling Dates: Run 1-02/03/11; Run 2- 02/06/11; Run 3- 02/08/11; ND = Non-Detect; R=Rejected because data did not meet data quality objectives.

3.6 Biological Field Survey

The Biological Field survey for Buckeye Brook was conducted on September 10, 2008 to further characterize the extent and severity of the impairment while bracketing potential stressors from outfalls and tributaries to Warwick Pond and Buckeye Brook. Table 3.10 lists those stations selected for biological sampling, their locations and the type of assessment that was conducted by ESS Group, Inc (ESS). Stations that were tested for toxicity are listed in Tables 3.2 and 3.3 for the dry and wet weather events.

Table 3.10 Buckeye Brook Stations Sampled by ESS in September 2008

Station	Location	Assessments Conducted
Tributaries to Warwick Pond (RI0007024R-05)		
BB00	Tributary to Warwick Pond above Airport Road	Habitat, Periphyton/Macroinvertebrate CPOM/FPOM
BB02	Tributary to Warwick Pond at Lakeshore Drive	Habitat Periphyton/Macroinvertebrate CPOM/FPOM
Buckeye Brook Watershed (RI0007024R-01)		
BB04	Buckeye Brook at Rufus Road	Habitat, Periphyton/Macroinvertebrate CPOM/FPOM
BB05A	Buckeye Brook downstream of Old Warwick Avenue	Habitat, Periphyton/Macroinvertebrate CPOM/FPOM
TA01	Unnamed tributary channel from Truk-Away Landfill	Habitat
OF08	T.F. Green Airport Outfall 008	Habitat
AP01	Downstream channel combining flows from the outfall OF08 and landfill stationTA01	Habitat, Periphyton/Macroinvertebrate CPOM/FPOM
Adamsville Bk Reference Site	At the USGS Gage off Route 81 in Little Compton, RI	Macroinvertebrate

Macroinvertebrates and periphyton are useful in biological monitoring because of the wide range of tolerances among taxa to various physical, chemical, and biological stressors. Coarse particulate organic matter (CPOM) and fine particulate organic matter (FPOM) were evaluated to assess the potential contribution of carbon availability and processing on observed patterns in the biological community. An evaluation of habitat quality is critical to any assessment as habitat and biological diversity in streams are closely linked. Habitat incorporates all aspects of physical and chemical constituents along with the biotic interactions. The presence of an altered habitat structure is considered one of the major stressors of aquatic systems.

3.7 Results of Biological Sampling

The full report for the biological sampling conducted by ESS Group within the study areas for Warwick Pond tributaries and Buckeye Brook can be requested through RIDEM. Excerpts from the full report summarizing the conditions found in the Buckeye Brook watershed when compared against a reference site at Adamsville Brook (ESS45) are provided.

3.7.1 Stream Habitat

The combination of physical characteristics and water quality parameters are used to characterize the health of streams and wadeable rivers provide an insight as to the ability of a stream to support a healthy aquatic community. The habitat assessment matrix in the EPA's Rapid Bioassessment Protocols for Stream and Wadeable Rivers (Barbour et al. 1999) was used to determine the habitat conditions for selected stations project's study area. All parameters are evaluated and rated on a numerical scale of 0 to 20 (highest) for each sampling reach. The range of scores are divided into 4 category conditions for each habitat parameter. Poor condition ranges from 0 to 5; Marginal range is 6 to 10; Suboptimal range is 11 to 15; Optimal range is 16 to 20. The ratings are then totaled and compared to a reference condition to provide a final habitat ranking. Scores increase as habitat quality increases, with 200 as the maximum total score.

Overall stream habitat scores ranged from 83 to 144 on a 200-point scale and were compared against the reference site at Adamsville Brook (ESS45), and lower scores represent lower quality habitat. Although the reference site was not assessed for stream habitat as part of the field surveys, it was assessed in 2008 by ESS Group as part of the statewide wadeable stream biomonitoring effort. Table 3.11 lists the EPA stream habitat classifications and shows the total habitat scores for each sampling location within the study area as compared against the reference site.

Stream habitat was in the best condition above the T.F. Green Airport (BB00) and below Warwick Pond (BB04 and BB05A) and poorest in the tributary channels sourced from the airport outfalls and the Truk-Away Landfill. Compared to the reference site (ESS45), which received a score of 142, three stations (BB00, BB04, and BB05A) were comparable to reference, one station (BB02) was supporting and three stations (AP01, OF08, and TA01) were partially supporting. One station (BB05A) scored marginally higher on the stream habitat assessment than the reference site. These results indicate poor stream habitat conditions exist throughout these two watershed areas and may be contributing to these stream's poor biological health. Stormwater discharges are likely contributing to at least some of these degraded habitat conditions (e.g. embeddedness, channel alteration, and sediment deposition).

Table 3.11 US EPA Habitat Attributes Assessed and Stream Habitat Classification

Site	Total Habitat Score	Instream Cover	Epifaunal Substrate	Embeddedness	Channel Alteration	Sediment Deposition	Frequency of Riffles	Channel Flow Status	Bank Vegetation Status	Bank Stability	Riparian Vegetative Zone Width
Tributaries to Warwick Pond (RI0007024R-05)											
BB00	SO	SO	M	SO	SO	SO	O	O	O	O	SO
BB02	SO	SO	M	**M**	SO	**M**	**M**	SO	O	O	O
Buckeye Brook Watershed (RI0007024R-01)											
BB04	SO	SO	M	M	O	O	M	SO	O	O	O
BB05A	SO	SO	M	M	O	O	M	SO	O	O	O
OF08	M	M	SO	O	SO	**M**	SO	**M**	SO	**P**	M
TA01	M	**P**	**P**	**P**	SO	O	**P**	**M**	O	O	SO
AP01	M	**P**	M	**P**	SO	**M**	M	O	SO	O	M
ESS45*	SO	O	M	O	SO	O	SO	O	SO	SO	SO

Site	Total Habitat Score	Instream Cover	Epifaunal Substrate	Embeddedness	Channel Alteration	Sediment Deposition	Frequency of Riffles	Channel Flow Status	Bank Vegetation Protection	Bank Stability	Riparian Vegetative Zone Width
Tributaries to Warwick Pond (RI0007024R-05)											
BB00	136	11	10	11	11	14	16	17	16	18	12
BB02	127	14	10	**9**	15	**10**	**6**	13	18	16	16
Buckeye Brook Watershed (RI0007024R-01)											
BB04	137	12	8	10	18	17	8	12	18	18	16
BB05A	144	13	8	10	18	17	9	15	18	18	18
OF08	100	10	14	16	12	**7**	12	**7**	12	**3**	7
TA01	95	**2**	**2**	**4**	12	18	**2**	**7**	16	18	14
AP01	95	**5**	6	**3**	11	**7**	8	16	13	18	8
ESS45*	142	17	10	17	12	18	12	16	15	15	10

Classification Range: Poor (P) = 0-5; Total Score <50; Marginal (M) = 6-10; Total Score 51-100; Sub-optimal (SO) = 11-15; Total Score 101-150; Optimal (O) = 16-20; Total Score>150; **Bold indicates values were <58% of the Reference Station ESS45 (Adamsville Brook).**

3.7.2 Macroinvertebrate Results

Assessment of macroinvertebrate community in the study areas for Warwick Pond tributaries and Buckeye Brook suggests that moderate to severe biological impairment exists across most, if not all, of the watershed in Table 3.12. The moderate level of impairment at BB05A is consistent with assessments conducted by ESS just upstream at BB05 in previous years, as part of the statewide wadeable stream biomonitoring program. However, stations on and just downstream of the tributary channels sourced by T.F. Green Airport and the Truk-Away Landfill (BB02, AP01, and BB04) appear to be more severely impaired. At these stations, sensitive taxa are found in very low abundances, if at all, indicating high levels of disturbance. Table 3.13 shows the dominant taxon for the six biological stations.

Table 3.12 Summary Statistics for Stations Assessed under the Biological Survey

Summary Statistic	Tributaries to Warwick Pond		Buckeye Brook			ESS45
	BB00	BB02	BB04	BB05A	AP01	
Total Taxa Richness	8.7	9.0	10.0	12.0	10.7	18.7
EPT Taxa Richness	1	0.7	1.7	2.0	0.0	7.0
EPT Abundance Per Kick Sample	94	1	16	80	0	282
Hilsenhoff-Biotic Index	5.94	8.26	8.02	6.26	7.59	4.08
Hilsenhoff-Water Quality	Fair	Poor	Poor	Fair	Poor	Very Good
Shannon Weaver Diversity Index	1.77	1.37	1.69	1.86	1.30	2.51
% Contribution of Dominant Taxon	45.1	56.2	46.0	34.5	65.2	22.0
Ratio of EPT to Chironomid Abundance	1.26	0.13	0.99	0.40	0.00	6.01
% Hydropsychidae to Total Trichoptera*	100	0.00	44.05	86.03	NA	45.53
Ratio Shredders/Total Number of Invertebrates	.02	0.03	0.00	0.03	0.00	0.02
Ratio Scrapers/Filterers	0.00	0.00	0.00	0.00	0.50	9.26
Community Loss Index	1.35	1.19	0.97	0.64	1.00	0.00
Relative Percent Similarity	30.4	26.1	17.4	39.1	17.4	NA
Biological Impairment Category	Moderately Impaired	Moderately Impaired	Severely Impaired	Moderately Impaired	Severely Impaired	Reference

Classification Ranges: Severely impaired = <17%; Moderately impaired = 21 – 50%; Slightly impaired = 54-79%; Non-impaired = >83%

Table 3.13 Dominant Taxon at the Biological Sampling Sites

Station	Dominant Taxon	Number
Tributaries to Warwick Pond (RI0007024R-05)		
BB00	Trichoptera (*Cheumatopsyche sp.*)	281
BB02	Oligochaeta (Tubifucudae)	101
Buckeye Brook (RI0007024R-01)		
BB04	Amphipoda (*Gammarus sp.*)	284
BB05A	Diptera (*Tanytarsus sp.*)	214
AP01	Diptera (Tanytarsini)	427
Adamsville Brook		
ESS45	Trichoptera (*Chimarra sp.*)	208

In Tributaries to Warwick Pond, the two sites, BB00 and BB02, are dominated by taxa suggesting poor water quality. *Cheumatopsyche* spp. are a common net-spinning caddisfly that are found in increasing abundance as water quality declines. *Cheumatopsyche* spp. are considered one of the most pollution tolerant genus within the Hydropsychidae in the Trichoptera family. Oligochaeta, aquatic worms, are generally an indication of polluted water and are low dissolved oxygen tolerant. By the time oligochaeta dominate the assemblage, most other aquatic organisms have been eliminated by poor water quality conditions.

Buckeye Brook also supports taxa suggestive of poor water quality. *Gammarus* spp. is a very diverse genus that has a wide tolerance range of multiple water quality indicators. *Tanytarsus* spp. are pollution-tolerant taxa that commonly occur in lower quality waters. Tanytarsini are considered somewhat tolerant of low dissolved oxygen. In contrast, Adamsville Brook's dominant taxa, *Chimarra* spp., are generally considered to be sensitive taxa found in higher quality waters. The dominance of genera tolerant of low oxygen and pollution confirms the biological impairment in Tributaries to Warwick Pond and Buckeye Brook compared to the dominance of a sensitive taxa at the reference site, ESS45 Adamsville Brook.

Although measurements of dissolved oxygen in 2006 and 2008 have consistently shown a dissolved oxygen sag to marginal levels (near 5.0 mg/L) in the vicinity of BB04 and BB05A, there was no obvious sign of additional metabolic stress due to low dissolved oxygen within the macroinvertebrate community at these stations. However, the overall level of impairment within the study areas and the fact that riffle habitats - generally the best oxygenated habitats of each stream reach - were sampled for macroinvertebrates make it difficult to discern the specific biological impacts of the observed low dissolved oxygen concentrations. Overall, the macroinvertebrate sampling results indicate moderate to severe biological impairments across a majority of the watershed. The most severe impairments are found downstream of the tributaries fed by the airport outfalls and the landfill.

3.7.3 Periphyton Results

In the absence of a true reference site or condition for periphyton, it is difficult to quantify the level of biological impairment over the drainage areas for the Warwick Pond tributaries and for Buckeye Brook as a whole. However, there is some indication that certain periphyton metrics, such as taxa richness, may be somewhat less than expected for small streams in the ecoregion. Additionally, the relatively high contribution of taxa that tend to be associated with some form of instream disturbance (e.g., siltation, nutrient enrichment, flashiness) may be reflective of an overall depression in biological and habitat condition throughout the study area. Habitat observations by ESS and nutrient data collected by RIDEM would appear to support this connection. Table 3.14 shows the Periphyton summary for the Buckeye Brook surveys while Table 3.15 shows the dominant Periphyton Taxa collected during the field surveys.

However, the trends in the periphyton community do not implicate a particular stressor or source in Buckeye Brook or the Tributaries to Warwick Pond. This may be due, in part, to the fact that the periphyton community is generally responsive to shorter term impacts than the macroinvertebrate community.

The presence of an orange to brown-colored flocculent was noted at several stations but was heaviest at OF08, AP01, and TA01. This flocculent material is characteristic of the bacterial colonies that oxidize the iron associated with both natural sources and landfill groundwater leachate, including *Gallionella ferruginea* and *Leptothrix ochracea*. In excess, the flocculent material can smother coarse substrates and clog the interstitial areas used as refuge by macroinvertebrates.

Patterns in the concentration of CPOM and FPOM did not display any significant trend in the downstream direction. However, when the two size fractions are combined, a trend of steady increase is apparent in the downstream direction. Nonetheless, it is difficult to infer an association with the observed biological patterns from a single measurement of POM.

Table 3.14 Periphyton Summary Table for the Buckeye Brook Study, September 10, 2008

Site	Average Generic Richness	Average % *Achanathes minutissima*	Average Diatom Pollution Tolerance Index	Average Biovolume ($\mu m^3/cm^2$)	Species Group	Average Biovolume ($\mu m^3/cm^2$)	Relative Biovolume (%)
Tributaries to Warwick Pond (RI0007024R-05)							
BB00	9.0	32.3	2.8	2.75E+05	blue-green	954	0.3
					cryptophyte	166	0.1
					diatom	210,728	76.7
					euglenoid	62,752	22.9
BB02	16.3	3.8	2.6	1.80E+06	blue-green	80,682	4.5
					cryptophyte	1,504	0.1
					diatom	1,665,236	92.6
					euglenoid	6,617	0.4
					green	43,303	2.4
Buckeye Brook (RI0007024R-01)							
BB04	14.7	5.2	2.4	5.46E+07	cryptophyte	510,937	0.9
					diatom	49,723,045	91.0
					euglenoid	1,132,075	2.1
					green	3,263,984	6.0
BB05A	16.7	1.0	2.3	7.52E+06	blue-green	581,101	7.7
					cryptophyte	340,210	4.5
					diatom	6,082,084	80.9
					euglenoid	483,790	6.4
					green	31,192	0.4
AP01	8.3	17.9	2.6	1.60E+07	cryptophyte	193,269	1.2
					diatom	11,365,208	69.3
					green	4,844,355	29.5

Table 3.15 Dominant Periphyton Taxa Collected for Buckeye Brook Biological Survey

Station	Group	Dominant Taxa (by Biovolume)
Tributaries to Warwick Pond (RI0007024R-05)		
BB00	Crytophytes	Rhodomonas
	Diatoms	Achnanthes, Cymbella, Epithemia, Cocconeis, Gomphonema, Tabellaria
	Euglenoids	Trachelomonas
BB02	Blue-greens	Oscillatoria
	Diatoms	Eunotia, Synedra, Nitzschia
Buckeye Brook (RI0007024R-01)		
BB04	Diatoms	Eunotia, Synedra, Navicula, Gomphoneis, Frustrulia
BB05A	Blue-greens	Oscillatoria
	Diatoms	Eunotia, Fragilaria, Synedra
	Euglenoids	Trachelomonas
AP01	Diatoms	Eunotia, Gomphonema, Synedra, Navicula, Achnanthes
	Greens	Cladophora

Adjustment of sampling frequency to include additional samples, especially over a full event hydrograph, may be useful for future efforts.

3.8 Aquatic Toxicity Study

Two of the four surveys conducted for the biodiversity study had stations that were tested for aquatic toxicity by the EPA Laboratory in Chelmsford, MA. The following sections of this report discuss the type of testing conducted, the stations selected for the testing, and summarizes the results of the dry and wet weather toxicity study. The full report is available at RIDEM upon request.

3.8.1 Dry Weather Toxicity Study

The dry weather toxicity survey was conducted from July 16-21, 2008 on six of the nine stations that were sampled during the biodiversity study for the Tributaries to Warwick Pond and Buckeye Brook. The first sampling run on July 16, 2008 collected field data (Dissolved Oxygen, Specific Conductivity, and Temperature), chemistry, and toxicity samples at Stations BB02, BB03, BB04, BB05A, as well as the Truk-Away landfill (TA01) and airport outfall (OF08) stations. Two other sampling runs were conducted every other day to collect water samples to replenish the water used in the toxicity tests at the EPA laboratory. This ensured that the water used in the toxicity tests would be fresh throughout the 7-day testing period.

Pimephales promelas **(fathead minnow)**

The results for the fathead minnow showed that neither the survivability nor the growth test (biomass) showed any statistically significant impact. One location (BB03) had a 5% lower survival rate when compared to the control and is not considered to be statistically and even less likely to be biologically significant. Examination of the test endpoint, growth, as shown by mean biomass, indicates that all but BB03 was equal to or greater than the mean biomass of the laboratory control sample. The biomass for the sample from BB03 was 18% lower, but not statistically different than the laboratory control as the 18% represents a difference of 0.11mg.

***Ceriodaphnia dubia* (daphnid)**
The results for the *C. dubia* indicate that there was no statistically significant reduction in survival for any of the site location samples when compared to the laboratory control. However, statistical analysis of the reproduction data does show a statistically significant reduction in the number of neonates produced in samples from Truk-Away landfill (TA01) and from the airport outfall (OF08). Both TA01 and OF08 reproduction mean values were 44% below the laboratory control sample.

In summary, during the dry weather sampling, there were not any significant toxicity issues for the fathead minnow at any station, but the daphnid did show some effects from the landfill and from the discharge for outfall OF08 which drains the main passenger terminal at the airport. Results from the chemical analysis show that at these stations, total iron and dissolved cadmium exceeded the chronic freshwater criteria for the dry survey. The criteria for total iron is 1000µg/L and the values at TA01 and OF08 were 11,586 µg/L and 2,844 µg/L respectively. The chronic criterion for total iron was also exceed at Stations BB04 and BB05A, but the results from the toxicity tests did not indicate any impact on the fathead minnow or the daphnid at these locations. The dissolved cadmium at TA01 and OF08 exceeded the chronic criteria by 30% and 6% respectively.

3.8.2 Wet Weather Toxicity Study

The second toxicity study was conducted during a winter, deicing conditions. Four sampling runs were conducted over a period of eight days starting February 1, 2011. Field measurements and chemistry samples were collected for all stations on every run, while toxicity sampling was only conducted at Stations BB00, BB02, BB03, BB04, outfall OF08, and TA01 for the last three runs of the storm event. A summary of the results from the winter toxicity survey is given below.

The test acceptability criteria (TAC) and nonlethal variability limits (PMSDs) were met for *Pimephales promelas* (fathead minnow). TAC for the *Ceriodaphnia dubia* (daphnid) was met for the survival endpoint, however the test TAC for reproduction fell below criteria.

***Pimephales promelas* (fathead minnow)**
All but one field sample, BB02, showed no significant statistical effect for survival. However, it was noted that due to the filamentous floc that developed in the test sample, it was a distinct possibility that the reduction in survival for BB02 may have been due to a physical impairment, rather than a true chemical effect. The survival rate for BB02 was 48% below the control sample, while all other stations were not affected.

There was a statistically significant reduction in biomass observed for Stations BB02, BB04, outfall OF08, and TA01, while Stations BB00 and BB03 showed no signs of growth impairment. However, interpretation of the results for the stations showing growth impairment was difficult base solely upon the test findings due in part to difficulties maintaining dissolved oxygen levels throughout the test period. While dissolved oxygen levels for these samples dropped below the minimum 4 mg/L, it may have been more a physical entrainment issue caused by the filamentous floc which contributed to the reduction in growth. Station BB02 had the largest biomass deficit below the control sample at 64%, with stations BB04 at 22%, TA01 at 20% and OF08 at 34% below the control for the wet weather survey. The dissolved oxygen sags that occurred during the toxicity test may have been influenced by the propylene glycol levels for these samples. The mean glycol at BB02 was 45 mg/L and the associated BOD_5 demand was 16.3 mg/L. Outfall station OF08 and BB04 had mean glycol values of 79 mg/L and 22 mg/L respectively, with the BOD_5 levels at 16.3 mg/L and 11.8 mg/L respectively.

Ceriodaphnia dubia **(daphnid)**
No significant effect on survival was observed for any sample stations for *Ceriodaphnia dubia*. The test failed to meet reproduction criteria. However, due to the difficulties capturing a winter storm event that met the parameters that occurred in this storm and the associated cost that would be incurred in doing so, the laboratory staff made the following observations in order to glean as much information from this test.

"The TAC are measured on the laboratory control organisms to evaluate, at least in part, test organism health. The laboratory controls represent the test organisms in the absence of any stressors. Therefore, it would be assumed that barring lab personnel performance issues, any improvement in health would be reflected across all test exposures. The current neonate production data indicates a maximum reduction in production at 10% is associated with sample location at BB02. All other neonate production is equal to or greater than the laboratory control response."

The laboratory staff stated that if the test organism health was improved and the test did meet TAC, or it was redone, a finding of no significant difference in reproduction for any of the samples would be the same. Therefore, it was decided to accept the results of the testing conducted on the *C. dubia* for this storm event.

In summary, the fathead minnow survival rate was not significantly impacted at any station except BB02 during the wet weather de-icing study. The reduced survival rate for BB02 was not a toxic response but likely due to a physical impairment from the filamentous floc in the sample. There was a significant difference in biomass growth for the minnow at stations BB02, BB04, TA01, and outfall OF08 which may again be connected to the filamentous floc that developed in the test sample. The dissolved oxygen sag observed in the samples could be in response to the propylene glycol which uses oxygen during the degradation process.

The daphnid survival rate was not affected for the toxicity testing but the reproduction data failed to meet test criteria. Again, the dissolved oxygen levels in the test samples may have been the cause of the low reproduction rather than any toxic effects from pollutants in the water column.

