# NONQUIT POND TRIBUTARIES

# WATER QUALITY STUDY AND POLLUTANT SOURCE IDENTIFICATION

# NATIONAL WATER QUALITY INITIATIVE


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# 1. PROBLEM DEFINITON/BACKGROUND

This report documents the results of water quality monitoring of tributaries of Nonquit Pond, conducted by the RI Department of Environmental Management's Office of Water Resources, in support of the National Water Quality Initiative, described in greater detail below. These tributaries include: Quaker Creek (RI0010031R-04), Borden Brook and an unnamed tributary to Borden Brook (RI0010031R-01), and an unnamed tributary to Nonquit Pond (RI0010031R-20).

The tributaries to Nonquit Pond are located in southwestern Tiverton, Rhode Island. The tributaries discharge into Nonquit Pond near the Four Corners area of Tiverton (near the intersection of Main and East Roads). The streams are tributaries to the Newport Water system, and are Class AA freshwater streams. With the exception of those properties serviced by private wells, the Newport Water system provides public water to all of Aquidneck Island. Newport Water maintains a distribution system which services retail customers in Newport, Middletown and a small section of Portsmouth. In addition, Newport Water provides water wholesale to the Portsmouth Water & Fire District and Naval Station Newport.

All nine source reservoirs of the Newport Water System exhibit degraded water quality. A TMDL study for the Newport Water reservoirs is pending. Analysis of data, collected for the study, has determined that Nonquit Pond is impaired for total phosphorus and total carbon.

As part of the National Water Quality Initiative (NWQI), RIDEM has agreed to utilize Section 319 funding to conduct monitoring of instream water quality of tributaries to Nonquit Pond. This work supports the collaborative effort between the Natural Resources Conservation Service (NRCS), US Environmental Protection Agency (EPA) and the RI Department of Environmental Management to work in partnership to restore water quality in watersheds affected by agricultural pollution sources. The goal of this sampling program is to further characterize the water quality of the Quaker Creek, Borden Brook and unnamed tributaries to Borden Brook and Nonquit Pond, and to determine whether water quality, related to nutrients, sediments, or livestock-related pathogens, has improved because of recently installed agricultural best management practices (BMPs) installed with National Water Quality Initiative funding. However, since neither the actual BMP location nor date of installation of any NWQI projects are known, these sampling results may be representative of existing conditions prior to the implementation of BMPs planned for the future. In addition to the sampling results, this report documents field observations of potential pollution sources.

Larger watersheds, which are either not meeting state water quality criteria or are contributing to an impairment in waterbodies downstream, were selected to participate in the NWQI. The Sakonnet River Watershed (HUC 010900040910) is one of three watersheds selected in RI for NWQI funding. Beginning in 2016, RIDEM focused its NWQI monitoring efforts in the Nonquit Pond watershed (a subwatershed of the Sakonnet River watershed), because of significant agricultural land use within its watershed, and because Nonquit Pond (a reservoir in the Newport Water supply system) exhibits degraded quality for which a TMDL is in development, as described above.

**Quaker Creek (RI0010031R-04)**

Quaker Creek (RI0007035R03-02A) arises from a large linear wetland, east of Pardon Gray Preserve. The wetland is bounded to the east by upland forest and the Tiverton landfill and to the west by Pardon Gray Preserve and Town recreational fields. A swale discharging landfill leachate and stormwater runoff from a portion of the landfill property discharges to the wetland downstream of the landfill access road. There appears to be no channel in the upper portion of the wetland corridor. Downstream of the landfill, the wetland corridor is bounded by upland forest. The stream then flows through a livestock area, including two horse farms and a cow farm. There are two run-of-the-river farm ponds along this reach of the stream, where livestock have access to the river. Downstream of the livestock area the stream flows through another extensive wetland corridor, bounded to the west by residential and commercial properties on Main Road. Quaker Creek is then culverted under East Road, where it merges with Borden Brook.

**Borden Brook (RI0010031R-01)**

Borden Brook originates at Basket Swamp, located to the south of Bulgarmarsh Road. The stream passes through Weetamoo Woods. The stream flows past a couple of residential lots and a hay field prior to crossing East Road. An unnamed tributary discharges to Borden Brook, immediately downstream of its crossing East Road. Downstream of its confluence with the unnamed tributary, Borden Brook parallels East Road. Downstream of its confluence with Quaker Creek, the stream jogs to the south where it flows past a hayfield and through a small pasture. The stream then flows through a wetland corridor, to a commercial area on Main Road. An unnamed tributary, discussed in the section below, discharges into Borden Brook just upstream of Main Road.

**Unnamed Tributary to Borden Brook (RI0010031R-01)**

An unnamed tributary to Borden Brook is composed of two forks. The northeastern fork originates from Eight Rod Pond and an extensive wetland complex. The northeastern fork flows northerly from Eight Rod Pond through a wetland corridor. West of Eight Rod Way, the stream flows through an upland forest and a couple of residential properties before merging with the southwestern fork of the tributary.