3.9 Aquatic Life Use Impairment Stressor Analysis

The primary objective of Rhode Island Department of Environmental Management's sampling effort was to characterize the geographic extent and severity of the Buckeye Brook Aquatic Life Use (AQLU) impairment and to identify potential causes and/or pollution sources contributing to the impairment. Water quality and/or benthic biological samples were collected from nine sites in the Buckeye Brook watershed over the course of surveys from July 2008 through February

2011 that consisted of four dry weather and two wet weather surveys, one of which was during a winter icing event. The results of the sampling program led to the identification of new impairments which were added to the state's 303(d) Impaired Waters List. While the September 10, 2008 survey proceeded as a dry weather survey, 4.39" of precipitation occurred between September 6th and 9th, with 0.29" of precipitation on September 9th. Therefore, these samples are likely influenced by precipitation. It was determined that the final assessment of trace metals would be not be affected by analysis as dry or wet weather, given that with a single sample only acute criteria would apply for wet weather. Analysis of acute criteria occurs under dry weather in the same manner as wet weather. The new impairments are: dissolved oxygen, total iron, and dissolved cadmium, copper, and lead. Dissolved copper and lead impairments apply to Buckeye Brook only.

The results of macroinvertebrate sampling on Tributaries to Warwick Pond and Buckeye Brook found moderate to severe impairments of the biological community in these streams, with the more severe impairments associated with areas near the airport and landfill. Poor stream habitat is contributing to degraded aquatic life use in these stream systems. The smothering of the streambed habitat by iron flocculent material was evident in each of the tributaries originating from the airport and/or landfill including stations OF08, AP01, and TA01. While this flocculent material was less visible in the Buckeye Brook station (BB04) downstream of the confluence with the tributaries' confluence with the brook, analysis of macroinvertebrate samples confirms its presence at this station. The hydrologic impacts (decreased groundwater recharge, lower base flows and increased runoff) associated with these streams' highly impervious watersheds alter stream morphology resulting in flashier, less stable streams which also degrade the quality of habitats for aquatic life.

The results of toxicity testing reveal that for the majority of the stations, there were no dry weather toxicity issues except for those stations receiving flow from the landfill and airport, TA01 and OF08 respectively, where there was a significant reduction in the number of daphnid neonates produced in samples from Truk-Away landfill (TA01) and from the airport outfall (OF08). The conditions (dry weather) leading to the observed toxic effects are likely contributing to the severity of the impairment of the biological community at these locations.

Toxicity testing conducted on samples collected during a winter storm requiring use of deicing compounds, the February 2011 storm, revealed statistically significant reduction in minnow biomass at stations located downstream of the airport and landfill, which was notably not observed at stations located upstream of the airport and at the outlet of Warwick Pond. It was noted by laboratory staff conducting the analysis that the observed effects were likely due to physical entrainment in the filamentous floc growing in the sample and not a toxic effect.

Instream copper criteria were exceeded only during wet weather with a single chronic exceedance in Tributaries to Warwick Pond and an acute and chronic exceedance in Buckeye Brook. One exceedance of the chronic criteria is acceptable, given that the State's Water Quality Regulations stipulate "the four-day average concentration of a pollutant should not exceed the chronic criteria more than once every three years on the average". Similarly, one exceedance of the acute criteria is acceptable, given that the State's Water Quality Regulations (WQRs) stipulate "the one-hour average concentration of a pollutant should not exceed the acute criteria more than once every three years on the average”. However, given the acute criteria exceeded during a wet weather event, then DEM considers it likely that the criteria would be exceeded again within a three-year period, and the data represent a violation of water quality standards. Under this assumption, only one exceedance of the acute criteria during wet weather is needed to identify an impairment.

A single exceedance of the criteria may be viewed as non-compliance with the standards if there is strong evidence that the criteria could be exceeded again within a three-year period. More specifically, one exceedance may be considered a violation of criteria where RIDEM has knowledge of an actual or potential upstream pollution source or where the exceedance occurred during a wet weather event, and it is considered likely that the condition would reoccur, and the criteria would be exceeded again within a three-year period. It was determined by RIDEM that the single exceedance in Buckeye Brook was likely to occur, and the dissolved copper impairment was included for Buckeye Brook only.

The total iron criterion was exceeded at the sampling stations located downstream of the airport and landfill (TA01, OF08, and AP01) and in Buckeye Brook downstream of these sources (BB04 and BB05A) during both dry weather events. During both wet weather events, nearly all stations exceeded the iron criterion, with the highest exceedances occurring at the landfill and airport sampling locations. It is noted that concentrations of iron are comparable between the Tributaries to Warwick Pond and Buckeye Brook in wet weather. Dissolved cadmium aquatic life criteria were exceeded at stations (BB00 and BB02) in the Warwick Pond tributaries and at OF08 and BB05A in Buckeye Brook during wet weather. During dry weather, no dissolved cadmium exceedances occurred at OF08 or AP01, but throughout other stations on Tributaries to Warwick Pond and Buckeye Brook. No dry weather lead exceedance occurred in Tributaries to Warwick Pond. In Buckeye Brook, a dry weather lead exceedance occurred at TA01. Wet weather exceedances were only found in the airport (OF08) and landfill stations (TA01). Finally, dissolved zinc was not exceeded in Tributaries to Warwick Pond or Buckeye Brook in dry or wet weather.

RIDEM staff reviewed the monitoring data from 2012 through 2017 submitted by RIAC as part of the permit requirements. Analysis of this data show that the levels of total iron in the discharges from airport outfalls 002 and 003 to the tributaries of Warwick Pond and outfall 008 to Buckeye Brook are similar to levels observed from RIDEM’s field work in 2008 – 2011 time period – confirming the airport as an ongoing source of total iron contributing to observed impairments in the receiving waters.

Iron fixing bacteria (*Sphaerotilus*) were observed to completely cover the streambed in the tributary channels originating at the landfill and the airport property (stations TA01, outfall OF08, and AP01) during the field sampling conducted by ESS, and historically have been observed in the channel flowing from airport outfalls (#002 and 003) that flow into the Warwick Pond Tributaries (Louis Berger, 2007). These bacteria were also observed in Buckeye Brook downstream of the confluence with the airport and landfill though not completely covering the streambed. These bacteria have been documented at other locations to cover entire streambeds near airports crowding out indigenous forms of aquatic life. In the process of metabolizing carbonaceous materials, such as propylene glycol, the bacteria consume available oxygen in the stream's water column and are believed to be contributing to the observed dissolved oxygen levels below the minimum 5.0 mg/L in Buckeye Brook. The extent of iron fixing bacteria in the channels leading from the airport and landfill and covering the substrate in Buckeye Brook is believed to be significantly impacting aquatic life in these stream systems (ESS, 2008).

Dissolved oxygen sags were observed in Buckeye Brook in different seasons and under various flow and weather conditions. Sampling conducted by RIAC during the February 2011 de-icing event documented spikes in BOD_5 and propylene glycol at stations located on the Tributaries to Warwick Pond and Buckeye Brook downstream of airport outfalls; these spikes coincide with dissolved oxygen sags documented by DEM during the same storm event though no violations of DO criteria were observed. DEM has also observed dissolved oxygen sags between the exit of Warwick Pond and the stream channel originating from the airport and landfill in dry weather summer conditions (with dissolved oxygen levels dropping an average of 3.2 mg/l). The observed DO concentrations at the BB04 station were in violation of RIDEM's instantaneous dissolved oxygen criteria. BOD_5 was not elevated – and thus not a factor in the summertime DO sag. However, as noted above iron fixing bacteria were observed to be covering the substrate of this reach of Buckeye Brook, and oxygen consumed by these bacteria is believed to be the cause of the dissolved oxygen sag in this reach.

In conclusion, this analysis of Aquatic Life Use stressors finds that a combination of stressors is contributing to the observed biodiversity impairments in Buckeye Brook and the Tributaries to Warwick Pond, as evident from benthic macroinvertebrate bioassessments. The uncontrolled discharge of stormwater and related hydrologic and stream habitat alterations associated with the highly urbanized watersheds combined with violations of ambient water quality criteria for various metals, discharge of propylene glycol, and extensive growth of iron fixing bacteria on substrates downstream of the airport outfalls and the Truk Away Landfill are all believed to be stressors contributing to the observed biodiversity impairments. This TMDL finds that the subwatersheds as depicted in Figure 3.12 are contributing to the pollutant impairments documented in Buckeye Brook.

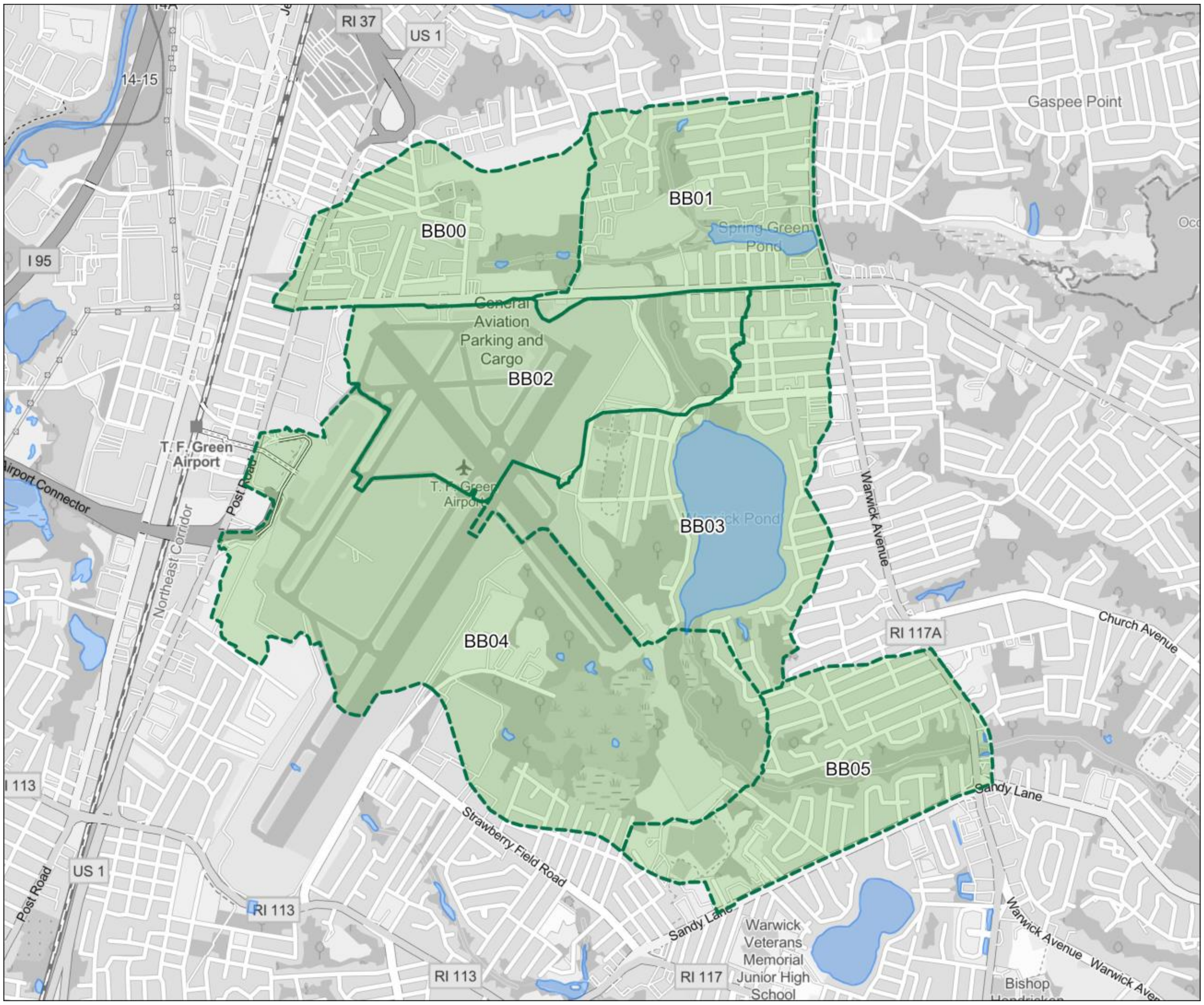


Figure 3.12 Subwatersheds contributing pollution to Buckeye Brook and Tributaries to Warwick Pond

4.0 POLLUTION SOURCES

Sources of impairments in the watersheds were identified using the analytical results from water samples collected during the four dry weather and two wet weather surveys. The results from the biological survey were also utilized in determining the sources of the impairments to portions of Buckeye Brook and Tributaries to Warwick Pond. The TMDL examination of actual and potential sources of metals contamination to the brook and its tributaries are summarized in Table 4.1 and further discussed below. The subwatersheds identified in Figure 3.12 document where reductions must happen from all sources to reduce pollution into Buckeye Brook and achieve water quality standards for the pollutants of concern in this TMDL.

4.1 Stormwater

With 42% of the combined watersheds covered by impervious surfaces, stormwater runoff is a significant source of pollution to the area. Throughout both watersheds, storm drainage systems collect, concentrate, and route polluted runoff from streets and highways directly to the mainstem and tributaries. T.F. Green Airport operates a separate stormwater collection system to convey runoff from runways, terminal, parking lots, and other impervious surfaces. Stormwater from parking lots and the commercial and industrial areas surrounding the airport may be discharged into municipal or state-owned drainage systems or may be conveyed directly to stream systems via overland flow, stormwater pipes, or other conveyances. Recent improvements by RI Airport Corporation include the construction of structural stormwater controls at select locations to treat runoff discharged from its facilities.

The amount of impervious areas in a watershed also affects the water quality of rivers and streams within the watershed. Study results from USGS in the New Hampshire seacoast region confirm that the percent impervious surface in a watershed can be used as an indicator of stream quality: the biological condition score was negatively correlated with the percent impervious surface (Deacon, et.al. 2005). Furthermore, a growing number of northeastern states are recognizing the relationship between impervious cover and water quality impairments and are utilizing percent impervious cover as a surrogate target for TMDL analyses.

Table 4.1 Actual and Potential Pollution Sources

Source	Location/ Explanation
Stormwater Runoff	Throughout these highly urbanized watersheds including T.F. Green Airport. Runoff from impervious areas such as parking lots, streets, roofs, and runoff contaminated with heavy metals (Cd, Cu, Pb, and Fe) among other pollutants.
Waste Sources	Waste sources include landfills such as the Truk Away Landfill.
Groundwater	Potential sources of contaminates to groundwater can be historic in origin and originate in landfills, open areas of unsupervised dumping, construction operations, backfilled areas with contaminated soils.
Non-Stormwater Urban Runoff	Overland flows from various land use practices enter storm drains, which including lawn irrigation runoff, car washing, sidewalk washing and commercial pavement washing. These urban flows can contain metals among other pollutants.

Urban land uses change watershed hydrology by affecting the quantity and quality of runoff. A combination of pollutants found in stormwater contributes to aquatic life impairments in streams, along with habitat destruction by flash floods and bank erosion. Often there is not a direct link to a specific source that is causing or contributing to exceedances of a pollutant specific water quality criterion. Quantifying pollutant loadings is especially difficult given the variability in types and amounts of pollutants associated with impervious cover. Aquatic life impairments associated with stormwater are not always caused by a single pollutant and are most often due to a complex array of pollutants transported by stormwater and other impacts of urban development.

Urban development also results in increases in stormwater runoff peaks and volumes and increased frequency of runoff from smaller storms. With increasing impervious cover within a watershed, the greater quantities of stormwater runoff wreak havoc with the physical structure and stability of streams and the habitat for aquatic life, and less base flow is available to aquatic life in streams during low flow periods.

4.2 Waste Sources

There are two waste sources within the watershed boundaries. One is the Truk-Away Landfill that is located off the departure end of Runway 16 and the other is the other is the Municipal Recycling Facility located behind the Mickey Stevens Sports Complex off Sandy Lane.

The landfill was in operation through the 1970s and was closed for operation in 1977 but never capped. In 1977, the property was sold to the state Department of Transportation (DOT) and ceased operations because of the hazards posed to air traffic by sea gulls attracted to the landfill. The landfill has never been "clean closed," meaning not all hazardous waste has been removed. The landfill is also listed on the Comprehensive Environmental Response, Compensation and Liability Information System (CERCLIS) and is listed on RIDEM's Management Landfill Closure Program.

Since the landfill is not capped hydraulically, any precipitation infiltrates through the buried waste and eventually can reach the groundwater table which may be flowing to the brook. Investigation is on-going regarding the movement of waste leachate from the site: http://www.dem.ri.gov/programs/customertech/truk-away-landfill-closure.php. Surface flow over the landfill can also end up discharging into the brook through an adjacent wetland area.

The City of Warwick's Municipal Recycling facility, located adjacent to the Mickey Stevens Sports Complex off Sandy Lane, processes yard waste for compost on a concrete pad that is adjacent to a large wetland area. This area was investigated, and it was determined that based upon the operating procedures followed and the layout of the site that this facility was not a source of concern relative to pollutants or nutrients discharged to Buckeye Brook.

4.3 Groundwater

Groundwater can contain pollutants from several sources, some of which include improperly maintained or closed landfills, leaking underground storage tanks, chemicals and road salts used to melt ice, and atmospheric deposition.

In 2007, the RIAC contracted a consultant (Louis Berger Group, 2007) to investigate the odor issues associated with airport operations and on the proliferation of bacteria in the areas downstream of the airport's stormwater outfalls. The study showed high levels of iron and that iron bacteria growth was prevalent in the stormwater systems for those outfalls that discharge directly to the tributaries to Warwick Pond and Buckeye Brook. The outfalls were flowing during dry weather conditions and had iron levels high enough which provided a food source for the bacteria. The report states that the outfall drainage channels received the groundwater recharge as a point source at the headwaters, where the iron rich groundwater is seeping into the storm water piping system. Additionally, this RIDEM field study showed that discharge from the largest outfall at the airport (008) had exceedances of metals criteria.

Contaminated groundwater comes from the leachate that percolates through the Truk-Away landfill. The presence of rust-orange sediments in the water at the landfill station TA01 verifies that the leachate from the landfill is rich in iron which provides a food source for the iron bacteria. The samples collected during dry weather by RIDEM staff at station TA01 on the small tributary fed by groundwater that drains the landfill also exceeded the freshwater metals criteria.

Sampling of the monitoring wells along the eastern perimeter of the landfill show that there are volatile organic compounds (VOCs) present. Soil samples from the area around the wells did contain some metals, but only arsenic exceeded the RIDEM industrial/commercial direct exposure or leachability criteria of 3.8 mg/Kg. Samples from TA01 did contain arsenic but at levels well below the freshwater criteria. Testing by EPA and toxicity testing conducted as part of this study do not show evidence that these contaminants are contributing to biodiversity impairments seen in Buckeye Brook.

5.0 TMDL ANALYSIS

This TMDL establishes numeric water quality targets for dissolved cadmium, copper, and lead and total iron. Dissolved copper and lead numeric water quality targets apply to Buckeye Brook only. Dissolved oxygen targets and benthic macroinvertebrate bioassessment targets are the numeric and narrative criteria in the RI Water Quality Regulations (RIDEM, 2018a).

5.1 Applicable Metals Water Quality Criteria

Freshwater aquatic life criteria for certain metals are expressed as a function of hardness, because hardness can affect the toxicity of these metals. Increasing hardness has the effect of decreasing the toxicity of metals. The water quality standards for toxics, including dissolved metals, are set forth in § 1.26 of Rhode Island’s Water Quality Regulations (RIDEM, 2018a). The chronic and acute freshwater aquatic life criteria of most metals apply to the dissolved form and are calculated using water hardness (in mg/l as CaCO3) for each waterbody segment based on equations in § 1.26 of Rhode Island’s Water Quality Regulations (RIDEM, 2018a). Table 5.1 reflects the range of criteria based on hardness values observed during this study. This approach to determine which hardness values would be used to establish the criteria was necessary in order to be conservative enough to provide adequate protection under all flow conditions.

Table 5.1 Range of Water Quality Criteria Utilized for the Buckeye Brook TMDL

Hardness as $CaCO_3$ (mg/L)	Cadmium (µg/L)		Copper (µg/L)		Lead (µg/L)	
	Acute Criteria	Chronic Criteria	Acute Criteria	Chronic Criteria	Acute Criteria	Chronic Criteria
15	0.31	0.07	2.25	1.77	7.30	0.28
30	0.62	0.11	4.32	3.20	17.0	0.66
60	1.23	0.17	8.31	5.79	36.9	1.44
90	1.82	0.23	12.2	8.18	57.6	2.24
100	2.01	0.25	13.4	8.96	64.6	2.52

5.2 Water Quality and Resource Impairments

Data collected by RIDEM over the course of four dry and two wet surveys conducted in the study areas confirm that portions of both watersheds exceed certain dissolved metals aquatic life criteria as stated in § 1.26 of Rhode Island's Water Quality Regulations (RIDEM, 2018a). In this case, the impaired use is the protection of aquatic life.

5.3 Critical Conditions and Seasonal Variation

The Clean Water Act, Section 303(d)(1)(C) requires that TMDLs "be established at a level necessary to implement the applicable water quality standards with seasonal variations…" The current regulation also states that determination of "TMDLs shall take into account critical conditions for stream flow, loading, and water quality parameters" [40 CFR 130.7(c)(1)].

Elevations of metals concentrations occur throughout the year and under various flow regimes and weather conditions, depending upon the location and metal in question. However, as documented in Table 3.5, exceedances of applicable metals criteria occur frequently. The acute and chronic aquatic life criteria for freshwaters shall not be exceeded at or above the lowest average 7 consecutive day low flow with an average recurrence frequency of once in 10 years (7Q10) (§ 1.26(D)(4); RIDEM, 2018) inclusive of all seasons and for all weather conditions.

5.4 Margin of Safety

A Margin of Safety (MOS), designed to account for uncertainty in TMDL calculations, is a required element of a TMDL [40 CFR 130.7]. The MOS may be incorporated into the TMDL in two ways. One can implicitly incorporate the MOS by using conservative assumptions throughout the TMDL development process or one may explicitly allocate a portion of the TMDL as the MOS. An explicit Margin of Safety of 10% was used for this TMDL.

An explicit MOS is calculated by taking 10 percent of the final TMDL concentrations, which are the calculated metals criteria. This 10 percent amount is essentially reserved: it is not available for wasteload or load allocation and therefore makes the allocations smaller and thus, more protective. For example, if the calculated criterion for dissolved copper at a particular survey site is 10µg/L, then 10% or 1µg/L would be allocated to the MOS. Therefore, the wasteload and load allocation would have to equal 9µg/L (10µg/L minus 1µg/L).

5.5 Technical Analysis

The total assimilative capacity, or loading capacity, is the maximum amount of pollutant that a waterbody can assimilate while maintaining water quality standards. The loading capacity is a function of different hydrodynamic processes that affect the environmental fate and transport of dissolved metals as they move through the system. For this TMDL, the allowable load or loading capacity is expressed as a concentration set equal to the applicable state water quality standard for each dissolved metal. This concentration is considered to apply daily, in that daily values are used to compare against the acute and chronic criteria. The allowable daily load is the criteria concentration times the flow in the receiving water. For the purposes of implementation, it is recommended that the concentration and percent reduction dissolved metals TMDL targets be used.

5.6 Establishing the Allowable Loading (TMDL)

EPA guidelines specify that a TMDL must identify the pollutant loading that a waterbody can assimilate per unit time without violating water quality standards, with loads expressed as mass per time, toxicity, or any other appropriate measure (40 CFR §130.2).

Trace metal reductions are unique in that the TMDL endpoints (acute and chronic criteria) must be met during a range of flows for a waterbody to maintain water quality standards and meet its designated uses. Consistent with EPA's Technical Support Document for Water Quality-based Toxics Control (1991), this dissolved metals TMDL was evaluated under both steady state and wet weather conditions.

5.7 Wasteload and Load Allocations

A TMDL is the combination of a total wasteload allocation (WLA) that allocates loadings for point sources, a total load allocation (LA) that allocates loadings for nonpoint sources and background sources and a Margin of Safety (MOS). In TMDL development, allowable WLA and LA from pollutant sources that cumulatively amount to no more than the TMDL must be established; this provides the basis to establish water quality-based controls. TMDLs can be expressed on a mass loading basis or as a concentration in accordance with provisions in federal regulations [40 CFR 130.2(i)]. The TMDLs and consequently the WLAs and LAs are expressed as concentration targets required to meet standards.

The LAs are assigned to nonpoint sources and natural background sources in the watershed. These sources include air deposition of metals and groundwater contributions and may or may not include anthropogenic sources. Since it is not possible to separate out the load allocation, it is included in the WLA and the MOS is explicit, therefore the TMDL equals the WLA.

5.8 Strengths and Weaknesses in the Technical Approach

Strengths

- The TMDL is based on extensive data and knowledge of the area.
- The TMDL incorporates the finding of field surveys conducted under both dry and wet conditions.
- The TMDL is based on actual data collected by RIDEM staff
- Following a weight of evidence approach to analyzing stressors finds that conditions associated with elevated metals concentrations (dissolved Cd, Cu, and Pb and total Fe applicable as denoted in Table 1.1), dense growth of iron fixing bacteria, and dissolved oxygen sags contribute to the observed benthic macroinvertebrate impairments.

Weaknesses

- The area is complex due to the characteristics of the watershed.
- Loadings could not be calculated because flow data was not collected.
- Additional site-specific information is required for identification and specification of BMPs to achieve TMDL targets.

5.9 Reasonable Assurance

EPA guidance calls for reasonable assurance when a TMDL is developed for waters impaired by both point and nonpoint sources. If a point source is given a less stringent wasteload (i.e. point source) allocation based on an assumption that nonpoint source load reductions will occur, there must be reasonable assurance that the nonpoint source reduction will occur. In this case, reasonable assurance is not required, because point sources are not given less stringent wasteload allocations. As mentioned in 5.7, the LA is not able to be separated, so it is included in the WLA and the MOS is explicit. Therefore, the TMDL is set equal to the WLA.

6.0 IMPLEMENTATION

Efforts to implement this TMDL must ensure that Buckeye Brook and the Tributaries to Warwick Pond meet water quality criteria for dissolved cadmium, copper, and lead and total iron, dissolved oxygen numeric criteria, and narrative criteria for protection of aquatic life. Dissolved copper and lead numeric water quality TMDL targets apply to Buckeye Brook only. Compliance with the TMDL will be accomplished by ensuring that all point source discharges (stormwater) and nonpoint sources meet the wasteload allocations for metals set forth in section 5.0 of this report.

Actions to mitigate the cause of the dissolved oxygen impairment and to avoid future violations of the in-stream dissolved oxygen criteria are either in place (RIAC’s stormwater permit requiring construction of a glycol treatment and diversion structures that went online in October 2014) or will be addressed by this TMDL’s target values for the discharge of total iron into the affected water bodies identified in this document.

This TMDL does not establish a separate target to address hydrologic alterations associated with the discharge of uncontrolled runoff from the highly impervious watersheds believed to be contributing to these river’s aquatic life use impairments. Actions to mitigate the uncontrolled discharge of runoff from the Rhode Island Department of Transportation and the City of Warwick as required by the Buckeye Brook Bacteria TMDL also address the associated hydrologic alterations. In addition to the previous permit requirements for stormwater management, this TMDL anticipates that RIAC's new permit will include requirements to manage stormwater to reduce runoff volumes consistent with requirements established for MS4 operators in the six minimum measures.

Implementation activities must focus on mitigating metals in groundwater from TF Green Airport, leachate from the Truk-Away landfill, and managing stormwater to reduce runoff volumes and metals concentrations throughout the watersheds. These efforts combined with actions implemented by RIAC to control the discharge of propylene glycol and actions to mitigate the uncontrolled stormwater discharges from the Rhode Island Department of Transportation and the City of Warwick, as required by the Buckeye Brook Bacteria TMDL, will lead to improvements in these streams' aquatic life as measured by benthic macroinvertebrate bioassessments. Both RIDOT and the City of Warwick are required to undertake structural improvements to eliminate or treat impervious cover to act as if it were eliminated to achieve a target 10% impervious cover.

6.1 Percent Reduction Recommendations

For all dissolved metals, a waterbody segment specific percent reduction was calculated for both wet and dry conditions only where an exceedance of criteria occurred. The waterbody segment's average percent reduction for each wet and dry condition was selected as a target reduction value to be used when implementing the TMDL. DEM recognizes any management measures to mitigate the release of pollutants implemented after the time samples were collected contribute to the required reductions.

For dry weather, the average hardness by waterbody segment and date was used to calculate the criteria. The calculated criteria were reduced by the 10% MOS to generate a TMDL concentration. The observed value by station was compared to the TMDL concentration to calculate the percent reduction and ultimately averaged with all exceedance percent reductions by segment.

For wet weather, hardness was averaged by storm as follow to calculate a criterion for each station, Wet Weather 1: Run 1 (12/10/08) + Run 2 (12/11/08); Wet Weather 2: Run 1 (2/3/11) + Run 2 (2/6/11), Run 2 (2/6/11) + Run 3 (2/8/11). The resulting criteria were then averaged for an average waterbody segment criterion. The resulting criteria was further reduced by the 10% MOS to generate a TMDL concentration. The observed metals concentrations were also averaged as described above by storm and were compared to the TMDL concentration to calculate the percent reduction for each station and ultimately averaged with all exceedance percent reductions by segment. The values are presented in Appendix B.

Table 6.1 Recommended Percent Reductions for Trace Metals

Waterbody	Dissolved Cd		Dissolved Cu		Dissolved Pb		Total Fe	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Tribs to Warwick	42.9	41.2	N/A	N/A	N/A	N/A	39.4	44.5
Buckeye Brook	62.1	30.2	No Reduction	20.0	12.4	32.4	58.8	51.4

6.2 Stormwater Runoff

The study area is highly impervious and contains a mix of urban and mixed rural areas. Work done by the Center for Watershed Protection (www.cwp.org) has shown that several stream quality indicators decrease as impervious cover (IC) percentages increase (Schueler, 2003), as shown in Figure 2.1. The trend becomes more pronounced within the 10-25% IC range, and impairment is almost inevitable when the watershed IC exceeds 25%.

Results from this TMDL’s investigations corroborate these findings. Results of macroinvertebrate sampling conducted as part of these investigations, presented in Table 3.12, show that the Tributaries to Warwick Pond and Buckeye Brook are moderately to severely impaired for aquatic life use. Table 3.2 presents the results from the analysis of the land use within these watersheds with the IC for the Tributaries to Warwick Pond averaging 45% while Buckeye Brook watershed is 41% IC.

Available literature (EPA/ENSR, 2005) suggests that stormwater management plans for these watersheds should establish a goal of achieving an effective impervious cover of 10% to reduce stormwater-associated pollutants, along with the other stressors to aquatic life such as channel scour and loss of pool/riffle habitat. Consistent with this literature finding, consent decrees established by EPA and RIDEM require that RIDOT and a consent agreement with the City of Warwick respectively apply the Impervious Cover Standard to manage stormwater to achieve Buckeye Brook Bacteria TMDL requirements. The concept behind the approach is that it is desirable for a watershed to be similar, in terms of water quality effects, to a watershed with 10% or less impervious cover overall. Accordingly, the amount of impervious cover that would need to be eliminated or treated to act as if it were eliminated to reach the 10% target is calculated. The target impervious cover condition represents the condition in which all these stressors are reduced to levels compatible with attainment of the aquatic life criteria as indicated by benthic macroinvertebrate metrics. No new separate impervious cover targets are established by this TMDL. Lowering the IC improves overall watershed health, not just for bacteria, but other pollutants, including the metals pollutants addressed by this TMDL, as well. This TMDL reiterates the need to reduce IC to a target of 10% to meet water quality standards.

When possible, efforts by the city, land trusts and others to preserve open space should continue. As land is developed, it is critical that significant natural hydrologic features be protected to maintain the area’s unique characteristics and to prevent further degradation of water quality – as can be achieved through use of conservation development and LID techniques. Redevelopment projects represent opportunities to reduce the water quality impacts from the watershed’s urbanized land uses by reducing impervious cover and/or attenuating runoff on-site. As described below, municipal ordinances must be reviewed and revised to make sure that future development projects do not add to water quality problems and that redevelopment projects reduce contributions to the water quality problems in either watershed.

In 2007, Rhode Island adopted the Smart Development for a Cleaner Bay Act (General Laws Chapter 45-61.2), requiring RIDEM and CRMC to update the Rhode Island Stormwater Design and Installations Manual to: maintain groundwater recharge at pre-development levels, maintain post-development peak discharge rates to not exceed pre-development rates, and use low impact development techniques as the primary method of stormwater control to the maximum extent practicable. The revised manual, adopted into regulation in 2018 (RIDEM, 2018b), provides minimum standards addressing LID Site Planning and Design Strategies, Groundwater Recharge, Water Quality, Redevelopment Projects, Pollution Prevention, Illicit Discharges, and Stormwater Management System Operation and Maintenance, among other concerns. This revised manual as adopted into regulation provides appropriate guidance for stormwater management on new development and redevelopment projects and, most importantly, incorporates LID as the "industry standard" for all sites, representing a fundamental shift in how development projects are planned and designed. The revised stormwater manual is available on-line at: https://rules.sos.ri.gov/regulations/part/250-150-10-8

A companion manual on LID site planning and design has also been prepared by RIDEM to provide Rhode Island-specific guidance regarding the site planning, design, and development strategies that communities should adopt to encourage low impact development. This manual is also available at:
http://www.dem.ri.gov/programs/benviron/water/permits/ripdes/stwater/t4guide/lidplan.pdf

Achieving water quality standards requires that both the quantity of stormwater and the pollutant concentrations in that storm water reaching waterbodies be reduced. Best Management Practices (BMPs) are effective, practical, structural, or non-structural methods which prevent or reduce the movement of pollutants from the land to surface or ground water. BMPs are designed to protect water quality and to prevent new pollution.

Structural BMPs are engineered constructed systems that can be designed to provide water quality and/or water quantity control benefits. The Rhode Island Stormwater Design and Installation Standards Manual (RIDEM, 2018b) contains detailed specifications for the design of these BMPs that can be used to meet water quality objectives.

Common structural BMPs include the following:

- *Green Infrastructure systems:* designed to treat runoff through vegetative uptake and filtration through soils (examples include bioretention cells, bioswales, and tree filters).
- *Infiltration systems*: designed to capture stormwater runoff, retain it, and encourage infiltration into the ground.
- *Detention systems*: designed to temporarily store runoff and release it at a gradual and controlled rate (considered acceptable for flood control only).
- *Retention systems:* designed to capture a volume of runoff and retain that volume until it is displaced in part or whole by the next runoff event (considered acceptable for flood control only).
- *Wet vegetated treatment systems:* designed to provide both water quality and water quantity control.
- *Filtration systems*: designed to remove particulate pollutants found in stormwater runoff through the use of media such as sand, gravel or peat.

Non-structural BMPs are a broad group of practices designed to prevent pollution through maintenance and management measures. They are typically related to the improvement of operational techniques or the performance of necessary stewardship tasks that are of an ongoing nature. These pollution-prevention practices are designed to control pollutants at their source and to prevent pollutants from entering stormwater runoff. Non-structural measures can be very effective at controlling pollution generation at the source, thereby reducing the need for costly "end-of-pipe" treatment by structural BMPs. Examples of non-structural BMPs include maintenance practices to help reduce pollutant contributions from various land uses and human operations, such as street sweeping, road and ditch maintenance, or specifications regarding how and when to spread manure or sludge.

Structural and non-structural BMPs are often used together. Effective pollution management is best achieved from a management systems approach, as opposed to an approach that focuses on individual practices. Some individual practices may not be very effective alone, but in combination with others, may be more successful in preventing water pollution.

6.2.1 RIPDES Phase II Stormwater Management Programs – SWMPPs and Six Minimum Measures

Stormwater runoff is most often carried to waterways by publicly owned drainage networks. Historically, storm drain networks were designed to carry stormwater away from roadways and other developed land as quickly as possible to prevent flooding with little to no treatment of pollutants. In 1999, EPA finalized its Stormwater Phase II rule, which required the operators of small municipal separate storm sewer systems (MS4s) to obtain permits and to implement a stormwater management program to control polluted discharges that is based on six minimum measures. Operators develop Stormwater Management Program Plans (SWMPPs) that detail how their stormwater management programs comply with the Phase II regulations. SWMPPs describe BMPs for the six minimum measures, including measurable goals and schedules. The implementation schedules include interim milestones, frequency of activities, and result reporting. Plans also include any additional requirements that are mandated for stormwater that discharges to impaired waters.

In Rhode Island, the RIDEM RIPDES Program administers the Phase II program using a General Permit that was established in 2003 (RIDEM, 2003). The City of Warwick and the Rhode Island Department of Transportation (RIDOT) are regulated under the Phase II program.

The six minimum measures are listed below:

- A public education and outreach program to inform the public about the impacts of stormwater on surface water bodies.
- A public involvement/participation program.
- An illicit discharge detection and elimination program.
- A construction site stormwater runoff control program for sites disturbing 1 or more acres.
- A post construction stormwater runoff control program for new development and redevelopment sites disturbing 1 or more acres.
- A municipal pollution prevention/good housekeeping operation and maintenance program.

In general, municipalities and RIDOT were automatically designated as part of the Phase II program if they were located either completely or partially within census-designated urbanized or densely populated area. The City of Warwick is a densely populated municipality with greater than 80,000 residents with a density of approximately 2300 people per square mile. Both Warwick and RIDOT have submitted the required Stormwater Management Program Plans (SWMPPs) for those areas of the study that are located within the densely populated areas.

6.2.2 Required SWMPP Amendments to TMDL Provisions

In Rhode Island, Part IV.D of the Phase II 2003 General Permit requires MS4 operators to address TMDL provisions in their SWMPP if the approved TMDL identifies stormwater discharges that directly or indirectly contain the pollutant(s) of concern (Part II.C3). Operators must comply with Phase II TMDL requirements if they contribute stormwater to priority outfalls via system interconnections, even if they do not own the outfall. Operators must identify amendments needed to their current SWMPP to comply with TMDL requirements. To avoid confusion and to better track progress, the SWMPP amendments should be addressed in a separate TMDL Implementation Plan (TMDL IP) or in the manner required by their current permit in future implementation.

It is common for state-owned and municipal-owned storm drains to interconnect. RIDEM encourages cooperation between municipalities and RIDOT when developing and implementing the six minimum measures and in conducting feasibility analyses and determining suitable locations for the construction of BMPs. An important first step in implementing this TMDL is to confirm the ownership of the priority outfalls for the affected watersheds. The Buckeye Brook Pathogen TMDL (December 2008) listed several priority outfalls for Buckeye Brook, which should have been investigated by the city to determine if there were any interconnections of the storm drain system. The list is a good starting point to help identify additional outfalls that may be contributing to the biodiversity impairments for the stream systems in this study. Additionally, RIDOT has completed stormwater control plans for Buckeye Brook and Warwick Pond, inclusive of the Tributaries to Warwick Pond as part of their consent decree obligations, including identification of outfall ownership and system contributions.

6.2.3 TMDL Implementation Plan (IP) Requirements

The TMDL IP must address all parts of the watershed that discharge to the impaired water and all impacts identified in the TMDL. The TMDL IP must describe the six minimum measures and other additional controls that are or will be implemented to address the TMDL pollutants of concern. The operators must provide measurable goals for the development and/or implementation of the six minimum measures and additional structural and non-structural BMPs that will be necessary to address provisions for the control of storm water identified in this TMDL including an implementation schedule, which includes all major milestone deadlines including the start and finish calendar dates, the estimated costs and proposed or actual funding sources, and the anticipated improvement(s) to water quality. If no structural BMPs are recommended, the operator must evaluate whether the six minimum measures alone (including any revisions to ordinances) are sufficient to meet the TMDL's goals. As mentioned previously, these requirements apply to any operators of MS4s contributing stormwater to specifically identified outfalls, regardless of outfall ownership.

The TMDL IP must specifically address the following requirements that are described in Part IV.D of the RIPDES Stormwater General Permit (RIDEM, 2003) or in the manner required by their current permit in future implementation.

1. Determine the land areas contributing to the discharges identified in TMDL using sub-watershed boundaries as determined from USGS topographic maps or other appropriate means.
2. Address all contributing areas and the impacts identified by the Department.
3. Assess the six-minimum control measure BMPs and additional controls currently being implemented or that will be implemented to address the TMDL provisions and pollutants of concern and describe the rationale for the selection of controls including the location of the discharge(s), receiving waters, water quality classification, and other relevant information.
4. Identify and provide tabular description of the discharges identified in the TMDL including:
    a. Location of discharge (latitude/longitude and street or another landmark).
    b. Size and type of conveyance (e.g. 15" diameter concrete pipe).
    c. Existing discharge data (flow data and water quality monitoring data).
    d. Impairment of concern and any suspected sources(s).
    e. Interconnections with other MS4s within the system.
    f. TMDL provisions specific to the discharge.
    g. Any additional outfall/drainage specific BMP(s) that have or will be implemented to address TMDL provisions.
    h. Schedule for construction of structural BMPs including those for which a Scope of Work is to be prepared, as described below.

5. If the TMDL does not recommend structural BMPs, the TMDL IP must evaluate whether the six minimum measures alone (including any revisions to ordinances) are sufficient to meet the TMDL's goals. The TMDL IP should describe the rationale used to select BMPs.
6. This TMDL has determined that structural BMPs are necessary in the watersheds of both the Tributaries to Warwick Pond and Buckeye Brook, and the TMDL IP must describe the tasks necessary to design and construct BMPs that reduce pollutants of concern (dissolved Cd, Cu, Pb, and Total Fe applicable to each segment as assigned in Table 1.1) and stormwater volumes to the *maximum extent practicable,* and otherwise manage runoff towards a watershed target of 10% impervious cover. The TMDL IP must describe the process and the rationale that will be used to select structural BMPs (or LID retrofits) and measurable goals to ensure that the TMDL provisions will be met. In a phased approach, operators must identify any additional outfalls that may contribute the greatest pollutant load and prioritize these for BMP construction. Referred to as a Scope of Work in the current permit, this structural BMP component of the TMDL IP must also include a schedule and cost estimates for the completion of the following tasks:

    a. Prioritization of drainage systems where BMPs are necessary. If not specified in TMDL, priority can be assessed using relative contribution of the pollutant of concern, percent effective impervious area, or pollutant loads as drainage area, pipe size, land use, etc. A targeted approach to construct stormwater retrofit BMPs at state and locally owned stormwater outfalls is recommended.
    b. Delineation of the drainage or catchment area.
    c. Determination of interconnections within the system and the approximate percentage of contributing area served by each operator's drainage system, as well as a description of efforts to cooperate with owners of the interconnected system.
    d. Completion of catchment area feasibility analyses to determine drainage flow patterns (surface runoff and pipe connectivity), groundwater recharge potentials(s), upland and end-of-pipe locations suitable for siting BMPs throughout the catchment area, appropriate structural BMPs that address the pollutants of concern, any environmental (severe slopes, soils, infiltration rates, depth to groundwater, wetlands or other sensitive resources, bedrock) and other siting (e.g. utilities, water supply wells, etc.) constraints, permitting requirements or restrictions, potential costs, preliminary and final engineering requirements.
    e. Design and construction of structural BMPs.
    f. Identification and assessment of all remaining discharges not identified in the TMDL owned by the operator contributing to the impaired waters addressed by the TMDL taking into consideration the factors discussed above.

7. This TMDL has determined that structural BMPs are necessary but has not identified or prioritized outfalls/drainage systems for BMP construction. The TMDL IP must first identify and assess outfalls owned by the operator discharging directly to the impaired waterbody. The operator must then complete all tasks described in section f above.

In summary, the SWMPPs must be revised to describe the six minimum measures and other additional controls that are or will be implemented to address the TMDL pollutants of concern. The operators must provide measurable goals for the development and/or implementation of the six minimum measures and additional structural and non-structural BMPs that will be necessary to address provisions for the control of storm water identified in this TMDL including an implementation schedule, which includes all major milestone deadlines including the start and finish calendar dates, the estimated costs and proposed or actual funding sources, and the anticipated improvement(s) to water quality. If no structural BMPs are recommended, the operator must evaluate whether the six minimum measures alone (including any revisions to ordinances) are sufficient to meet the TMDL's goals.

6.3 Modifications to Six Minimum Measures

As described previously, MS4 operators must assess the six-minimum control measure BMPs included in their SWMPPs for compliance with this TMDL plan's provisions and provide measurable goals in the TMDL IP for any needed amendments or in the manner required by their current permit in future implementation. The operator must also describe the rationale for the selection of controls including the location of the discharge(s), receiving waters, water quality classification, and other relevant information (General Permit Part IV.D.3.c; RIDEM, 2003). The following sections outline activities that the city and RIDOT should implement and/or consider when modifying their six minimum measures.

6.3.1 Public Education/Public Involvement

The public education program must focus on both water quality and water quantity concerns associated with stormwater discharges within the watershed. Public education material should target the audience being addressed, while public involvement programs should actively involve the community in addressing stormwater concerns.

An educational campaign targeted to residential land uses should include activities that residents can take to minimize water quality and water quantity impacts. Reducing trace metals can include measures that can reduce the quantity of water that runs off during a wet weather event which can aid in preventing these pollutants from reaching impaired waterbodies. These include decreasing effective impervious area and by providing on-site attenuation of runoff. Roof runoff can be infiltrated using green roofs, dry wells, or by redirecting roof drains to lawns and forested areas. Reducing land runoff can be accomplished by grading the site to minimize runoff and to promote storm water attenuation and infiltration, creating rain gardens, and reducing paved areas such as driveways. Driveways can be made of porous materials such as crushed shells, stone, or porous pavement. Buffer strips and swales that add filtering capacity through vegetation can also slow runoff. Properties adjacent to connected streams and wetland areas should establish and maintain natural buffers, planted with native plants, shrubs and/or trees to minimize impacts of development and restore valuable habitat.