The southwestern fork of the unnamed tributary to Borden Brook originates from wetlands located on a dairy farm. The southwestern fork flows northerly, where it parallels Main Road. The stream then flows past residential areas, as well as a hay field and small pasture, before it merges with the northeast fork of the unnamed tributary. Downstream of the confluence, the tributary flows past a hay field and residence and discharges into Borden Brook, immediately upstream (east) of Main Road.

**Unnamed Tributary to Nonquit Pond (RI0010031R-20)**

An unnamed tributary to Nonquit Pond is composed of two forks. The northeastern fork originates from a wetland area, located within a cow pasture. The stream flows past a couple of residences before crossing Main Road, where it skirts the northern edge of a crop field. The northeastern fork then flows along the rear edge of several residential lawns, prior to its confluence with the southwestern fork of the unnamed tributary.

The southwestern fork of the unnamed tributary to Nonquit Pond originates from a large linear wetland. Upland forest as well as hay fields border the wetland corridor. As it exits the wetland, the southwestern fork flows along the rear of a lawn associated with a large-lot residential property. Downstream of Main Road, the southwest fork bisects a crop field, prior to its confluence with the northeast fork of the tributary, just upstream of the cul-de-sac of Peaceful Way.

## 2. SAMPLING DESIGN

RIDEM conducted instream sampling at numerous locations along the tributaries to Nonquit Pond. All samples were analyzed for turbidity, total suspended solids (TSS), total and dissolved phosphorus, ammonia, Total Kjeldahl Nitrogen (TKN), nitrate, dissolved organic carbon (DOC), and enterococci. Temperature, dissolved oxygen (DO), specific conductance, and pH were also measured in the field at all sampling stations, using a YSI Pro Plus multiparameter meter. Because of the presence of a landfill in the Quaker Creek watershed, an effort was made to document any potential adverse effects on the water quality of Quaker Creek, from the discharge of landfill leachate and stormwater. Samples from Quaker Creek were analyzed for potential pollutants from the landfill, including dissolved metals (e.g. cadmium, chromium, copper, lead, and selenium), total iron, and hardness (dissolved metals criteria are hardness-dependent).

Three instream sampling surveys were conducted during dry wet weather, with an additional three surveys taking place during wet weather (Table 1). Dry weather was defined as less than 0.25 in. of rainfall during the 48-hour period preceding a sampling event. Wet weather was defined as greater than 0.25 in. of rainfall during the 48-hour period preceding a sampling event.

**Table 1. Dates of Dry and Wet-Weather Sampling Events.**

| Dry-Weather Sampling Events | Wet-Weather Sampling Events |
|---|---|
| 3/22/17 | 11/30/16 |
| 5/4/17 | 4/26/17 |
| 6/1/17 | 10/25/17 |

Wet-weather sampling, for the first two wet-weather events, was conducted after the cessation of rainfall. Although it is preferable to conduct wet-weather sampling during a rainfall and to ideally capture the "first flush" of pollutants, stormwater runoff was still visibly flowing and slightly turbid in several locations, indicating that the tributaries were still affected by wet-weather conditions. Wet-weather sampling was conducted on November 30, 2016, after 1.69 in. of precipitation on November 29, 2016 and after 0.10 in. of rain on the day of sampling. Wet-weather sampling was conducted on April 26, 2017, after 1.13 in. of precipitation on the preceding day, and after 0.86 in. of rain in the early morning hours of the day of sampling. Wet-weather sampling was conducted on October 25, 2017, during 1.13 in. of rain.

As previously discussed, stations were generally selected to help identify and bracket agriculturally-related source areas of sediment, nutrients and bacteria and to assess water quality - both post implementation of any existing BMPs, and prior to implementation of BMPs planned for the future. The landfill was also bracketed, because of its potential significance as a source of pollutants.

Figure 1 shows the sampling locations for the study, and Table 2 provides a detailed description of sample station locations, and the purpose of selecting these locations. Samples were collected at four stations along the main stem of Quaker Creek (Stations Q1 through Q4). Samples were also collected near the terminus of a swale discharging landfill leachate and stormwater runoff from a portion of the landfill to Quaker Creek (Station LDF). The landfill swale discharges to Quaker Creek immediately downstream of Station Q1. Borden Brook was sampled at three locations (B1 through B3). An unnamed tributary to Borden Brook was sampled at Station Bt, near its confluence with Borden Brook. An unnamed tributary to Nonquit Pond was sampled at two locations (N1 and N2). The landfill swale (Station LDF) and the unnamed tributary to Borden Brook (Station Bt) were sampled later in the study, during two dry-weather and two wet-weather events, rather than the three dry and wet-weather events that the others were sampled.