Other audiences include commercial, industrial, and institutional property owners, land developers, and landscapers. In addition to the activities discussed above for residential land use, educational programs for these audiences could discuss BMPs that should be used when redeveloping or re-paving a site to minimize runoff and promote infiltration. Measures such as minimizing road widths, installing porous pavement, infiltrating catch basins, breaking up large tracts/areas of impervious surfaces, sloping surfaces towards vegetated areas, and incorporating buffer strips and swales should be used where possible. Section 6.2 discusses changes to the RI Stormwater Design and Installation Standards Manual (RIDEM, 2018b) that promote these measures using low impact development (LID) techniques.

The University of Rhode Island Cooperative Extension's Storm Water Phase II Public Outreach and Education Project provides participating MS4s with education and outreach programs that can be used to address TMDL public education recommendations. This project is funded by RIDOT and has many partners, including RIDEM. More information may be found on the URI website http://www.ristormwatersolutions.org/.

In addition to the more generalized outreach and education efforts described above, MS4 operators are required to provide public education materials to the highly impervious industrial, commercial, and institutional property owners informing them of good housekeeping and pollution prevention techniques, and other practices to reduce runoff volumes.

6.3.2 Construction/Post Construction

MS4 operators are required to establish post construction storm water runoff control programs for new land development and redevelopment at sites disturbing *one or more acres*. Land development and re-development projects must utilize best management practices if the waterbodies in this TMDL are to be successfully restored. Consistent with the revised RI Stormwater Design and Installation Manual (RIDEM, 2018b), local ordinances meant to comply with the post construction minimum measures (General Permit Part IV.B.5.a.2.; RIDEM, 2003) must require that applicable development and re-development projects use Low Impact Development (LID) techniques as the primary method of stormwater control to the maximum extent practicable and maintain groundwater recharge to predevelopment levels.

New land development projects must employ stormwater controls to prevent any net increase in runoff volume and metals to the impaired waterbodies in the Tributaries to Warwick Pond and Buckeye Brook Watersheds.

As mentioned previously, examples of acceptable reduction measures include reducing impervious surfaces, sloping impervious surfaces to drain towards vegetated areas, using porous pavement, and installing infiltration catch basins where feasible. Other reduction measures to consider are the establishment of buffer zones, vegetated drainage ways, cluster zoning or low impact development, transfer of development rights, and overlay districts for sensitive areas. The revised RI Stormwater Design and Installation Standards Manual (RIDEM, 2018b) contains detailed information on use of low impact development (LID) techniques.

6.3.3 Good Housekeeping/ Pollution Prevention

The Storm Water General Permit (see Part IV.B.6.a.2 and Part IV.B.6.b.1; RIDEM, 2003) extends storm water volume reduction requirements to operator-owned facilities and infrastructure. Similarly, municipal and state facilities could incorporate measures such as reducing impervious surfaces, sloping impervious surfaces to drain towards vegetated areas, incorporating buffer strips and swales, using porous pavement and infiltration catch basins where feasible. In addition, any new municipal construction project or retrofit should incorporate BMPs that reduce storm water and promote infiltration such as the before-mentioned measures.

The TMDL Implementation Plan should provide a list of municipally owned properties and any BMPs that may have been implemented to date, and/or where opportunities exist for future implementation. As part of their Good Housekeeping/Pollution Prevention requirements, municipal MS4 operators and RIDOT must investigate the feasibility of increased street sweeping and/or stormwater system maintenance to address loads of copper, cadmium, iron, and lead to the stream systems. At least one street sweeping, and storm drain cleaning should be conducted in the spring when the last reasonable chance of snowfall has passed.

6.3.4 Structural BMP Requirements in Rhode Island

As described previously, this TMDL finds that the six minimum measures alone are insufficient to restore water quality and that structural BMPs are needed. MS4 owners must identify priority outfalls as discussed above in section 6.2.3. As described in detail in section 6.2.3, an Implementation Plan must be completed that details the tasks necessary to design and construct BMPs that reduce the pollutants of concern and stormwater volumes to the maximum extent practicable or in the manner required by their current permit in future implementation. As noted previously, TMDL provisions apply to any MS4 operators contributing stormwater to identified outfalls regardless of outfall ownership. The BMP study should include all the components of Part IV.D.4 (RIDEM, 2003) that were previously described in the TMDL IP section or the permit requirements in place at time of implementation. It must evaluate the feasibility of distributing infiltration or equivalent BMPs throughout the drainage area of the priority outfalls as an alternative to end of pipe technologies since the amount of land available for BMP construction is limited.

6.4 MS4 Operator Specific Stormwater Measures

City of Warwick

The City of Warwick (Permit RIR40031) is authorized to discharge stormwater under the General Permit listed above. Upon notification by RIDEM of the US Environmental Protection Agency's approval of this TMDL, the city will have 180 days to amend its SWMPP consistent with Part IV.D of the General Permit. The City of Warwick must evaluate the sufficiency of its six minimum measures to meet the TMDL water quality objectives as outlined in Section 6.2 and at a minimum must modify its ordinances related to post construction stormwater controls to prevent further degradation of these impaired waters, as detailed in Section 6.2.2. In addition, the City of Warwick must also assess and prioritize drainage systems for the design and construction of BMPs that reduce the pollutants of concern and stormwater volumes to the *maximum extent practicable* as detailed in Section 6.2.3. The evaluation of six minimum measures, all modifications and proposed BMPs must be documented in the TMDL Implementation Plan along with a schedule for implementation.

RIDOT

RIDOT is authorized to discharge stormwater under the RIPDES Phase II Stormwater General Permit (Permit RIR040036). Upon notification by RIDEM of the US Environmental Protection

Agency's approval of this TMDL, RIDOT will have 180 days to amend their SWMPP consistent with Part IV.D of the General Permit. In addition to the modifications to the six minimum measures described in Section 6.2, RIDOT must also assess and prioritize drainage systems for the design and construction of BMPs that reduce the pollutants of concern and stormwater volumes to the *maximum extent practicable* as detailed in Section 6.2.3. The evaluation of six minimum measures, all modifications and proposed BMPs must be documented in the TMDL Implementation Plan along with a schedule for implementation.

6.5 Stormwater from Industrial Activities

6.5.1 Industrial Activities covered by Individual Permits

The Rhode Island Airport Corporation (RIAC) has applied for and obtained an individual permit (RI0021598) to discharge stormwater to the Tributaries to Warwick Pond and to Buckeye Brook. It is the only facility covered by an individual permit that discharges to the receiving waters addressed by this TMDL. The permit requires the implementation of the permittee's existing Storm Water Pollution Prevention Plan (SWPPP) as of the effective date of the permit. The permit establishes a schedule that requires the permittee to amend the SWPPP to include additional BMPs as specified in the permit. The goal of the SWPPP is to help identify the source of pollutants in the discharge of storm water and to ensure practices are being implemented to minimize pollutants associated with industrial activities from entering any storm water discharge. This Plan emphasizes the use of Best Management Practices (BMPs) to provide the flexibility to address different sources of pollutants.

The SWPPP includes required elements and BMPs to mitigate the impacts of the following: aircraft, vehicle, and equipment maintenance, aircraft and pavement deicing/anti-icing fueling and washing, aircraft lavatory service, illicit discharge detection and elimination, pesticide management, building and grounds maintenance, chemical and fuel handling and storage, materials handling, stormwater pollution prevention education, outdoor area and floor wash-down, and water quality monitoring.

A revised RIPDES Stormwater permit went into effect for T.F. Green Airport on September 1, 2012 that required RIAC to develop and implement BMPs to promote source reduction and pollution prevention that will be protective of water quality standards in receiving waters to include dissolved oxygen, aquatic toxicity, foaming, nuisance odors and nuisance bacteria growth. The long-term deicing management system became operational in October 2014. It is constructed and sized to collect greater than 99% of all flows above the glycol diversion concentrations of 2,950 mg/L for the terminal area and 1,000 mg/L for the cargo area. Glycol impacted snow is also collected and snowmelt diverted to storage at concentrations above 2,950 mg/L for the terminal area and 1,000 mg/L at the cargo pad. These snow piles are melted with a snow melter and discharged to the collection system, and on-site monitoring of the major outfalls that discharge to Buckeye Brook are to be monitored quarterly.

The consulting firm VHB revised the Drainage Master Plan for T.F. Green Airport and the airport's Stormwater Pollution Prevention Plan (SWPPP) in March 2017. The airport drainage areas were updated to reflect changes to the airport since 2008 by revising and adding structure, pipe, and BMP information, which included the glycol treatment facility. The PVD Deicer

Treatment and Management System consists of a passive stormwater collection system within the terminal and cargo ramps that connect to large pump stations that can divert glycol contaminated stormwater to two 2.9-million-gallon (2.9MG) storage tanks, treated on-site and later discharged to the Warwick Sewer Authority sewer system. Additionally, there are four 10,000 gallon above ground storage tanks (AST) used for storage of used glycol collected using mobile recovery units prior the glycol solution being transferred to the processing facility.

The VHB report identified two outfalls, 008 for the terminal area, and 002 for the cargo area as potential sources of propylene glycol to the Warwick Pond and Buckeye Brook watersheds. There are 170 acres of impervious areas of which approximately 70% or 119 acres are directly connected to the stormwater system which can be treated. The remaining portion of the impervious area runoff is treated using infiltration systems, retention ponds, and underground chamber detention systems. The amount of rainfall required to fill the glycol retention tanks that receive the polluted runoff from the 119 impervious acres is 1.8 inches. The conversion of rainfall to snow depth ranges from 10 to 15 inches of snow per inch of rain, depending on the temperature. Colder temperatures result in a lower rain-to-snow ratio (less dense), so the depth of snow estimated to fall at the airport that would fill the retention tanks would be 18 to 27 inches of snow. Additionally, the snow would have to melt to provide the runoff required to fill these two tanks. Since the facility has been operational, there have not been any weather events that have fully expended the capacity of the treatment facility.

Major components of the improved Deicer Management System include the following:

- Terminal pump station
- Terminal online monitoring system
- Force main from terminal pump station to storage tanks
- Cargo pump station
- Cargo online monitoring system
- Force main from cargo pump station to storage tanks
- Portable snow melter
- Two above ground storage tanks
- Biological treatment system
- Force main from treatment to sanitary sewer

Interested parties may request a copy of the permit by contacting the RIPDES permitting section in the Office of Water Resources at RIDEM.

During 1999-2001 when RIAC first evaluated the airport's impact on instream dissolved oxygen levels, the annual efficiency for glycol collection was 18 to 28 percent. Since that time, the airport has implemented best management practices and improved collection efficiencies such that the annual 2010-2011 collection efficiency averaged 44 percent, with a 50 percent average for the February 2011 winter monitoring event. With the construction of the glycol treatment and diversion structures that went online in October 2014, the collection efficiency is expected to increase such that RIDEM believes that this will be sufficient to avoid future violations of the in-stream dissolved oxygen criteria due to propylene glycol discharges.

The permit also requires the airport to conduct instream water quality monitoring at four locations on the main stem of Buckeye Brook to evaluate storm water impacts to the brook. The monitoring is to be conducted during a frozen precipitation event (i.e., snow, sleet, freezing rain) during the deicing season (October 1 – March 31) at the T.F. Green Airport while aircraft deicing is occurring and must be coordinated with storm water outfall sampling.

As noted earlier, review of the monitoring reports required by the permit from the 2012 through the 2017 deicing seasons shows that the deicing management system that became operational at T.F. Green Airport in October 2014 has markedly improved the propylene glycol collection efficiencies and reduced propylene glycol concentrations in stormwater. Monitoring of deicing events for the 2014-2015 through 2016-2017 seasons after the facility became operational finds an average propylene glycol collection efficiency of 65%. These results show a marked improvement from propylene glycol collection efficiencies reported prior to the facility becoming operational which averaged 39% for the 2011-2012 through 2013-2014 seasons. It also compares favorably with the expected collection efficiency of 60% reported in the 2012 RIPDES Permit Fact Sheet. Concentrations of propylene glycol in stormwater discharged from the airport's outfalls reflect improvements made to their deicing management system. Comparing outfall monitoring results from pre- and post- facility operations finds Outfalls 002 and 003, which discharge to Tributaries to Warwick Pond, had an average decrease of propylene glycol concentrations of 69%, whereas Outfall 008 had a 97% reduction.

Comparing stream monitoring results for the same periods finds propylene glycol concentrations to have decreased from an average of 14 mg/L before the facility was operational to below detection (<10 mg/L) for deicing events after the facility was operational. In-stream concentrations of COD and BOD for the same period finds average decreases of 77% and 82%, respectively. Appendix C contains the results of deicing event monitoring of the outfalls and stream stations as well as the propylene glycol collection efficiencies.

Section 4.3 referenced a RIAC contracted study that showed high levels of iron and iron bacteria were present in the outfalls that discharge to the Tributary to Warwick Pond and Buckeye Brook. The high iron levels are present in the dry weather flows as well and that the seepage of iron rich groundwater into these storm drainage systems is the source of contamination. As previously documented, metals concentrations in the channel receiving the discharge from Outfall 008 exceed ambient water quality criteria. Review of data from 2012 to 2017 collected by RIAC as required by their RIPDES permit show that Outfalls 002A, 003A and 008A continue to exceed the freshwater criteria for total iron.

It is noted that iron levels in groundwater are thought to be contributing to elevated levels of iron in both wet and dry weather flows. The field investigation by the ESS Group (Buckeye Brook Biodiversity Impairment Data Report, 2008, ESS Group. Inc., April 2009) found that smothering of habitat by iron flocculent material was noted within each of the tributaries originating from the airport and/or landfill. Examination of the macroinvertebrates at Stations BB04 and BB02 also showed evidence of impact from the iron flocculent. In excess, this material can smother coarse substrates and clog interstitial areas used as refuge by macroinvertebrates. The report found that the impairment was most readily detected in the biological communities at BB02, BB04, and TA01. It concluded that some degree of improvement could be achieved by addressing the leachate issues at the landfill and through implementation of new aircraft/airfield source water contamination prevention measures at the airport.

RIDEM Office of Water Resources is currently working to re-issue RIAC's RIPDES permit which expired in September 2017. It is expected the revised permit will incorporate requirements to address dry and wet weather discharges of the pollutants of concern identified in this TMDL from outfalls that discharge to Tributaries to Warwick Pond and Buckeye Brook and to otherwise manage stormwater to reduce runoff volumes consistent with requirements established for MS4 operators.

6.5.2 Industrial Activities covered by the Statewide Multi-Sector General Permit

The TMDL has shown that stormwater is a major source contributing to the impairments to the watershed. Stormwater discharges from industrial activities may be discharged to these waters directly or via the MS4s and may contain metals that contribute to these impairments. Stormwater discharges from facilities that discharge "stormwater associated with industrial activity" are regulated under the statewide general RIPDES permit prescribed in Chapter 46-12, 42-17.1 and 42-35 of the General Laws of the State of Rhode Island.

In accordance with Part I.B.3.j of the RIPDES Multi-Sector General Permit, prior to authorization to discharge stormwater associated with industrial activity, the applicant is required to demonstrate that the stormwater discharge is consistent with the requirements of the TMDL. With completion of this TMDL, facilities currently authorized to discharge under the permit must either demonstrate that the existing Storm Water Pollution Prevention Plan (SWPPP) is consistent with the TMDL or amend their plan demonstrating consistency with the TMDL. More specifically, the TMDL requires that facilities currently authorized or seeking authorization to discharge to the waterbodies must demonstrate that their SWPPP reduces copper, cadmium, lead, and iron to the maximum extent practicable. Permittees will have 90 days from written notification by RIDEM to submit this documentation including revised SWMPPPs to RIDEM.

The owner/operators of facilities currently authorized to discharge to the streams within the watershed are listed below:

- Jay Packing Group (Buckeye Brook)

This facility (covered by MSG Permit RIR 50X002) discharges stormwater to the channel which also receives drainage from Outfall 008 from TF Green Airport and flows into Buckeye Brook. Jay Packaging Group's SWPPP must identify the potential sources of pollution, including specifically the TMDL pollutants of concern (Pb, Cd, Cu, and Fe), which may reasonably be expected to affect the quality of storm water discharges from the facility; and describe and ensure implementation of practices, which the permittee will use to reduce metals in storm water discharges from the facility, and to attenuate runoff on-site.

The SWPPP must address all areas of the facility and describe existing and/or proposed BMPs that will be used and, at a minimum, must include the following:

- Frequent sweeping of roads, parking lots and other impervious areas
- Effective management (storage and disposal) of solid waste and trash
- Regular inspection and cleaning of catch basins and other stormwater BMPs
- Other pollution prevention and stormwater BMPs as appropriate

Where structural BMPs are necessary, selection of BMPs should take into consideration:

1) The quantity and nature of the pollutants, and their potential to impact the water quality of receiving waters;
2) Opportunities to combine the dual purposes of water quality protection and local flood control benefits (including physical impacts of high flows on streams - e.g., bank erosion, impairment of aquatic habitat, etc.); and
3) Opportunities to offset the impact of impervious areas of the facility on ground water recharge and base flows in local streams.

For existing facilities, the SWPPP must include a schedule specifying when each control will be implemented. Facilities that are not currently authorized will be required to demonstrate compliance with these requirements prior to authorization.

6.6 Truk-Away Landfill

Truk-Away landfill is located at the end of Industrial Drive and was open from 1970 until 1977. The landfill has an area of 52 acres. Approximately 32 acres was used for waste disposal with the remaining area consisting of open land and freshwater wetlands. A small tributary stream to Buckeye Brook flows in a northeasterly direction along the southern edge of the landfill property where it merges with another unnamed tributary that receives discharges from the airport outfall 008. The confluence of these tributaries with Buckeye Brook is approximately 430 yards (400 meters) from the exit of Warwick Pond. As documented in Section 3.5, leachate from the landfill contributes to elevated levels of pollutants in the tributary stream flowing to Buckeye Brook. To meet the water quality criteria requirements for dissolved and total metals and dissolved oxygen impairments in Buckeye Brook, leachate from the landfill will need to be controlled.

Since 2003, the Rhode Island Department of Administration has been the responsible agency for the Truk-Away Landfill. The landfill was closed in 1977 and has not been properly capped. As documented by sampling results at station TA01, pollutants of concern are originating from the landfill and contributing to aquatic life impairments of Buckeye Brook during wet and dry weather. The landfill must be properly closed to prevent leachate and stormwater runoff of the pollutants of concern addressed by this TMDL. There are efforts currently underway to bring together the identified stakeholders who used the dump prior to its closing. Letters of Responsibility (LOR) were sent to representatives from the state, municipalities, and private companies, referred to as the Potentially Responsible Parties (PRP), to set up a meeting with all the concerned entities to coordinate a group effort to investigate the extent of contamination from the landfill, and to set a schedule for a plan to permanently close the landfill. The first meeting was held in January 2016, and the next step of the process was to form a core RRP group to facilitate the initiation of a new site investigation.

A study conducted by GZA and completed in June 2020 was submitted to RIDEM with recommendations for remediation of the Truk-Away Landfill. The recommendations were to set an Environmental Land Use Restriction (ELUR) for the site. Additionally, the report recommended capping the landfill and re-grading the site with long term monitoring requirements for Truk-Away. The full report is available here: http://www.dem.ri.gov/programs/benviron/waste/trukaway/200619sir.pdf.

RIDEM's Office of Customer and Technical Assistance responded to the report requesting further information on the proposed remedial alternative, specifically regarding PCBs, solid waste removal from the wetlands, final capping permeability, and incorporation of appropriate gas controls. In March 2021, a supplemental site investigation was submitted in response to the RIDEM/OCTA detailing the underground injection control investigation, supplemental gas survey, and supplemental waste delineation conducted December 2020 through January 2021. As of 2021, the closure of the landfill is an on-going process. Recent documentation and studies are found here: http://www.dem.ri.gov/programs/customertech/truk-away-landfill-closure.php

7.0 PUBLIC PARTICIPATION

RIDEM presented the draft TMDL plan to the general public and stakeholders, including public officials and other agencies, in a public meeting on January 9, 2018. Letters were sent to key stakeholders in advance of the meeting. In addition, the meeting was publicized through public notices that posted at the Warwick City Hall and the Warwick Public Library. The draft TMDL was made available to the public on RIDEM's website approximately one month prior to the public meeting. The public comment period closed on May 10, 2018. RIDEM determined substantial revisions were required to address the public comments. Comments were reviewed and included as necessary.

A preview draft TMDL with a response to comments was circulated to commenters on the original draft TMDL in June 2021. Additional stakeholders, the City of Warwick and the RI Department of Administration via representation by Orson and Brusini, Ltd., were notified of the issuance of the preview draft. A second opportunity to publicly comment on a revised draft TMDL was conducted Monday August 2nd, 2021 to September 1, 2021. Comments were reviewed and included as necessary. The comments received during the 2021 public comment period and RIDEM response appear in Appendix D.

8.0 FUTURE MONITORING

This is a phased implementation TMDL. Results of water quality monitoring by various entities will allow RIDEM to track compliance with the water quality objectives as remedial actions are accomplished. RIDEM anticipates re-visiting Buckeye Brook and Tributaries to Warwick Pond as part of the state's ambient water quality monitoring efforts. To assess the effectiveness of stormwater and other controls implemented at the airport, RIDEM will review both outfall and ambient stream monitoring data collected by RIAC, as required by their stormwater permit. RIDEM will also evaluate the ambient monitoring data that is being collected on these stream systems by the Buckeye Brook Coalition and other volunteers participating in URI's Watershed Watch Program.

REFERENCES

APHA, AWWA, WPCF. 1998. *Standard Methods for the Examination of Water and Wastewater. 20th Edition*. American Public Health Association, American Water Works Association, Water Pollution Control Federation, Washington, D.C.

Center for Watershed Protection, March 2003, "*Impacts of Impervious Cover on Aquatic Systems*." (www.cwp.org)

EPA/ENSR, 2005. *Pilot TMDL Applications using the Impervious Cover Method*, October 2005.

ESS, 2002. *Quality Assurance Project Plan for Taxonomic Identification of Benthic Macroinvertebrates*, Rhode Island. ESS Project No. R298-001. Environmental Science Services, Inc., Wellesley, MA.

GZA, 2020. *Site Investigation Report, Former Truk-Away Landfill, Warwick Industrial Drive, Warwick, RI*, Providence, RI
http://www.dem.ri.gov/programs/benviron/waste/trukaway/200619sir.pdf

Mackenthun, K.M., 1973. *Toward a Cleaner Environment*, U.S. Environmental Protection Agency, Washington, D.C.
https://www.epa.gov/wqc/quality-criteria-water-gold-book

RIDEM 2003. *General Permit Rhode Island Pollutant Discharge Elimination System Storm Water Discharge from Small Municipal Separate Storm Sewer Systems and from Industrial Activity at Eligible Facilities Operated by Regulated Small MS4s*, Rhode Island Department of Environmental Management, Office of Water Resources, Providence, RI.
http://www.dem.ri.gov/pubs/regs/regs/water/ms4final.pdf

RIDEM 2008. *Quality Assurance Project Plan: Sampling Plan to Characterize Buckeye Brook Biodiversity Impairment and Potential Causes and/or Pollution Sources Contributing to the Impairment, July, 2008*, Rhode Island Department of Environmental Management, Office of Water Resources, Providence, RI.

RIDEM, 2012. *State of RI and Providence Plantations 2012 Integrated Water Quality Monitoring and Integrated Report*. Rhode Island Department of Environmental Management, Providence, RI. http://www.dem.ri.gov/programs/benviron/water/quality/pdf/iwqmon12.pdf

RIDEM, 2014. *State of RI and Providence Plantations, Consolidated Assessment and Listing Methodology for the Preparation of The Integrated Water Quality Monitoring and Assessment Report Pursuant to Clean Water Act Sections 303(d) and 305(b), 2014 Assessment and Listing Cycle*. Rhode Island Department of Environmental Management, Office of Water Resources, Providence, RI.
http://www.dem.ri.gov/programs/benviron/water/quality/pdf/calm14.pdf

RIDEM 2018a. *Water Quality Regulations*, Rhode Island Department of Environmental Management, Office of Water Resources, Providence, RI. https://rules.sos.ri.gov/regulations/part/250-150-05-1

RIDEM 2018b. *Stormwater Management, Design, and Installation Rules*, Rhode Island Department of Environmental Management, Office of Water Resources, Providence, RI. https://rules.sos.ri.gov/regulations/part/250-150-10-8

The Louis Berger Group, 2007. *Technical Report Data Analysis Summary for Odor and Iron Bacteria Investigation, T.F. Green Airport, Warwick, RI.* Albany, NY

Vanasse Hangen Brusrtlin, Inc., 2017. *Drainage Master Plan for T.F. Green Airport, Warwick, RI*, Providence, RI

Vanasse Hangen Brusrtlin, Inc., 2017. *Stormwater Pollution Prevention Plan, T.F. Green Airport, Warwick, RI*, Providence, RI

APPENDIX A
Trace Metal Evaluations

Dry Weather Metals

Dry Weather Dissolved Cadmium (Cd)

Dry Weather Hardness as $CaCO_3$ (mg/L)				
Station	**7/16/08**	**9/10/08**	**12/9/08**	**2/1/11**
BB00	R	40.0	51.0	59.4
BB02	R	41.0	52.0	49.9
BB03	R	NS	51.0	53.7
BB04	R	45.0	58.0	59.1
BB05A	R	44.0	57.0	60.4
TA01	R	NS	98.0	96.6
OF08	R	NS	42.0	45.3
AP01	NS	43.0	NS	NS

Dry Weather Average Hardness by Waterbody (mg/L)				
Water Body	**7/16/08**	**9/10/08**	**12/9/08**	**2/1/11**
Warwick Pond	R	40.5	51.5	54.7
Buckeye Brook	R	44.0	61.2	63.0

Dry Weather Dissolved Cadmium Criteria by Waterbody (µg/L)								
Water Body	**7/16/08**		**9/10/08**		**12/9/08**		**2/1/11**	
	Acute	**Chronic**	**Acute**	**Chronic**	**Acute**	**Chronic**	**Acute**	**Chronic**
Warwick Pond	R	R	0.84	0.13	1.06	**0.16**	1.12	**0.16**
Buckeye Brook	R	R	0.91	0.14	1.25	**0.17**	1.29	0.18

Dry Weather Dissolved Cadmium (µg/L)				
Station	**7/16/08**	**9/10/08**	**12/9/08**	**2/1/11**
BB00	R	0.08	**0.40**	**0.26**
BB02	R	0.11	**0.18**	0.09
BB03	R	NS	0.15	<0.05
BB04	R	<0.06	0.11	0.14
BB05A	R	<0.06	**0.31**	0.05
TA01	R	NS	**0.58**	0.09
OF08	R	NS	0.17	0.06
AP01	NS	<0.06	NS	NS

Dry Weather Dissolved Cadmium Exceedances								
Station	**7/16/08**		**9/10/08**		**12/9/08**		**2/1/11**	
	Acute	**Chronic**	**Acute**	**Chronic**	**Acute**	**Chronic**	**Acute**	**Chronic**
BB00						**EXD**		**EXD**
BB02						**EXD**		
BB03								
BB04								
BB05A						**EXD**		
TA01						**EXD**		
OF08								
AP01								

Dry Weather Dissolved Copper (Cu)

Dry Weather Hardness as $CaCO_3$ (mg/L)

Station	7/16/08	9/10/08	12/9/08	2/1/11
BB00	R	40.0	51.0	59.4
BB02	R	41.0	52.0	49.9
BB03	R	NS	51.0	53.7
BB04	R	45.0	58.0	59.1
BB05A	R	44.0	57.0	60.4
TA01	R	NS	98.0	96.6
OF08	R	NS	42.0	45.3
AP01	NS	43.0	NS	NS

Dry Weather Average Hardness by Waterbody (mg/L)

Water Body	7/16/08	9/10/08	12/9/08	2/1/11
Warwick Pond	R	40.5	51.5	54.7
Buckeye Brook	R	44.0	61.2	63.0

Dry Weather Dissolved Copper Criteria by Waterbody (µg/L)

Water Body	7/16/08		9/10/08		12/9/08		2/1/11	
	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute	Chronic
Warwick Pond	R	R	5.73	4.14	7.19	5.08	7.61	5.34
Buckeye Brook	R	R	6.20	4.44	8.46	5.89	8.70	6.04

Dry Weather Dissolved Copper (µg/L)

Station	7/16/08	9/10/08	12/9/08	2/1/11
BB00	R	2.10	1.80	1.33
BB02	R	1.19	1.03	1.30
BB03	R	NS	0.98	2.94
BB04	R	1.24	1.21	1.52
BB05A	R	1.68	3.24	2.51
TA01	R	NS	2.01	1.40
OF08	R	NS	0.74	1.03
AP01	NS	1.08	NS	NS

Dry Weather Dissolved Copper Exceedances

Station	7/16/08		9/10/08		12/9/08		2/1/11	
	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute	Chronic
BB00								
BB02								
BB03								
BB04								
BB05A								
TA01								
OF08								
AP01								

Dry Weather Dissolved Lead (Pb)

Dry Weather Hardness as $CaCO_3$ (mg/L)

Station	7/16/08	9/10/08	12/9/08	2/1/11
BB00	R	40.0	51.0	59.4
BB02	R	41.0	52.0	49.9
BB03	R	NS	51.0	53.7
BB04	R	45.0	58.0	59.1
BB05A	R	44.0	57.0	60.4
TA01	R	NS	98.0	96.6
OF08	R	NS	42.0	45.3
AP01	NS	43.0	NS	NS

Dry Weather Average Hardness by Waterbody (mg/L)

Water Body	7/16/08	9/10/08	12/9/08	2/1/11
Warwick Pond	R	40.5	51.5	54.7
Buckeye Brook	R	44.0	61.2	63.0

Dry Weather Dissolved Lead Criteria by Waterbody (µg/L)

Water Body	7/16/08		9/10/08		12/9/08		2/1/11	
	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute	Chronic
Warwick Pond	R	R	23.84	0.93	31.14	1.21	33.26	1.30
Buckeye Brook	R	R	26.14	1.02	37.69	**1.47**	38.93	1.52

Dry Weather Dissolved Lead (µg/L)

Station	7/16/08	9/10/08	12/9/08	2/1/11
BB00	R	<0.07	0.27	0.09
BB02	R	<0.07	R	0.11
BB03	R	NS	0.18	0.29
BB04	R	0.18	0.61	1.50
BB05A	R	<0.07	0.66	0.37
TA01	R	NS	**1.51**	0.73
OF08	R	NS	0.08	<0.08
AP01	NS	<0.07	NS	NS

Dry Weather Dissolved Lead Exceedances

Station	7/16/08		9/10/08		12/9/08		2/1/11	
	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute	Chronic
BB00								
BB02								
BB03								
BB04								
BB05A								
TA01						**EXD**		
OF08								
AP01								

Dry Weather Dissolved Zinc (Zn)

Dry Weather Hardness as $CaCO_3$ (mg/L)

Station	7/16/08	9/10/08	12/9/08	2/1/11
BB00	R	40.0	51.0	59.4
BB02	R	41.0	52.0	49.9
BB03	R	NS	51.0	53.7
BB04	R	45.0	58.0	59.1
BB05A	R	44.0	57.0	60.4
TA01	R	NS	98.0	96.6
OF08	R	NS	42.0	45.3
AP01	NS	43.0	NS	NS

Dry Weather Average Hardness by Waterbody (mg/L)

Water Body	7/16/08	9/10/08	12/9/08	2/1/11
Warwick Pond	R	40.5	51.5	54.7
Buckeye Brook	R	44.0	61.2	63.0

Dry Weather Dissolved Zinc Criteria by Waterbody (µg/L)

Water Body	7/16/08		9/10/08		12/9/08		2/1/11	
	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute	Chronic
Warwick Pond	R	R	54.48	54.93	66.78	67.33	70.28	70.86
Buckeye Brook	R	R	58.45	58.92	77.30	77.93	79.22	79.87

Dry Weather Dissolved Zinc (µg/L)

Station	7/16/08	9/10/08	12/9/08	2/1/11
BB00	R	28.20	24.88	4.49
BB02	R	13.90	R	<1.12
BB03	R	NS	6.93	1.97
BB04	R	7.14	12.21	5.99
BB05A	R	7.75	9.87	4.13
TA01	R	NS	27.20	3.36
OF08	R	NS	10.46	2.86
AP01	NS	10.40	NS	NS

Dry Weather Dissolved Zinc Exceedances

Station	7/16/08		9/10/08		12/9/08		2/1/11	
	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute	Chronic
BB00								
BB02								
BB03								
BB04								
BB05A								
TA01								
OF08								
AP01								

Dry Weather Total Iron (Fe)

Dry Weather Total Iron (µg/L)				
Station	**7/16/08**	**9/10/08**	**12/9/08**	**2/1/11**
BB00	732	522	654	741
BB02	648	824	**1,185**	**1,989**
BB03	186	NS	308	432
BB04	**2,078**	**1,258**	**3,112**	**1,892**
BB05A	**1,347**	**1,439**	**1,112**	**1,010**
TA01	**11,586**	NS	**19,180**	**9,088**
OF08	**2,844**	NS	**4,334**	**3,954**
AP01	NS	**3,008**	NS	NS

Bold and Shaded = Exceeded Criteria (1000 µg/L)

Dry Weather Total Iron Chronic Exceedances				
Station	**7/16/08**	**9/10/08**	**12/9/08**	**2/1/11**
BB00				
BB02			**EXD**	**EXD**
BB03				
BB04	**EXD**	**EXD**	**EXD**	**EXD**
BB05A	**EXD**	**EXD**	**EXD**	**EXD**
TA01	**EXD**		**EXD**	**EXD**
OF08	**EXD**		**EXD**	**EXD**
AP01		**EXD**		

Wet Weather Metals

Wet Weather 1 Dissolved Cadmium Acute Criteria Evaluation

WW1 Hardness as $CaCO_3$ (mg/L)

Station	Run 1 12/10/08	Run 2 12/11/08
BB00	44.0	37.0
BB02	32.0	24.0
BB03	42.0	52.0
BB04	53.0	45.0
BB05A	52.0	44.0
TA01	45.0	50.0
OF08	15.0	15.0

Ave Hardness All Stations on WB by Run (mg/L)

Water Body	Run 1 12/10/08	Run 2 12/11/08
Warwick Pond	38.0	30.5
Buckeye Brook	41.4	41.2

WW1 Cadmium Acute Criteria on WB by Run (µg/L)

Water Body	Run 1 12/10/08	Run 2 12/11/08
Warwick Pond	0.79	0.63
Buckeye Brook	0.85	0.85

WW1 Dissolved Cadmium (µg/L)

Station	Run 1 12/10/08	Run 2 12/11/08
BB00	0.17	0.16
BB02	0.22	0.39
BB03	<0.06	<0.06
BB04	<0.06	<0.06
BB05A	0.29	<0.06
TA01	0.08	0.09
OF08	0.19	0.19

WW1 Dissolved Cadmium Acute Exceedances

Station	Run 1 12/10/08	Run 2 12/11/08
BB00		
BB02		
BB03		
BB04		
BB05A		
TA01		
OF08		

Wet Weather 1 Dissolved Cadmium Chronic Criteria Evaluation

WW1 Hardness as $CaCO_3$ (mg/L)

Station	Run 1 12/10/08	Run 2 12/11/08
BB00	44.0	37.0
BB02	32.0	24.0
BB03	42.0	52.0
BB04	53.0	45.0
BB05A	52.0	44.0
TA01	45.0	50.0
OF08	15.0	15.0

Average Hardness by Station and Segment (mg/L)

Station	$CaCO_3$
BB00	34.3
BB02	
BB03	41.3
BB04	
BB05A	
TA01	
OF08	

WW1 Cadmium Chronic Criteria (µg/L)

Station	Cadmium
BB00	**0.12**
BB02	
BB03	0.13
BB04	
BB05A	
TA01	
OF08	

WW1 Dissolved Cadmium (µg/L)

Station	Run 1 12/10/08	Run 2 12/11/08
BB00	0.17	0.16
BB02	0.22	0.39
BB03	<0.06	<0.06
BB04	<0.06	<0.06
BB05A	0.29	<0.06
TA01	0.08	0.09
OF08	0.19	0.19

Value of 0.0 used for average if below DL/RL

WW1 Average Dissolved Cadmium (µg/L)

Station	Average R1+R2
BB00	**0.17**
BB02	**0.31**
BB03	
BB04	
BB05A	**0.15**
TA01	0.09
OF08	**0.19**

WW1 Dissolved Cadmium Chronic Exceedances

Station	Average R1+R2
BB00	EXD
BB02	EXD
BB03	
BB04	
BB05A	EXD
TA01	
OF08	EXD

Wet Weather 1 Dissolved Copper Acute Criteria Evaluation

WW1 Hardness as $CaCO_3$ (mg/L)

Station	Run 1 12/10/08	Run 2 12/11/08
BB00	44.0	37.0
BB02	32.0	24.0
BB03	42.0	52.0
BB04	53.0	45.0
BB05A	52.0	44.0
TA01	45.0	50.0
OF08	15.0	15.0

Ave Hardness All Stations on WB by Run (mg/L)

Water Body	Run 1 12/10/08	Run 2 12/11/08
Warwick Pond	38.0	30.5
Buckeye Brook	41.4	41.2

WW1 Copper Acute Criteria on WB by Run (µg/L)

Water Body	Run 1 12/10/08	Run 2 12/11/08
Warwick Pond	5.40	4.39
Buckeye Brook	5.85	5.83

WW1 Dissolved Copper (µg/L)

Station	Run 1 12/10/08	Run 2 12/11/08
BB00	2.04	2.22
BB02	3.37	2.19
BB03	0.89	0.72
BB04	0.90	0.88
BB05A	1.56	1.63
TA01	1.04	1.83
OF08	4.26	2.66

WW1 Dissolved Copper Exceedances

Station	Run 1 12/10/08	Run 2 12/11/08
BB00		
BB02		
BB03		
BB04		
BB05A		
TA01		
OF08		

Wet Weather 1 Dissolved Copper Chronic Criteria Evaluation

WW1 Hardness as $CaCO_3$ (mg/L)

Station	Run 1 12/10/08	Run 2 12/11/08
BB00	44.0	37.0
BB02	32.0	24.0
BB03	42.0	52.0
BB04	53.0	45.0
BB05A	52.0	44.0
TA01	45.0	50.0
OF08	15.0	15.0

Average Hardness by Station and Segment (mg/L)

Station	$CaCO_3$
BB00	34.3
BB02	
BB03	41.3
BB04	
BB05A	
TA01	
OF08	

WW1 Copper Chronic Criteria (µg/L)

Station	Copper
BB00	3.6
BB02	
BB03	4.2
BB04	
BB05A	
TA01	
OF08	

WW1 Dissolved Copper (µg/L)

Station	Run 1 12/10/08	Run 2 12/11/08
BB00	2.04	2.22
BB02	3.37	2.19
BB03	0.89	0.72
BB04	0.90	0.88
BB05A	1.56	1.63
TA01	1.04	1.83
OF08	4.26	2.66

WW1 Average Dissolved Copper (µg/L)

Station	Average R1+R2
BB00	2.13
BB02	2.78
BB03	0.81
BB04	0.89
BB05A	1.60
TA01	1.44
OF08	3.46

WW1 Dissolved Copper Chronic Exceedances

Station	Average R1+R2
BB00	
BB02	
BB03	
BB04	
BB05A	
TA01	
OF08	

Wet Weather 1 Dissolved Lead Acute Criteria Evaluation

WW1 Hardness as $CaCO_3$ (mg/L)

Station	Run 1 12/10/08	Run 2 12/11/08
BB00	44.0	37.0
BB02	32.0	24.0
BB03	42.0	52.0
BB04	53.0	45.0
BB05A	52.0	44.0
TA01	45.0	50.0
OF08	15.0	15.0

Ave Hardness All Stations on WB by Run (mg/L)

Water Body	Run 1 12/10/08	Run 2 12/11/08
Warwick Pond	38.0	30.5
Buckeye Brook	41.4	41.2

WW1 Lead Acute Criteria on WB by Run (µg/L)

Water Body	Run 1 12/10/08	Run 2 12/11/08
Warwick Pond	22.20	17.36
Buckeye Brook	24.43	24.30

WW1 Dissolved Lead (µg/L)

Station	Run 1 12/10/08	Run 2 12/11/08
BB00	0.30	0.49
BB02	0.78	0.49
BB03	<0.07	0.18
BB04	<0.07	<0.07
BB05A	0.24	0.22
TA01	0.94	1.70
OF08	1.08	0.20

WW1 Dissolved Lead Acute Exceedances

Station	Run 1 12/10/08	Run 2 12/11/08
BB00		
BB02		
BB03		
BB04		
BB05A		
TA01		
OF08		

Wet Weather 1 Dissolved Lead Chronic Criteria Evaluation

WW1 Hardness as $CaCO_3$ (mg/L)

Station	Run 1 12/10/08	Run 2 12/11/08
BB00	44.0	37.0
BB02	32.0	24.0
BB03	42.0	52.0
BB04	53.0	45.0
BB05A	52.0	44.0
TA01	45.0	50.0
OF08	15.0	15.0

Average Hardness by Station and Segment (mg/L)

Station	$CaCO_3$
BB00	34.3
BB02	
BB03	41.3
BB04	
BB05A	
TA01	
OF08	

WW1 Lead Chronic Criteria (µg/L)

Station	Lead
BB00	0.77
BB02	
BB03	0.95
BB04	
BB05A	
TA01	
OF08	

WW1 Dissolved Lead (µg/L)

Station	Run 1 12/10/08	Run 2 12/11/08
BB00	0.30	0.49
BB02	0.78	0.49
BB03	<0.07	0.18
BB04	<0.07	<0.07
BB05A	0.24	0.22
TA01	0.94	1.70
OF08	1.08	0.20

Value of 0.0 used for average if below DL/RL

WW1 Average Dissolved Lead (µg/L)

Station	Average R1+R2
BB00	0.40
BB02	0.64
BB03	0.09
BB04	
BB05A	0.23
TA01	**1.32**
OF08	0.64

WW1 Dissolved Lead Chronic Exceedances

Station	Average R1+R2
BB00	
BB02	
BB03	
BB04	
BB05A	
TA01	**EXD**
OF08	

Wet Weather 1 Dissolved Zinc Acute Criteria Evaluation

WW1 Hardness as $CaCO_3$ (mg/L)		
Station	Run 1 12/10/08	Run 2 12/11/08
BB00	44.0	37.0
BB02	32.0	24.0
BB03	42.0	52.0
BB04	53.0	45.0
BB05A	52.0	44.0
TA01	45.0	50.0
OF08	15.0	15.0

Ave Hardness All Stations on WB by Run (mg/L)		
Water Body	Run 1 12/10/08	Run 2 12/11/08
Warwick Pond	38.0	30.5
Buckeye Brook	41.4	41.2

WW1 Zinc Acute Criteria on WB by Run (µg/L)		
Water Body	Run 1 12/10/08	Run 2 12/11/08
Warwick Pond	51.62	42.85
Buckeye Brook	55.51	55.28

WW1 Dissolved Zinc (µg/L)		
Station	Run 1 12/10/08	Run 2 12/11/08
BB00	25.48	27.19
BB02	28.71	24.48
BB03	<6.46	<6.46
BB04	7.09	8.25
BB05A	20.64	25.43
TA01	9.18	21.80
OF08	33.51	26.17

WW1 Dissolved Zinc Acute Exceedances		
Station	Run 1 12/10/08	Run 2 12/11/08
BB00		
BB02		
BB03		
BB04		
BB05A		
TA01		
OF08		

Wet Weather 1 Dissolved Zinc Chronic Criteria Evaluation

WW1 Hardness as $CaCO_3$ (mg/L)		
Station	Run 1 12/10/08	Run 2 12/11/08
BB00	44.0	37.0
BB02	32.0	24.0
BB03	42.0	52.0
BB04	53.0	45.0
BB05A	52.0	44.0
TA01	45.0	50.0
OF08	15.0	15.0

Average Hardness by Station and Segment (mg/L)	
Station	$CaCO_3$
BB00	34.3
BB02	
BB03	41.3
BB04	
BB05A	
TA01	
OF08	

WW1 Zinc Chronic Criteria (µg/L)	
Station	Zinc
BB00	47.7
BB02	
BB03	55.8
BB04	
BB05A	
TA01	
OF08	

WW1 Dissolved Zinc (µg/L)		
Station	Run 1 12/10/08	Run 2 12/11/08
BB00	25.48	27.19
BB02	28.71	24.48
BB03	<6.46	<6.46
BB04	7.09	8.25
BB05A	20.64	25.43
TA01	9.18	21.80
OF08	33.51	26.17

WW1 Average Dissolved Zinc (µg/L)	
Station	Average R1+R2
BB00	26.34
BB02	26.60
BB03	
BB04	7.67
BB05A	23.04
TA01	15.49
OF08	29.84

WW1 Dissolved Zinc Chronic Exceedances	
Station	Average R1+R2
BB00	
BB02	
BB03	
BB04	
BB05A	
TA01	
OF08	

Wet Weather 2 Dissolved Cadmium Acute Criteria Evaluation

WW2 Hardness as $CaCO_3$ (mg/L)

Station	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
BB00	52.2	32.3	43.4
BB02	41.0	28.4	34.4
BB03	79.2	43.8	35.2
BB04	56.8	40.4	50.7
BB05A	59.0	36.2	44.4
TA01	42.7	62.2	77.4
OF08	33.0	16.2	24.2

Ave Hardness All Stations on WB by Run (mg/L)

Water Body	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
Warwick Pond	46.6	30.4	38.9
Buckeye Brook	54.1	39.8	46.4

WW2 Cadmium Acute Criteria on WB by Run (µg/L)

Water Body	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
Warwick Pond	0.96	0.63	0.80
Buckeye Brook	1.11	0.82	0.95

WW2 Dissolved Cadmium (µg/L)

Station	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
BB00	0.21	0.09	0.16
BB02	0.14	0.12	0.13
BB03	<0.05	<0.05	<0.05
BB04	<0.05	<0.05	0.06
BB05A	0.06	<0.05	0.14
TA01	<0.05	<0.05	<0.05
OF08	0.10	<0.05	0.20

WW2 Dissolved Cadmium Acute Exceedances

Station	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
BB00			
BB02			
BB03			
BB04			
BB05A			
TA01			
OF08			

Wet Weather 2 Dissolved Cadmium Chronic Criteria Evaluation

WW2 Hardness as $CaCO_3$ (mg/L)

Station	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
BB00	52.2	32.3	43.4
BB02	41.0	28.4	34.4
BB03	79.2	43.8	35.2
BB04	56.8	40.4	50.7
BB05A	59.0	36.2	44.4
TA01	42.7	62.2	77.4
OF08	33.0	16.2	24.2

WW2 Ave Hardness by Station and Segment as $CaCO_3$ (mg/L)

Station	Ave R1+R2	Ave R2+R3
BB00, BB02	38.5	34.7
BB03, BB04, BB05A, TA01, OF08	47.0	43.1

WW2 Cadmium Chronic Criteria (µg/L)

Station	Ave R1+R2	Ave R2+R3
BB00, BB02	**0.13**	0.12
BB03, BB04, BB05A, TA01, OF08	0.15	0.14

WW2 Dissolved Cadmium (µg/L)

Station	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
BB00	0.21	0.09	R
BB02	0.14	0.12	R
BB03	<0.05	<0.05	R
BB04	<0.05	<0.05	R
BB05A	0.06	<0.05	R
TA01	<0.05	<0.05	R
OF08	0.10	<0.05	R

Value of 0.0 used for average if below DL/RL

WW2 Ave Dissolved Cadmium (µg/L)

Station	Ave R1+R2	Ave R2+R3
BB00	**0.15**	N/A
BB02	0.13	N/A
BB03		N/A
BB04		N/A
BB05A	0.03	N/A
TA01		N/A
OF08	0.05	N/A

WW2 Dissolved Cadmium Chronic Exceedances

Station	Ave R1+R2	Ave R2+R3
BB00	EXD	N/A
BB02		N/A
BB03		N/A
BB04		N/A
BB05A		N/A
TA01		N/A
OF08		N/A

Wet Weather 2 Dissolved Copper Acute Criteria Evaluation

WW2 Hardness as $CaCO_3$ (mg/L)

Station	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
BB00	52.2	32.3	43.4
BB02	41.0	28.4	34.4
BB03	79.2	43.8	35.2
BB04	56.8	40.4	50.7
BB05A	59.0	36.2	44.4
TA01	42.7	62.2	77.4
OF08	33.0	16.2	24.2

Ave Hardness All Stations on WB by Run (mg/L)

Water Body	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
Warwick Pond	46.6	30.4	38.9
Buckeye Brook	54.1	39.8	46.4

WW2 Copper Acute Criteria on WB by Run (µg/L)

Water Body	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
Warwick Pond	6.55	4.37	5.52
Buckeye Brook	**7.54**	5.64	6.52

WW2 Dissolved Copper (µg/L)

Station	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
BB00	2.16	2.17	1.53
BB02	2.32	4.05	3.32
BB03	1.05	1.63	0.81
BB04	1.71	2.35	1.46
BB05A	**8.48**	2.02	1.26
TA01	1.48	1.34	1.36
OF08	1.74	3.59	4.22

WW2 Dissolved Copper Acute Exceedances

Station	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
BB00			
BB02			
BB03			
BB04			
BB05A	**EXD**		
TA01			
OF08			

Wet Weather 2 Dissolved Copper Chronic Criteria Evaluation

WW2 Hardness as $CaCO_3$ (mg/L)

Station	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
BB00	52.2	32.3	43.4
BB02	41.0	28.4	34.4
BB03	79.2	43.8	35.2
BB04	56.8	40.4	50.7
BB05A	59.0	36.2	44.4
TA01	42.7	62.2	77.4
OF08	33.0	16.2	24.2

WW2 Ave Hardness by Station and Segments $CaCO_3$ (mg/L)

Station	Ave R1+R2	Ave R2+R3
BB00	38.5	34.7
BB02		
BB03	47.0	43.1
BB04		
BB05A		
TA01		
OF08		

WW2 Copper Chronic Criteria (µg/L)

Station	Ave R1+R2	Ave R2+R3
BB00	4.29	3.90
BB02	3.63	**3.33**
BB03	5.91	4.05
BB04	4.83	4.57
BB05A	**4.75**	4.12
TA01	5.16	6.59
OF08	2.70	**2.28**

WW2 Dissolved Copper (µg/L)

Station	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
BB00	2.16	2.17	1.53
BB02	2.32	4.05	3.32
BB03	1.05	1.63	0.81
BB04	1.71	2.35	1.46
BB05A	8.48	2.02	1.26
TA01	1.48	1.34	1.36
OF08	1.74	3.59	4.22

WW2 Average Dissolved Copper (µg/L)

Station	Ave R1+R2	Ave R2+R3
BB00	2.17	1.85
BB02	3.19	**3.69**
BB03	1.34	1.22
BB04	2.03	1.91
BB05A	**5.25**	1.64
TA01	1.41	1.35
OF08	2.67	3.91

WW2 Dissolved Copper Chronic Exceedances

Station	Ave R1+R2	Ave R2+R3
BB00		
BB02		**EXD**
BB03		
BB04		
BB05A	**EXD**	
TA01		
OF08		

Wet Weather 2 Dissolved Lead Acute Criteria Evaluation

WW2 Hardness as $CaCO_3$ (mg/L)

Station	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
BB00	52.2	32.3	43.4
BB02	41.0	28.4	34.4
BB03	79.2	43.8	35.2
BB04	56.8	40.4	50.7
BB05A	59.0	36.2	44.4
TA01	42.7	62.2	77.4
OF08	33.0	16.2	24.2

Ave Hardness All Stations on WB by Run (mg/L)

Water Body	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
Warwick Pond	46.6	30.4	38.9
Buckeye Brook	54.1	39.8	46.4

WW2 Lead Acute Criteria on WB by Run (µg/L)

Water Body	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
Warwick Pond	27.87	17.26	22.79
Buckeye Brook	32.89	23.38	27.74

WW2 Dissolved Lead (µg/L)

Station	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
BB00	0.16	1.28	0.16
BB02	0.35	0.51	0.17
BB03	0.10	0.33	<0.08
BB04	0.13	0.38	<0.08
BB05A	0.53	0.15	0.20
TA01	0.19	0.22	0.37
OF08	2.62	0.22	0.11

WW2 Dissolved Lead Acute Exceedances

Station	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
BB00			
BB02			
BB03			
BB04			
BB05A			
TA01			
OF08			

Wet Weather 2 Dissolved Lead Chronic Criteria Evaluation

WW2 Hardness as $CaCO_3$ (mg/L)

Station	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
BB00	52.2	32.3	43.4
BB02	41.0	28.4	34.4
BB03	79.2	43.8	35.2
BB04	56.8	40.4	50.7
BB05A	59.0	36.2	44.4
TA01	42.7	62.2	77.4
OF08	33.0	16.2	24.2

WW2 Ave Hardness by Station as $CaCO_3$ (mg/L)

Station	Ave R1+R2	Ave R2+R3
BB00, BB02	38.5	34.7
BB03, BB04, BB05A, TA01, OF08	47.0	43.1

WW2 Lead Chronic Criteria (µg/L)

Station	Ave R1+R2	Ave R2+R3
BB00, BB02	0.88	0.78
BB03, BB04, BB05A, TA01, OF08	1.1	1.0

WW2 Dissolved Lead (µg/L)

Station	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
BB00	0.16	1.28	0.16
BB02	0.35	0.51	0.17
BB03	0.10	0.33	<0.08
BB04	0.13	0.38	<0.08
BB05A	0.53	0.15	0.20
TA01	0.19	0.22	0.37
OF08	2.62	0.22	0.11

Value of 0.0 used for average if below DL/RL

WW2 Average Dissolved Lead (µg/L)

Station	Ave R1+R2	Ave R2+R3
BB00	0.72	0.72
BB02	0.43	0.34
BB03	0.22	0.17
BB04	0.26	0.19
BB05A	0.34	0.18
TA01	0.21	0.30
OF08	**1.42**	0.17

WW2 Dissolved Lead Chronic Exceedances

Station	Ave R1+R2	Ave R2+R3
BB00		
BB02		
BB03		
BB04		
BB05A		
TA01		
OF08	**EXD**	

Wet Weather 2 Dissolved Zinc Acute Criteria Evaluation

WW2 Hardness as $CaCO_3$ (mg/L)

Station	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
BB00	52.2	32.3	43.4
BB02	41.0	28.4	34.4
BB03	79.2	43.8	35.2
BB04	56.8	40.4	50.7
BB05A	59.0	36.2	44.4
TA01	42.7	62.2	77.4
OF08	33.0	16.2	24.2

Ave Hardness All Stations on WB by Run (mg/L)

Water Body	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
Warwick Pond	46.6	30.4	38.9
Buckeye Brook	54.1	39.8	46.4

WW2 Zinc Acute Criteria on WB by Run (µg/L)

Water Body	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
Warwick Pond	61.36	42.67	52.65
Buckeye Brook	69.67	53.64	61.11

WW2 Dissolved Zinc (µg/L)

Station	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
BB00	17.51	21.13	5.55
BB02	13.60	22.60	<1.13
BB03	1.15	1.94	<1.13
BB04	<1.13	3.30	<1.13
BB05A	14.86	2.68	<1.13
TA01	1.44	1.91	<1.13
OF08	10.29	15.40	9.26

WW2 Dissolved Zinc Acute Exceedances

Station	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
BB00			
BB02			
BB03			
BB04			
BB05A			
TA01			
OF08			

Wet Weather 2 Dissolved Zinc Chronic Criteria Evaluation

WW2 Hardness as $CaCO_3$ (mg/L)

Station	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
BB00	52.2	32.3	43.4
BB02	41.0	28.4	34.4
BB03	79.2	43.8	35.2
BB04	56.8	40.4	50.7
BB05A	59.0	36.2	44.4
TA01	42.7	62.2	77.4
OF08	33.0	16.2	24.2

WW2 Ave Hardness by Station as $CaCO_3$ (mg/L)

Station	Ave R1+R2	Ave R2+R3
BB00, BB02	38.5	34.7
BB03, BB04, BB05A, TA01, OF08	47.0	43.1

WW2 Zinc Chronic Criteria (µg/L)

Station	Ave R1+R2	Ave R2+R3
BB00, BB02	52.6	48.2
BB03, BB04, BB05A, TA01, OF08	62.3	57.9

WW2 Dissolved Zinc (µg/L)

Station	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
BB00	17.51	21.13	5.55
BB02	13.60	22.60	<1.13
BB03	1.15	1.94	<1.13
BB04	<1.13	3.30	<1.13
BB05A	14.86	2.68	<1.13
TA01	1.44	1.91	<1.13
OF08	10.29	15.40	9.26

Value of 0.0 used for average if below DL/RL

WW2 Average Dissolved Zinc (µg/L)

Station	Ave R1+R2	Ave R2+R3
BB00	19.32	13.34
BB02	18.10	11.30
BB03	1.55	0.97
BB04	1.65	1.65
BB05A	8.77	1.34
TA01	1.68	0.96
OF08	12.85	12.33

WW2 Dissolved Zinc Chronic Exceedances

Station	Ave R1+R2	Ave R2+R3
BB00		
BB02		
BB03		
BB04		
BB05A		
TA01		
OF08		

Wet Weather 1 Total Iron Chronic Criteria Evaluation

WW1 Total Iron (µg/L)		
Station	Run 1 12/10/08	Run 2 12/11/08
BB00	897	1,082
BB02	1,377	1,419
BB03	296	470
BB04	2,385	3,287
BB05A	1,991	1,423
TA01	4,725	18,912
OF08	2,049	1,726

WW1 Average Total Iron (µg/L)	
Station	Average R1+R2
BB00	990
BB02	**1,398**
BB03	383
BB04	**2,836**
BB05A	**1,707**
TA01	**11,819**
OF08	**1,888**

WW1 Total Iron Chronic Exceedances	
Station	Average R2+R3
BB00	
BB02	EXD
BB03	
BB04	EXD
BB05A	EXD
TA01	EXD
OF08	EXD

Wet Weather 2Total Iron WW2 Chronic Criteria Evaluation

WW2 Total Iron (µg/L)			
Station	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11
BB00	2,307	948	648
BB02	1,747	1,475	2,403
BB03	449	462	1,617
BB04	3,112	1,605	1,799
BB05A	1,168	981	1,172
TA01	4,976	1,250	3,693
OF08	2,454	1,928	2,441

WW2 Average Total Iron (µg/L)		
Station	Average R1+R2	Average R2+R3
BB00	**1,628**	798
BB02	**1,875**	**1,939**
BB03	456	**1,040**
BB04	**2,359**	**1,702**
BB05A	**1,075**	**1,077**
TA01	**3,113**	**2,472**
OF08	**2,191**	**2,185**

WW2 Total Iron Chronic Exceedances		
Station	Average R1+R2	Average R2+R3
BB00	EXD	
BB02	EXD	EXD
BB03		EXD
BB04	EXD	EXD
BB05A	EXD	EXD
TA01	EXD	EXD
OF08	EXD	EXD

Bold and Shaded = Exceeded Criteria (1000 µg/L)

APPENDIX B
TMDL Implementation Reductions

Dissolved Cadmium (µg/L)												
Station	Dry Weather				Wet Weather 1			Wet Weather 2				
	DW1 7/16/08	DW2 9/10/08	DW3 12/9/08	DW4 2/1/11	Run 1 12/10/08	Run 2 12/11/08	Ave R1+R2	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11	Ave R1+R2	Ave R2+R3
Tributaries to Warwick Pond (RI0007024R-05)												
BB00	R	0.08	0.40	0.26	0.17	0.16	0.17	0.21	0.09	R	0.15	R
BB02	R	0.11	0.18	0.09	0.22	0.39	0.31	0.14	0.12	R	0.13	R
Buckeye Brook (RI0007024R-01)												
BB03	R	NS	0.15	<0.05	<0.06	<0.06	<0.06	<0.05	<0.05	R	<0.05	R
BB04	R	<0.06	0.11	0.14	<0.06	<0.06	<0.06	<0.05	<0.05	R	<0.05	R
BB05A	R	<0.06	0.31	0.05	0.29	<0.06	0.15	0.06	<0.05	R	<0.05	R
TA01	R	NS	0.58	0.09	0.08	0.09	0.09	<0.05	<0.05	R	<0.05	R
OF08	R	NS	0.17	0.06	0.19	0.19	0.19	0.10	<0.05	R	0.05	R
AP01	NS	<0.06	NS	NS								

*If sample values were below the Detection Limit (DL), a value of 0.0 was used for averages.

Dissolved Cadmium (µg/L)							
Station	Dry Weather Chronic Criteria				Wet Weather 1 Chronic Criteria	Wet Weather 2 Chronic Criteria	
	DW1 7/16/08	DW2 9/10/08	DW3 12/9/08	DW4 2/1/11	Ave R1+R2	Ave R1+R2	Ave R2+R3
Tributaries to Warwick Pond (RI0007024R-05)							
BB00	R	0.13	0.16	0.16	0.12	0.13	R
BB02							
Buckeye Brook (RI0007024R-01)							
BB03	R	0.14	0.17	0.18	0.13	0.15	R
BB04							
BB05A							
TA01							
OF08							
AP01							

Station	Dry Weather Dissolved Cadmium % Reduction based on 90% criteria				Wet Weather 1 Dissolved Cadmium % Reduction based on 90% criteria	Wet Weather 2 Dissolved Cadmium % Reduction based on 90% criteria	
	7/16/2008	9/10/2008	12/9/2008	2/1/2011	Ave R1+R2	Ave R1+R2	Ave R2+R3
	Chronic	Chronic	Chronic	Chronic	Chronic	Chronic	Chronic
Tributaries to Warwick Pond (RI0007024R-05)							
BB00			64.0%	44.6%	36.5%	22.0%	
BB02			20.0%		65.2%		
Buckeye Brook (RI0007024R-01)							
BB03							
BB04							
BB05A			50.6%		22%		
TA01			73.6%				
OF08					38.4%		
AP01							

Dissolved Copper (µg/L)

Station	Dry Weather				Wet Weather 1			Wet Weather 2				
	DW1 7/16/08	DW2 9/10/08	DW3 12/9/08	DW4 2/1/11	Run 1 12/10/08	Run 2 12/11/08	Ave R1+R2	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11	Ave R1+R2	Ave R2+R3
	Tributaries to Warwick Pond (RI0007024R-05)											
BB00	R	2.10	1.80	1.33	2.04	2.22	2.13	2.16	2.17	1.53	2.17	1.85
BB02	R	1.19	1.03	1.30	3.37	2.19	2.78	2.32	4.05	3.32	3.19	3.69
	Buckeye Brook (RI0007024R-01)											
BB03	R	NS	0.98	2.94	0.89	0.72	0.81	1.05	1.63	0.81	1.34	1.22
BB04	R	1.24	1.21	1.52	0.90	0.88	0.89	1.71	2.35	1.46	2.03	1.91
BB05A	R	1.68	3.24	2.51	1.56	1.63	1.60	8.48	2.02	1.26	5.25	1.64
TA01	R	NS	2.01	1.40	1.04	1.83	1.44	1.48	1.34	1.36	1.41	1.35
OF08	R	NS	0.74	1.03	4.26	2.66	3.46	1.74	3.59	4.22	2.67	3.91
AP01	NS	1.08	NS	NS								

Dissolved Copper (µg/L)

Station	Dry Weather Chronic Criteria				Wet Weather 1 Chronic Criteria	Wet Weather 2 Chronic Criteria		Wet Weather 2 Acute Criteria		
	DW1 7/16/08	DW2 9/10/08	DW3 12/9/08	DW4 2/1/11	Ave R1+R2	Ave R1+R2	Ave R2+R3	Run 1	Run 2	Run 3
Tributaries to Warwick Pond (RI0007024R-05)										
BB00	R	4.14	5.08	5.34	3.58	3.96	3.62	6.55	4.37	5.52
BB02										
Buckeye Brook (RI0007024R-01)										
BB03	R	4.44	5.89	6.04	4.1	4.67	4.32	7.54	5.64	6.52
BB04										
BB05A										
TA01										
OF08										
AP01										

Station	Dry Weather Dissolved Copper % Reduction based on 90% criteria				Wet Weather 1 Dissolved Copper % Reduction based on 90% criteria	Wet Weather 2 Dissolved Copper % Reduction based on 90% criteria		Wet Weather 2 Dissolved Copper % Reduction based on 90% Acute criteria
	7/16/2008	9/10/2008	12/9/2008	2/1/2011	Ave R1+R2	Ave R1+R2	Ave R2+R3	Run 1
	Chronic	Chronic	Chronic	Chronic	Chronic	Chronic	Chronic	Acute
Tributaries to Warwick Pond (RI0007024R-05)								
BB00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
BB02	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Buckeye Brook (RI0007024R-01)								
BB03								
BB04								
BB05A						19.9%		20.0%
TA01								
OF08								
AP01								

Dissolved Lead (µg/L)

Station	Dry Weather				Wet Weather 1			Wet Weather 2				
	DW1 7/16/08	DW2 9/10/08	DW3 12/9/08	DW4 2/1/11	Run 1 12/10/08	Run 2 12/11/08	Ave R1+R2	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11	Ave R1+R2	Ave R2+R3
	Tributaries to Warwick Pond (RI0007024R-05)											
BB00	0.59	<0.07*	0.27	0.09	0.30	0.49	0.40	0.16	1.28	0.16	0.72	0.72
BB02	0.44	<0.07*	0.34	0.11	0.78	0.49	0.64	0.35	0.51	0.17	0.43	0.34
	Buckeye Brook (RI0007024R-01)											
BB03	1.93	NS	0.18	0.29	<0.07*	0.18	0.09	0.10	0.33	<0.08*	0.22	0.17
BB04	1.62	0.18	0.61	1.50	<0.07*	<0.07*	0.00	0.13	0.38	<0.08*	0.26	0.19
BB05A	0.51	<0.07*	0.66	0.37	0.24	0.22	0.23	0.53	0.15	0.20	0.34	0.18
TA01	0.90	NS	1.51	0.73	0.94	1.70	1.32	0.19	0.22	0.37	0.21	0.30
OF08	0.45	NS	0.08	<0.08*	1.08	0.20	0.64	2.62	0.22	0.11	1.42	0.17
AP01	NS	<0.07*	NS	NS								

*If sample values were below the Detection Limit (DL), a value of 0.0 was used for averages. (Dissolved Lead DL: DW1-3, WW1 - <0.07; DW4, WW2 - <0.08)

Dissolved Lead (µg/L)

Station	Dry Weather Chronic Criteria				Wet Weather 1 Chronic Criteria	Wet Weather 2 Chronic Criteria	
	DW1 7/16/08	DW2 9/10/08	DW3 12/9/08	DW4 2/1/11	Ave R1+R2	Ave R1+R2	Ave R2+R3
	Tributaries to Warwick Pond (RI0007024R-05)						
BB00 **BB02**	1.15	0.93	1.21	1.30	0.77	0.88	0.78
	Buckeye Brook (RI0007024R-01)						
BB03 **BB04** **BB05A** **TA01** **OF08** **AP01**	1.53	1.02	1.47	1.52	0.96	1.10	1.00

Station	Dry Weather Dissolved Lead % Reduction based on 90% criteria				Wet Weather 1 Dissolved Lead % Reduction based on 90% criteria	Wet Weather 2 Dissolved Lead % Reduction based on 90% criteria	
	7/16/2008	9/10/2008	12/9/2008	2/1/2011	Ave R1+R2	Ave R1+R2	Ave R2+R3
	Chronic	Chronic	Chronic	Chronic	Chronic	Chronic	Chronic
Tributaries to Warwick Pond (RI0007024R-05)							
BB00	N/A	N/A	N/A	N/A	N/A	N/A	N/A
BB02	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Buckeye Brook (RI0007024R-01)							
BB03							
BB04							
BB05A							
TA01			12.4%		34.5%		
OF08						30.2%	
AP01							

Dissolved Zinc (µg/L)

Station	Dry Weather				Wet Weather 1			Wet Weather 2				
	DW1 7/16/08	DW2 9/10/08	DW3 12/9/08	DW4 2/1/11	Run 1 12/10/08	Run 2 12/11/08	Ave R1+R2	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11	Ave R1+R2	Ave R2+R3
	Tributaries to Warwick Pond (RI0007024R-05)											
BB00	R	28.20	24.88	4.49	25.48	27.19	26.34	17.51	21.13	5.55	19.32	13.34
BB02	R	13.90	13.32	<1.12*	28.71	24.48	26.60	13.60	22.60	<1.12*	18.1	11.3
	Buckeye Brook (RI0007024R-01)											
BB03	R	NS	6.93	1.97	<6.46*	<6.46*	0.00	1.15	1.94	<1.12*	1.55	0.97
BB04	R	7.14	12.21	5.99	7.09	8.25	7.67	<1.12*	3.30	<1.12*	1.65	1.65
BB05A	R	7.75	9.87	4.13	20.64	25.43	23.04	14.86	2.68	<1.12*	8.77	1.34
TA01	R	NS	27.20	3.36	9.18	21.80	15.49	1.44	1.91	<1.12*	1.68	0.96
OF08	R	NS	10.46	2.86	33.51	26.17	29.84	10.29	15.40	9.26	12.85	12.33
AP01	NS	10.40	NS	NS								

*If sample values were below the Detection Limit (DL), a value of 0.0 was used for averages. (Dissolved Zinc DL: DW1-3, WW1 - <6.46; DW4, WW2 - <1.12)

Dissolved Zinc (µg/L)

Station	Dry Weather Acute Criteria				Wet Weather 1 Chronic Criteria	Wet Weather 2 Chronic Criteria	
	DW1 7/16/08	DW2 9/10/08	DW3 12/9/08	DW4 2/1/11	Ave R1+R2	Ave R1+R2	Ave R2+R3
	Tributaries to Warwick Pond (RI0007024R-05)						
BB00	R	54.48	66.78	70.23	47.56	52.56	48.07
BB02							
	Buckeye Brook (RI0007024R-01)						
BB03	R	58.45	77.30	79.24	55.37	61.94	57.35
BB04							
BB05A							
TA01							
OF08							
AP01							

^The calculation of acute zinc criteria produces a slightly lower value than chronic, so the acute value is presented here

Station	Dry Weather Dissolved Zinc % Reduction based on 90% criteria				Wet Weather 1 Dissolved Zinc % Reduction based on 90% criteria	Wet Weather 2 Dissolved Zinc % Reduction based on 90% criteria	
	7/16/2008	9/10/2008	12/9/2008	2/1/2011	Ave R1+R2	Ave R1+R2	Ave R2+R3
	Acute	Acute	Acute	Acute	Chronic	Chronic	Chronic
Tributaries to Warwick Pond (RI0007024R-05)							
BB00	N/A	N/A	N/A	N/A	N/A	N/A	N/A
BB02	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Buckeye Brook (RI0007024R-01)							
BB03							
BB04							
BB05A							
TA01							
OF08							
AP01							

Station	Dry Weather				Wet Weather 1			Wet Weather 2				
	DW1 7/16/08	DW2 9/10/08	DW3 12/9/08	DW4 2/1/11	Run 1 12/10/08	Run 2 12/11/08	Ave R1+R2	Run 1 02/03/11	Run 2 02/06/11	Run 3 02/08/11	Ave R1+R2	Ave R2+R3
	Tributaries to Warwick Pond (RI0007024R-05)											
BB00	732	522	654	741	897	1,082	990	2,307	948	648	1,628	798
BB02	648	824	1,185	**1,989**	1,377	1,419	1,398	1,747	1,475	2,403	1,611	1,939
	Buckeye Brook (RI0007024R-01)											
BB03	186	NS	308	432	296	470	383	449	462	1,617	456	1,040
BB04	2,078	1,258	3,112	1,892	2,385	3,287	2,836	3,112	1,605	1,799	2,359	1,702
BB05A	1,347	1,439	1,112	1,010	1,991	1,423	1,707	1,168	981	1,172	1,075	1,077
TA01	11,586	NS	19,180	9,088	4,725	18,912	11,819	4,976	1,250	3,693	3,113	2,472
OF08	2,844	NS	4,334	3,954	2,049	1,726	1,888	2,454	1,928	2,441	2,191	2,185
AP01	NS	3,008	NS	NS								

Table: **Total Iron (µg/L)**

Station	Dry Weather Chronic Criteria				Wet Weather 1 Chronic Criteria	Wet Weather 2 Chronic Criteria	
	DW1 7/16/08	DW2 9/10/08	DW3 12/9/08	DW4 2/1/11	Ave R1+R2	Ave R1+R2	Ave R2+R3
	Tributaries to Warwick Pond (RI0007024R-05)						
BB00 / **BB02**	1000	1000	1000	1000	1000	1000	1000
	Buckeye Brook (RI0007024R-01)						
BB03 / **BB04** / **BB05A** / **TA01** / **OF08** / **AP01**	1000	1000	1000	1000	1000	1000	1000

Table: **Total Iron (µg/L)**

Station	Dry Weather Total Iron % Reduction based on 90% criteria				Wet Weather 1 Total Iron% Reduction based on 90% criteria	Wet Weather 2 Total Iron % Reduction based on 90% criteria	
	7/16/2008	9/10/2008	12/9/2008	2/1/2011	Ave R1+R2	Ave R1+R2	Ave R2+R3
	Chronic	Chronic	Chronic	Chronic	Chronic	Chronic	Chronic
Tributaries to Warwick Pond (RI0007024R-05)							
BB00						44.7%	
BB02			24.1%	54.8%	35.6%	44.1%	53.6%
Buckeye Brook (RI0007024R-01)							
BB03							13.5%
BB04	56.7%	28.5%	71.1%	52.4%	68.3%	61.8%	47.1%
BB05A	33.2%	37.5%	19.1%	10.9%	47.3%	16.3%	16.4%
TA01	92.2%		95.3%	90.1%	92.4%	71.1%	63.6%
OF08	68.4%		79.2%	77.2%	52.3%	58.9%	58.8%
AP01		70.1%					

APPENDIX C
Stream System Propylene Glycol Evaluation Before and After Construction of Diversion Facility

Average deicing event values for RIAC waterbody stream stations before and after the Propylene Glycol facility commenced operations in October 2014. Samples below reporting limit were set to 0.0 for averaging.

Surveys Before Glycol Facility Operational

January 17-19, 2012 Averages					
Station	DO (mg/L)	DO % Saturation	COD (mg/L)	BOD_5 (mg/L)	Propylene Glycol (mg/L)
BB02	10.7	84.3	35	12	9
BB03	10.9	85.1	24	4	<10
BB07	10.7	82.6	80	24	29
BB08	10.9	85.9	44	16	34

January 21-23, 2013 Averages					
Sample ID:	DO (mg/L)	DO % Saturation	COD (mg/L)	BOD_5 (mg/L)	Propylene Glycol (mg/L)
BB02	10.1	72.6	29	16	12
BB03	10.7	76.2	19	9	8
BB04	9.8	71.7	114	27	26
BB07	10.8	77.5	28	15	15

February 13-15, 2014 Averages					
Sample ID:	DO (mg/L)	DO % Saturation	COD (mg/L)	BOD_5 (mg/L)	Propylene Glycol (mg/L)
BB02	10.8	82.9	91	40	2
BB03	10.9	83.4	126	52	1
BB04	10.6	85.6	73	28	5
BB07	10.6	88.9	120	32	18

Surveys After Glycol Facility Operational

March 20-22, 2015 Averages					
Station	DO (mg/L)	DO % Saturation	COD (mg/L)	BOD5 (mg/L)	Propylene Glycol (mg/L)
BB02	12.0	89.8	41	11	<10
BB03	11.6	84.9	18	<12	<10
BB04	11.1	84.0	16	<12	<10
BB07	11.6	87.1	17	<12	<10

January 23-25, 2016 Averages					
	Sample ID:	DO % Saturation	COD (mg/L)	BOD5 (mg/L)	Propylene Glycol (mg/L)
BB02	11.3	82.8	7	<12	<10
BB03	13.1	91.3	13	<12	<10
BB04	11.3	86.3	26	<12	<10
BB07	11.8	92.5	13	<12	<10

February 1-3, 2017 Averages					
Sample ID:	DO (mg/L)	DO % Saturation	COD (mg/L)	BOD5 (mg/L)	Propylene Glycol (mg/L)
BB02	12.2	93.4	8	4	<10
BB03	12.7	99.7	1	1	<10
BB04	11.0	80.6	11	1	<10
BB07	12.7	92.5	10	<6	<10

Average deicing event values for RIAC outfall stations before and after the Propylene Glycol facility commenced operations in October 2014. Samples below reporting limit set to 0.0 for averages.

Surveys Before Glycol Facility Operational

January 17, 2012 Averages					
Station	COD (mg/L)	BOD_5 (mg/L)	P. Glycol (mg/L)	TOC (mg/L)	Iron (µg/l)
002A	202	71	95	78	5,720
003A	37	13	9	2	950
008A	944	219	580	305	2,556

January 21-22, 2013 Averages					
Station	COD (mg/L)	BOD_5 (mg/L)	P. Glycol (mg/L)	TOC (mg/L)	Iron (µg/l)
002A	158	71	117	53	9,978
003A	<10	<12	<10	<5	645
008A	33	14	16	26	5,675

February 13, 2014 Averages					
Station	COD (mg/L)	BOD_5 (mg/L)	P. Glycol (mg/L)	TOC (mg/L)	Iron (µg/l)
002A	386	64	<10	116	12,738
003A	259	54	<10	70	3,386
008A	312	49	<10	65	6,386

Surveys After Glycol Facility Operational

March 20-21, 2015 Averages					
Station	COD (mg/L)	BOD_5 (mg/L)	P. Glycol (mg/L)	TOC (mg/L)	Iron (µg/l)
002A	247	151	43	65	14,833
003A	50	28	14	14	1,262
008A	55	27	12	15	2,389

January 23-24, 2016 Averages					
Station	COD (mg/L)	BOD_5 (mg/L)	P. Glycol (mg/L)	TOC (mg/L)	Iron (µg/l)
002A	27	15	<10	9	9,024
003A	5	2	<10	0.7	2,337
008A	41	22	7	12	2,424

February 1, 2017 Averages					
Station	COD (mg/L)	BOD_5 (mg/L)	P. Glycol (mg/L)	TOC (mg/L)	Iron (µg/l)
002A	124	62	18	32	5,430
003A	122	76	20	32	1,692
008A	40	25	4	12	1,291

T. F. Green Seasonal Propylene Glycol Collection Efficiencies

Season Before Glycol Facility Operational			
Season	PG Applied (gal)	PG Collected (gal)	Collection Efficiency (%)
2011-2012	18,405	6,244	34%
2012-2013	44,046	16,407	37%
2013-2014	61,835	26,236	42%

Season After Glycol Facility Operational			
Season	PG Applied (gal)	PG Collected (gal)	Collection Efficiency (%)
2014-2015	42,352	28,304	67%
2015-2016	27,731	17,359	63%
2016-2017	31,068	20,313	65%

APPENDIX D
Public Comments and RIDEM Response to Comments

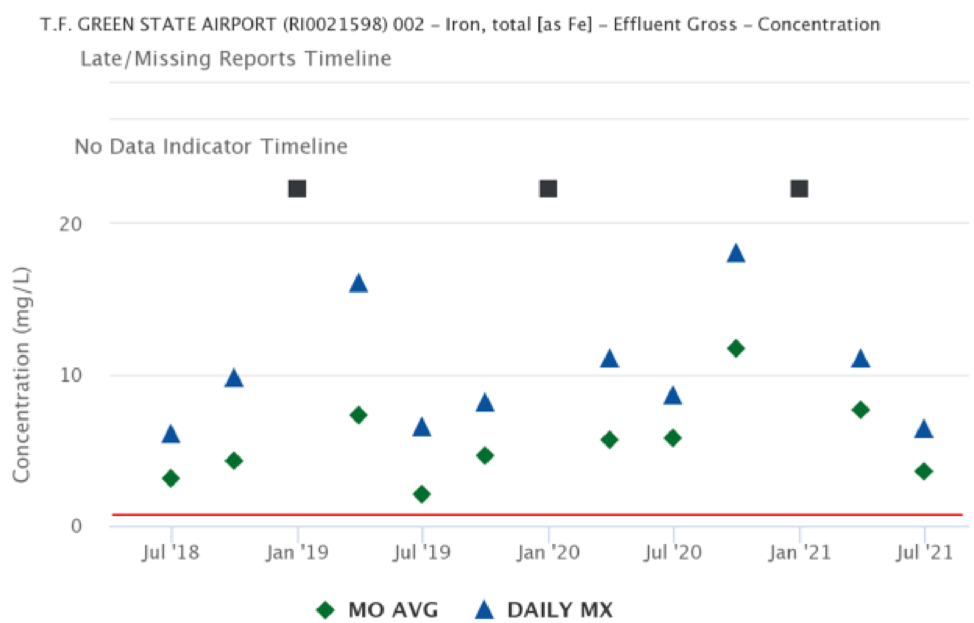
CDM Smith Memorandum on behalf of RI Airport Corporation (RIAC) dated August 24, 2021

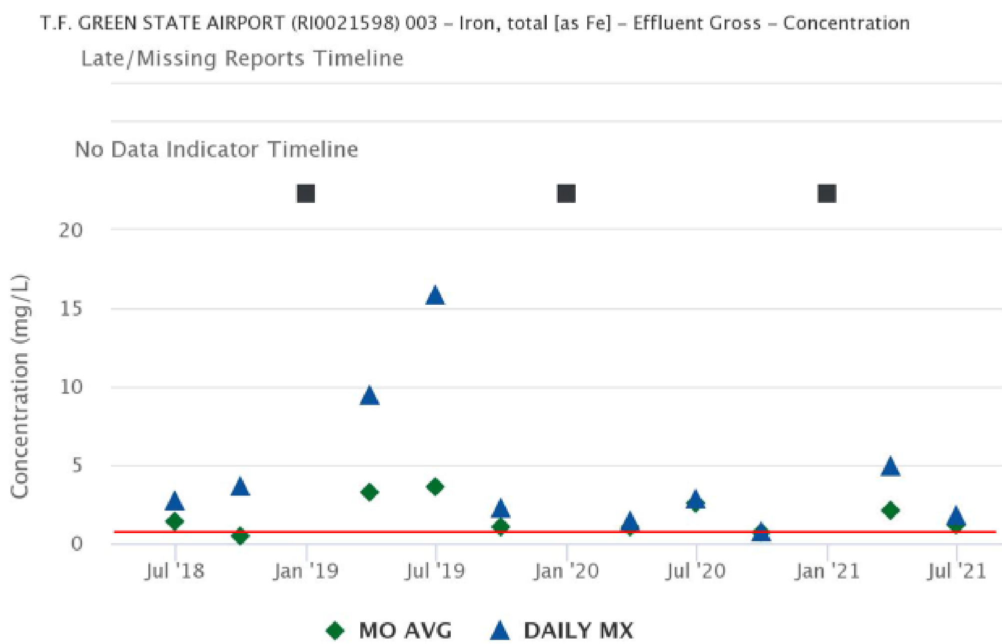
1. The sampling design and implementation is not adequate to determine whether water quality criteria are met during critical low flow conditions.
   Based on nearby gage data, all data collected in support of this TMDL was collected at or above 7Q10, which the critical condition as stated in the TMDL and the water quality standards.

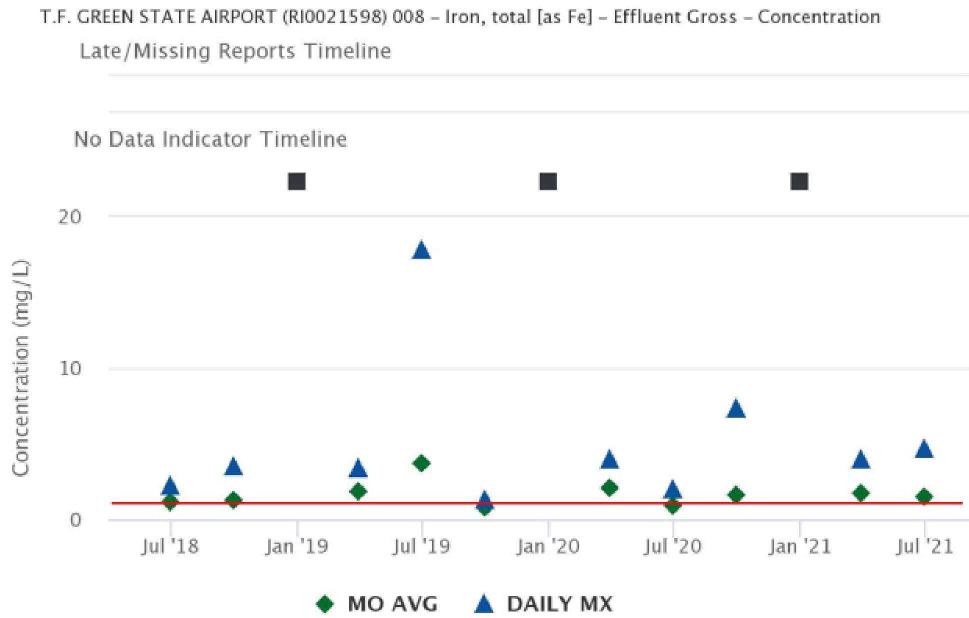
   a. The water quality data used to support the TMDL analysis were not collected using clean metals sampling techniques and were not demonstrated to be collected using appropriate quality control procedures following the approved Quality Assurance Project Plan.
      All data was collected under an EPA-approved QAPP, and any data that did not meet data quality objectives or indicators was not used in the TMDL. An updated document examining the data and documenting which data are appropriate to use in the TMDL is available: http://www.dem.ri.gov/programs/benviron/water/quality/rest/pdfs/tmdl-buckeye-aquatic-report.pdf. All data used in the TMDL were confirmed to be collected in acid washed bottles using deionized water for quality control sampling. As noted in The Field Sampling SOP-BB2 and as is standard data collection technique in lotic systems, all samples were collected to minimize disruption of sediment via entry to the stream downstream of the sampling location and collection facing upstream. The criteria applicable to iron data is measured as total iron, therefore, no dissolved fraction was analyzed.

   b. The second draft TMDL report does not consider all available data for its assessment of existing loading.
      The comment refers to water quality data collected quarterly at stormwater outfalls as well as annual data collected in-stream at BB02, BB03, BB04, and BB07 by RIAC. RIAC samples outfalls at predetermined hourly rates for fecal coliform, biological oxygen demand (BOD), total suspended solids (TSS), surfactants, chemical oxygen demand (COD), total organic carbon (TOC), Oil & Grease – 1664, propylene glycol, dissolved potassium and sodium, and total metals (aluminum, chromium, copper, iron, lead, and zinc) and in-stream stations for BOD, COD, and propylene glycol. Field measurements for pH, specific conductance, temperature, and dissolved oxygen are collected at outfalls and in-stream stations, with in-stream stations also including percent saturation for dissolved oxygen.

      RIDEM has reviewed this information for applicability to the impairments included in this TMDL. The criteria for metals are expressed as hardness-based equations for dissolved copper and lead. Without associated hardness or dissolved fraction, the metals data can not be evaluated in compliance with the hardness-based equations as expressed in the water quality regulations. The total iron criterion is a single chronic value of 1000 µg/L (equivalent to 1 mg/L). The total iron outfall data are reported as monthly averages and daily maximums, which are not applicable for the determination of a total maximum daily load. However, a review of the those reported monthly averages and daily maximums from July 30, 2018 to July 30, 2021 demonstrate that the outfalls discharging to Tributaries to Warwick Pond and Buckeye Brook are routinely over the 1 mg/L total iron criterion, which is denoted on each graph with a red line.



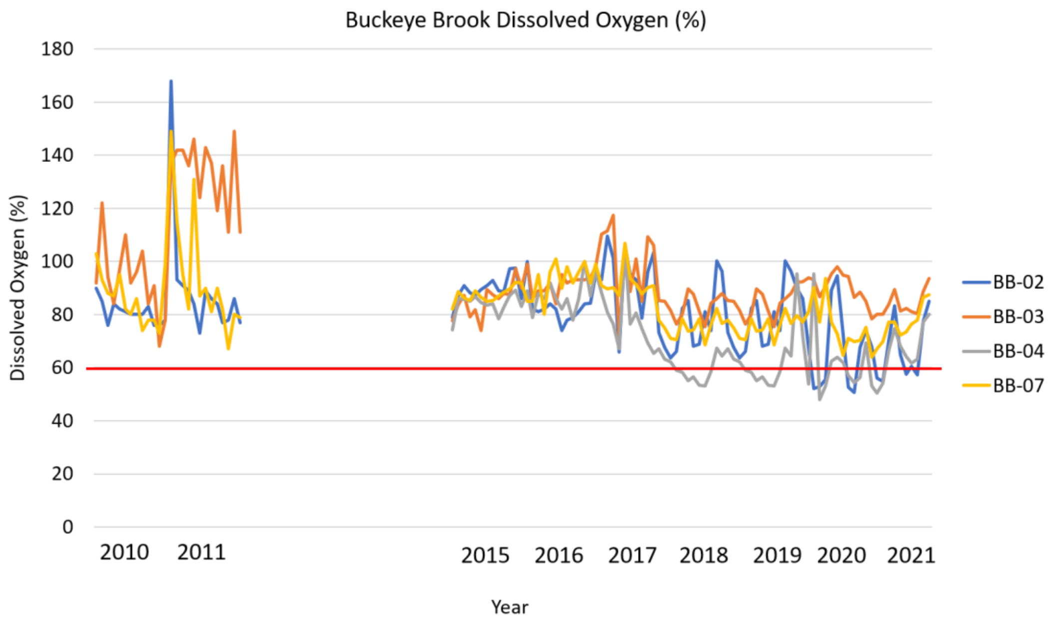




The in-stream data was also reviewed for dissolved oxygen concentration (mg/L) and percent saturation 2010 to 2021. The water quality regulations state for warm water fish habitat:

"Dissolved oxygen content of not less than 60% saturation, based on a daily average, and an instantaneous minimum dissolved oxygen concentration of at least 5.0mg/l, except as naturally occurs. The 7 day mean water column dissolved oxygen concentration shall not be less than 6 mg/l."

The instream dissolved oxygen concentration expressed as mg/L from the 2010 to 2021 did not have any excursions below the instantaneous concentration of 5.0mg/L nor the 7 day mean water column dissolved oxygen concentration of 6.0mg/L; however, several excursions below the 60% dissolved oxygen saturation criterion occurred 2018 through 2021. Further hourly data is required to calculate a daily average for comparison to the water quality criterion, which is most accurately collected through deployment of continuous data sondes. Additionally, the stream data are collected once per year, which further limits the utility of the data collected for TMDL development.



The memorandum also discusses the RIAC data presented in TMDL Figure 3.12 not matching RIAC data, specifically OF08 RIAC average of 2,274 µg/L as opposed to the RIDEM 8,000 µg/L as presented in the TMDL document. The total iron data provided previously by RIAC was reviewed, and the values provided match what is presented in the document. However, the total iron data from Outfalls 002, 003, and 008 were only collected on February 1, 2011, which has now been documented to occur in dry conditions. Therefore, the wet weather figure in question has been removed from the final document for clarity.

The memorandum also discusses that the stormwater controls implemented after 2011 should be applied to this TMDL. Language was included regarding the measures RIAC has undertaken to reduce the discharge of deicing and anti-icing fluids. Additional language was added for this draft that appears in the TMDL implementation section to indicate that measures to mitigate the release of pollutants implemented after the time samples were collected contribute to the reductions.

c. The dry and wet weather sampling criteria are poorly defined and do not meet the criteria established for the TMDL study nor the RIPDES permit requirements for wet weather sampling.

RIDEM reviewed precipitation data and concurred that the September 10, 2008 data was collected after precipitation. As noted on pg. 32 of the TMDL: “While the September 10, 2008 survey proceeded as a dry weather survey, 4.39” of precipitation occurred between September 6th and 9th, with 0.29” of precipitation on September 9th. Therefore, these samples are likely influenced by precipitation. It was determined that the final assessment of trace metals would not be affect by analysis as dry or wet weather, given that with a single sample only acute criteria would apply for wet weather. Additionally, a note has been added to Table 3.3 on pg. 30 to indicate this date is likely influenced by precipitation.

d. Summary: Additional water quality data are required to determine whether exceedances of acute and chronic metals and the DO criteria exist.

   i. Collect data using clean metals sampling techniques appropriate for detection of trace metals
   See response to Item 1a.

   ii. Collect sufficient data to evaluate whether exceedances of water quality criteria indicate impairment, consistent with the Rhode Island Water Quality Regulations and the CALM
   See response to Item 1b.

   iii. Properly define wet and dry weather criteria
   See response to Item 1c.

   iv. Collect additional wet weather data to account for seasonal variability
   Data was collected from both dry and wet weather conditions across multiple seasons. Wet weather conditions were collected during wet precipitation and snowfall conditions to represent conditions with and without propylene glycol.

   v. Collect flow and concentration data at appropriate locations to reliably determine pollutant sources and/or develop a watershed water quality model that can be used to complete a load allocation.
   Pollutant sources are documented in Section 4.0. TMDLs can be expressed on a mass loading basis or as a concentration in accordance with provisions in federal regulations [40 CFR 130.2(i)]. The TMDLs and consequently the WLAs and LAs in Section 5.0 are expressed as concentration targets required to meet standards.

2. The revised hardness analysis does not correctly identify ambient hardness in the receiving water and RIDEM should establish a critical hardness concentration that will be used to set the TMDL load allocation.

   a. The ambient hardness in Buckeye Brook is not calculated correctly.
   This comment refers to the use of average hardness. The updated TMDL approach expresses the TMDLs as a concentration set equal to the applicable state water quality standard hardness-based equation and for total iron the single chronic criterion of 1000 µg/L with a 10% margin of safety for each dissolved metal applied daily. When applying the hardness-based equations, which are the TMDLs, the hardness at time of sample is the appropriate expression of hardness to calculate the metals concentration

criteria. The averaging of hardness values is used for the purposes of calculating a recommended percent reduction for implementation purposes, which is not the TMDL.

b. The revised average hardness concentrations are not representative of ambient conditions during the September 10, 2008 event.
We refer to the previous comment response 2a. Additionally, we note that none of the hardness-based recommended percent reductions resulted from the September 10, 2008 data.

c. The ambient hardness should be established as a single value to set an allowable load.
We refer to the previous comment response 2a. Additionally, the hardness-based equations are variable in nature due to the effect of hardness on the toxicity of the metals. The TMDL document also includes recommended percent reductions to provide guidance for implementation activities.

3. The second draft TMDL report does not consider whether exceedances of iron and dissolved oxygen criteria are naturally occurring.
The comment cites the Water Quality Regulations § 1.4(A)(53) in its entirety including that waters in their natural hydraulic condition may fail to meet their assigned water quality criteria from time to time due to natural causes. The data from Tributaries to Warwick Pond and Buckeye Brook demonstrate the exceedance of water quality criteria are not occurring time to time. The exceedance of criteria occurs across various flow, precipitation, and seasonal conditions. We acknowledge the Water Quality Regulations also do allow for waters in their natural hydraulic condition may fail to meet their assigned water quality criteria. We highlight the use of the term "natural hydraulic condition". The waters of Tributaries to Warwick Pond and Buckeye Brook do not reside in their natural hydraulic condition, given the immediate study area in undeveloped categories of forest and wetland and open is 24.9% leaving the 75.1% as developed land uses.

The comment also in several instances discusses whether the total iron and low dissolved oxygen values are of natural occurrence. A review of total iron data available from other stream or rivers in the Pawtuxet watershed, in which Tributaries to Warwick Pond and Buckeye Brook are located, range in averages from 218µg/L to 644µg/L. In dry weather, Tributaries to Warwick Pond and Buckeye Brook total iron in this study averaged 912 µg/L and 3,787 µg/L respectively. In wet weather, Tributaries to Warwick Pond and Buckeye Brook total iron in this study averaged 1,430µg/L and 2,655 µg/L respectively. These discrepancies within the same watershed indicate there is not a natural background source of total iron. Additionally, a review of dissolved oxygen data showed all Pawtuxet watershed riverine sites met dissolved oxygen criteria.

The comment also suggests that Figure 3.4 is potentially misleading by displaying a mean and the implication that the dissolved oxygen at TF002-003 was zero via no bar displayed. Two footnotes have been added for clarity stating: ”Instantaneous criterion is displayed for informational purposes only. Procedures for assessment purposes under the Clean Water Act Section 303(d) is described in the Rhode Consolidated Assessment and Listing Methodology (CALM)” and “A single dissolved oxygen value was collected at AP01”. Additionally, the label for TF002-003 has been removed from the figure.

The comment also discusses Table 3.7 data at TA01 is higher during dry weather than other sites. This site is primarily influenced by the Truk-Away landfill potentially with other watershed stormwater influence. Both potential sources of pollutants are identified in the TMDL and steps for implementation are documented in Section 6.0 for implementation to meet water quality standards.

Further on this comment overall, the attribution of natural background sources is included in the load allocation. Parsing out natural background conditions, which is not possible in this study, would not remove obligations to the pollutant sources to do less removal.

4. The second draft TMDL does not include a loading analysis to link water quality to pollutant sources or a load allocation to allocate loads among pollutant sources and does not consider all potential sources of pollutants to the receiving water.
   a. The second draft TMDL report does not include a loading analysis, contrary to EPA regulations and guidance.
      This comment further states that a load allocation and loading capacity analysis are required by EPA regulations. As the required under 40 CFR § 130.7, the load allocation is stated in Section 5.7 Wasteload and Load Allocations. It is unclear what the commenter is referring to with a loading capacity analysis requirement, but 40 CFR § 130.2(f) and the 2002 EPA TMDL guidance document, which are referenced by the comment, discusses the requirement to identify the loading capacity, which is defined as the greatest amount of pollutant that a water can receive without violating water quality standards. This pollutant loading may be expressed as either mass-per-time, toxicity, or other appropriate measure (40 CFR § 130.2(i)). The TMDL is expressed as a concentration by the hardness-based equations or single criterion as found in the Water Quality Regulations with the required margin of safety, which is considered an appropriate measure of pollutant loading. Further, the TMDL submittal contains documentation supporting the TMDL analysis including the basis for any assumptions; a discussion of strengths and weaknesses in the analytical process; and critical condition are documented. Water quality modeling is not required as a condition of TMDL development and submission and is therefore not presented as it was not conducted.

      The commenter also suggests that the document does not contain either a source assessment or loading analysis that can be “used to establish the cause-and-effect relationship between the numeric target and the identified pollutant sources" or that can be used to "identify the portion of loading capacity attributed to existing and future nonpoint sources and to natural background". We further reviewed this comment and note that the quotations from the 2002 EPA guidance documents are from a section describing loading capacity, not loading analysis, and load allocation, not source assessment, respectively.

The first quotation discussing cause-and-effect relationship is taken from a discussion regarding pollutant loading expression, not loading capacity. The pollutant loadings for the metals impairments are expressed as concentrations as allowable under 40 CFR §130.2(i), and the sources described in Section 4.0 (stormwater, waste sources, groundwater, and non-stormwater urban runoff) are well documented to carry pollutants such as the metals subject to this TMDL. The second quotation is from a section on load allocations as part of a description of what a load allocation is comprised of. As required, the TMDL does contain load allocations for non-point sources as described in Section 5.7.

b. The second draft TMDL report fails to consider other potential sources of pollution besides the Truk-Away landfill and T.F. Green Airport.

RIDEM concurs that other potential sources of pollution besides Truk-Away landfill and T.F. Green Airport must be addressed to improve the water quality of Tributaries to Warwick Pond and Buckeye Brook. Reductions must be achieved on a watershed basis. While airport outfalls are marked on the figures, the document details multiple sources must reduce inputs to Buckeye Brook and Tributaries to Warwick Pond. Obligations to implement MS4 permits and industrial general permit are detailed in Section 6.2 as implementation.

The commenter acknowledges that the TMDL identifies actions are required by City of Warwick and RIDOT, but states that data from other outfalls are not presented similar to Outfall 08. The TMDL document contains identification of BB05A station sited to capture stormwater outfalls in Table 3.1. An edit to the table to identify RIDOT and City of Warwick has been added and edits to the introductory text in Section 1.0 have been added for clarity of sources.

Additionally, the commenter discusses the watershed boundary as depicted in the document. A map has been added in response to this comment to depict the subwatersheds that contribute to the impairment of Buckeye Brook and Tributaries to Warwick Pond. Further language in the document has been added naming the subwatersheds found to impact the biodiversity in Buckeye Brook and Tributaries to Warwick Pond.

The commenter indicates that a critical period is not defined in the document. The draft contains a section noting the critical condition, which is a requirement of 40 CFR 130.7(c)(1). As noted in the document, elevations of metals concentrations occur throughout the year and under various flow regimes and weather conditions. Therefore, the critical period is set in accordance with the Rhode Island Water Quality Regulations at or above the lowest average 7 consecutive day low flow with an average recurrence frequency of once in 10 years (7Q10) inclusive of all seasons and for all weather conditions.

Further comments in this section refer to the determination of natural or other sources. We refer to previous sections' comment responses above.

5. The stormwater reduction goals may not be achievable if a large portion of the load is attributable to natural sources.
   The description of this comment discusses whether a 10 percent impervious cover target will achieve the aquatic life use goals and suggests that removal of impervious cover will increase dry weather exceedances via increased groundwater flow through subsurface infiltration. There is a well-documented relationship between aquatic life health and removal of impervious cover.

   Additionally, it is unclear why the commenter states that an increase of groundwater will increase the concentration of total iron in dry weather. No further documentation is presented that this is a possible outcome of removal of impervious cover and no changes were made in response to this comment. Regarding the comment that a large portion of the load is attributable to natural sources, we refer to responses to this comment in Response #3

6. The analysis of DO and propylene glycol in the second draft TMDL does not consider current conditions following RIAC's improved stormwater controls in 2014. Moreover, the data do not support that DO impairments exist in wet weather.
   As noted above, language was included regarding the measures RIAC has undertaken to reduce the discharge of deicing and anti-icing fluids. Additional language was added for this draft that appears in the TMDL implementation section to indicate that measures to mitigate the release of pollutants implemented after the time samples were collected contribute to the reductions.

   The commenter discusses that the dissolved oxygen data as presented in Figure 3.9 may obscure the influence of the low DO measurements at TA01, which they state may account for DO sags between BB03 and BB04. The document discusses the DO data from TA01 prior to Figure 3.9. The TMDL document notes that TA01 low oxygen values likely are attributable to the stagnant nature of the conditions at TA01, which would not influence the oxygen in the downstream flowing stations.

The comment also discusses whether a dissolved oxygen impairment continues to exist. We refer to the response to Comment 1B.

7. The recommended percent reductions to achieve the TMDL target concentrations are relative to an outdated reference condition and do not represent the reductions necessary to meet water quality criteria across the entire water quality segment.
   a. The recommended percent reductions reference an outdated reference condition.
   As noted above, language was included regarding the measures RIAC has undertaken to reduce the discharge of deicing and anti-icing fluids. Additional language was added for this draft that appears in the TMDL implementation section to indicate that measures to mitigate the release of pollutants implemented after the time samples were collected contribute to the meeting required concentration targets.

   This comment also refers to the "metals load reductions Table 6.1 (i.e., WLA in the draft TMDL)". We note that, as stated in Sections 5.6, the TMDLs are the hardness-based equations resulting in a concentration in the case of dissolved cadmium, copper, and lead, or the single chronic concentration criterion for total iron with a margin of safety as appropriate for each Buckeye Brook and Tributaries to Warwick Pond. Section 5.7 is the discussion of the wasteload and load allocation. Table 6.1 are the recommended percent reductions for implementation purposes.

   b. The recommended percent reductions are not representative of the improvements necessary to meet water quality criteria within each segment.
   The comment provides examples of reductions by station. The maximum concentration was selected as a conservative method to ensure water quality standards are met for the entirety of the water quality segment. However, in light of this comment, the percent reductions have been updated to use an average percent reduction. As noted above, reductions must be achieved on a watershed basis.

   The comment also discusses the wet weather recommended percent reductions in Appendix B denote the selected percent reduction is 36.5%, which appears in the row for AP01, which as the commenter pointed out was not sampled during wet weather. This value should have been in the cell above for OF08 and with a reduction of 38.4%. This typo has been corrected and all percent reductions confirmed.

8. Iron reduction targets are not demonstrated to be consistent with the causal mechanism of impairment discussed in the TMDL and RIDEM has not shown that iron-fixing bacteria are contributing to DO impairments.
   It is well documented that iron fixing bacteria will use oxygen to convert soluble ferrous iron back into an insoluble reddish precipitate, which is evident upstream of the sag documented at BB04, which continues to be present (See Response Comment 1B). As noted in Section 3.9 of the TMDL, observation of iron flocculant material was evident in each of the tributaries originating from the airport and/or landfill stations OF08, AP01,

and TA01. The evidence overwhelmingly points to extreme iron conditions exist in the tributaries and headwaters of Buckeye Brook that are impacting dissolved oxygen conditions at BB04.

RIDEM acknowledges that the chronic criterion of 1000µg/L is based on an endpoint to protect aquatic life from toxic effects of iron and not recovery of dissolved oxygen. The inclusion of the dissolved oxygen TMDL targets of the water quality regulation end point is to ensure that the dissolved oxygen must be met in order support aquatic life use in Buckeye Brook.

9. The Integrated Report should be updated to reflect the data validation performed by RIDEM
   The comment notes that the Buckeye Brook should be delisted for total zinc based on the reanalysis of the quality control samples and Data Quality Objectives stated in the Quality Assurance Project Plan (QAPP). We first note that the impairment is dissolved zinc. RIDEM anticipates submitting a delisting of dissolved zinc from Buckeye Brook in the 2022 303(d) List submission, which is a part of the Integrated Report format.

10. Additional documentation should be added to the TMDL report describing the critical flow analysis performed by RIDEM.
    RIDEM did not complete a critical flow analysis for this TMDL, due to the lack of flow records for Tributaries to Warwick Pond and Buckeye Brook. In order to evaluate flow conditions watershed-wide, RIDEM reviewed the following USGS gages with daily discharge records for the time period of sampling: Hunt River, East Greenwich (01117000), South Branch Pawtuxet River at Washington (01116000), and Pawtuxet River (01116500). Those gages were compared to the 7Q10 value used by the RIPDES program in 1993 and 2018. All gages were above 7Q10 for dry weather samples as defined in the TMDL.

Friends of Warwick Ponds (FOWPS) Public Comments On This TMDL.

TOTAL MAXIMUM DAILY LOAD ANALYSIS FOR BUCKEYE BROOK AND TRIBUTARIES TO WARWICK POND DRAFT REPORT JUNE 2021
303(d) listings addressed in this study: Buckeye Brook and Unnamed Tributaries (RI0007024R-01): Benthic- Macroinvertebrate Bioassessments, Dissolved Oxygen, Total Iron, Dissolved Cadmium, Copper, Lead, and Zinc Tributaries to Warwick Pond (RI0007024R-05): Benthic- Macroinvertebrate Bioassessments, Total Iron, Dissolved Cadmium
It is obvious that the poor water quality issues emanate largely from Storm Water Runoff. We believe there are 4 major issues that need to be addressed from this TMDL

.

1. The volume and number of outfalls into Buckeye Brook and Tributaries to Warwick Pond must be substantially reduced. Obviously it would be cost prohibitive to relocate outfalls so there must be an alternative. Each outfall must be sampled for runoff volume and quality. From that data a plan must be designed and implemented to reduce either the runoff or improve the quality.

   Pursuant to a federal court ruling in Virginia Department of Transportation v. EPA (2013), stormwater runoff or flow is not a “pollutant”. Following earlier guidance, EPA had established a TMDL for stormwater flow into Accotink Creek on the basis that flow is a surrogate for sediment. Since stormwater is not a pollutant under the statutory definition of “pollutant” the Court held that EPA lacked authority to regulate stormwater via a TMDL. Therefore, EPA has since revised its guidance in 2014 to remove references to the regulation of stormwater flow as a pollutant or pollutant surrogate.

   However, discharges of non-stormwater flows from the City of Warwick and Rhode Island Department of Transportation (RIDOT) are regulated under the Rhode Island Pollutant Discharge Elimination System (RIPDES) Phase II Stormwater Management Program. Under this program, operators develop Stormwater Management Program Plans (SWMPPs) that detail how their stormwater management programs comply with Phase II regulations and describe best management practices (BMPs) for the six minimum measures: http://www.dem.ri.gov/programs/water/permits/ripdes/stormwater/six-minimum-control-measures.php, which includes an illicit discharge detection and elimination program along with other measures that will reduce non-allowable non-stormwater discharges in stormwater runoff and improve water quality. Additionally, SWMPPs must be updated to comply with Phase II TMDL requirements if they contribute stormwater to priority outfalls via system interconnections, even if they do not own the outfall. Lastly, a TMDL Implementation Plan requires several items that will reduce pollutants in runoff and improve water quality, including documentation of discharges identified by the TMDL with location, size, discharge data, etc.

A. As a possible alternative where reduction is not possible or practical the use of filtration should be implemented. FOWPS is working with a Filtration Company on a plan to submit a proposal to filter major Catch Basins discharging into Buckeye Brook and Warwick Pond.

As indicated above, stormwater flow in itself is not a pollutant and DEM is not authorized to regulate it via TMDL. However, in instances where stormwater contains pollutants, one valid option to address the discharge of these pollutants is through the filtration of this stormwater, effectively eliminating the discharge of that pollutant.

B. There must be regulations for roof drains both residential and commercial. We estimate there are millions of gallons of roof runoff being discharged into our environment. The commercial roof drains are underground and there is no way to know what the quantity of runoff is, or the quality of runoff is or where it will end up. The home drains go from the roof under the lawn and discharge into the street.

As indicated above, stormwater flow is not a pollutant and the discharge of stormwater, either via roof drains or other conveyances, is an allowable discharge under the MS4 permit. Any efforts to prohibit these types of stormwater discharges to the MS4 system would require local ordinance/rule changes and are not required under the RIPDES permit.

2. The former Truk-Away Landfill closed more than 40 years ago is still leaching hazardous waste into the wetlands. There have been many studies of this site with 3 or 4 recommendations. In around 2009 or 2010 one of the recommendations was to cover the landfill with 2 feet of clean fill. This was executed around that time and did not work. Now in 2020 we have another study by GZA that one of the recommendations is to cover the landfill with 2 feet of clean fill.

Someone, please remind me what the definition of INSANITY is. Oh, I remember.

DOING THE SAME THING AND EXPECTING A DIFFERENT RESULT.

The residents that live in and abut the wetlands, as well as the people who work in these wetlands, as well as the children who play in these wetlands want these hazardous materials physically removed. That is the only way to ensure there is no potential Health and Safety risks to them.

The Site Remediation Regulations (250-RICR-140-30-1) require all sites are remediated in a way that ensures compliance with all applicable regulations including RI Water Quality Standards (see 250-RICR-140-30-1 § 1.10(1.10.2)(A)(2)). A new site investigation, including new data has been conducted by the firm GZA, and a report submitted in June 2020 with recommendations for the landfill. RIDEM's Office of Customer and Technical Assistance (OCTA) issued a comment letter leading to a supplemental site investigation documented in a March 2021 Supplemental Site Investigation Report. RIDEM/OCTA most recently issued a comment letter on the March 2021 report.

All recent reports and RIDEM comment letters can be found here: http://www.dem.ri.gov/programs/customertech/truk-away-landfill-closure.php Closure of the landfill in accordance with all applicable regulations is on-going.

3. This issue of Aircraft De-icing does not pose a problem to us. We have no problem with this policy in place and executed to protect the safety of Aircraft Passengers. We also believe that the addition of the De-icing recovery facility has had a positive impact on the amount of De-icing fluid being discharged into the wetlands.

   We do have a problem with the numbers of De-icing Fluid that is being reported in the RIAC De-icing Management Plan (DMPP). This report has major issues in the accuracy of how the data is collected and reported. The report is riddled with words like, Estimated, Best Estimate, Assumed, Approximately, Reconciliation, Data Gaps, and Calculated. Let's all remember this is a report to collect data for a Chemical being discharged into our environment. This report should not be skewed to benefit the entity that is reporting it.
   We will address this issue in detail when the next RIPDES Permit is reissued to RIAC for public comment.

   This comment is noted and no changes to the TMDL were made in response to the comment.

4. Last but not least are the recommendations to the City of Warwick and RIDOT. We cannot speak to the past performance for RIDOT, but we can speak to the City of Warwick's past performance.

   History has shown us that the City of Warwick has not taken the environmental issues that they are responsible for seriously. We can site chapter and verse if required. For example Public Outreach (non-existent), MS4 Report (3 years overdue), executing the O&M Plan at Winslow Park (never documented), delinquent on actions from the 2016 Consent Decree between RIDEM and the City of Warwick, need we go on?
   How will you ensure that the City takes this document seriously and implements the recommendations?

   DEM will continue to use formal and informal enforcement options, as appropriate, to enforce the City's requirements under both the MS4 General Permit and its consent agreement with DEM.

Mission: We will partner with our community to restore and preserve the health of Warwick's water resources to ensure their safe enjoyment by future generations.

Respectfully
Philip D'Ercole Sr.
Facilitator