**Figure 1. Nonquit Pond Tributary Sampling Station Locations.**

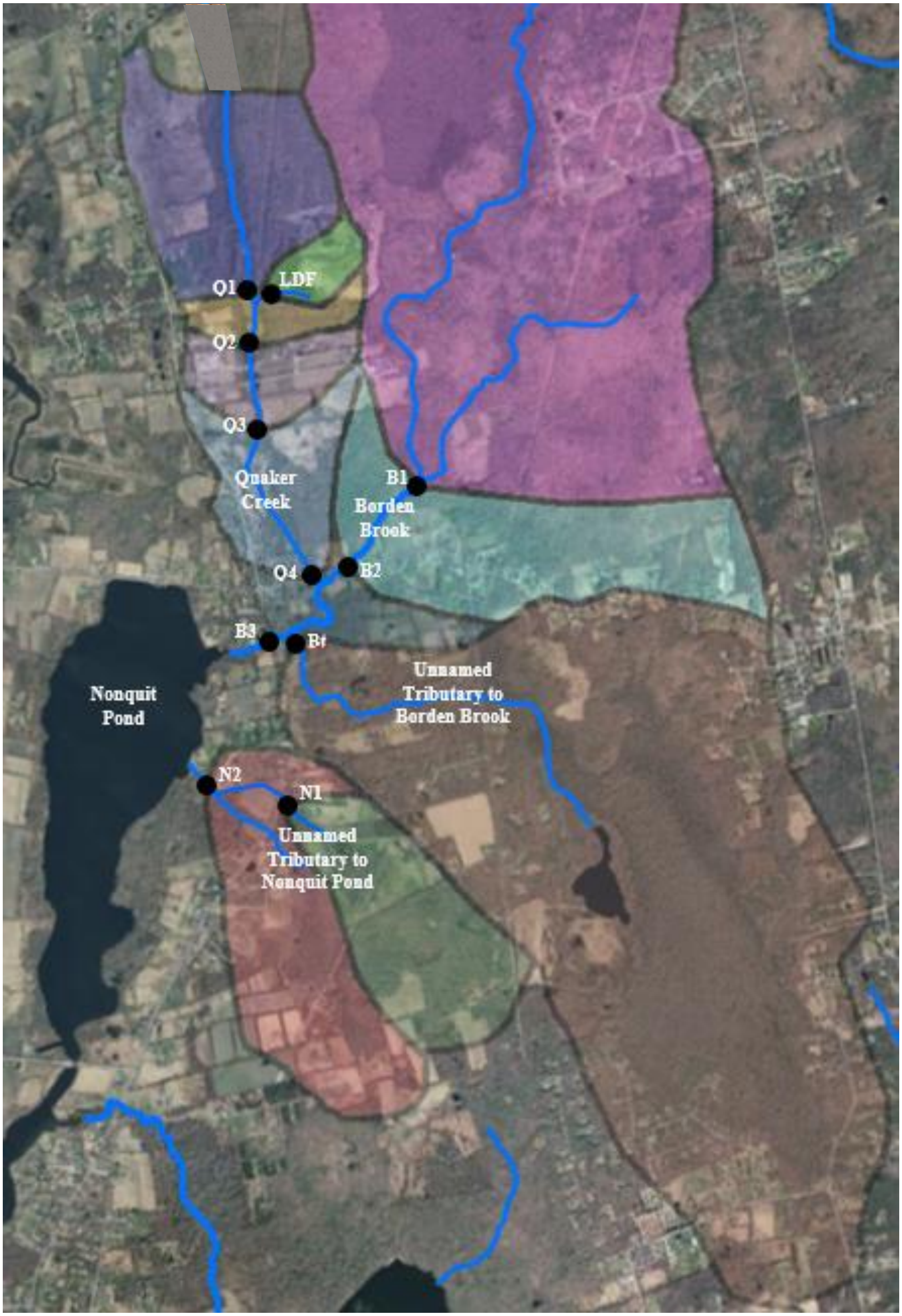


**Table 2. Sampling Station Locations.**

| Station ID | Waterbody | Location | Purpose |
|---|---|---|---|
| **Q1** | Quaker Creek | Immediately downstream of the landfill access road. Closest of two culverts to the landfill. | Most upstream location on Quaker Creek where there was consistent flow in dry weather |
| **LDF** | Landfill Swale | Adjacent to the landfill access road approximately 250 ft. upstream of Quaker Creek. | Assesses both dry-weather and stormwater discharge from Tiverton landfill. |
| **Q2** | Quaker Creek | Downstream boundary of landfill property and northern boundary of livestock area. | Assesses landfill impact on stream water quality and is background for livestock area. |
| **Q3** | Quaker Creek | Downstream of livestock area. | Assesses impact of livestock area. |
| **Q4** | Quaker Creek | Immediately upstream of East Road. | Assesses impact of Quaker Creek on the water quality of Borden Brook. |
| **Bt** | Unnamed Tributary to Borden Brook | At rear of commercial area on Main Road, approximately 100 ft. upstream of its confluence with Borden Brook. | Assesses tributary watershed and impact of tributary on water quality of Borden Brook. |
| **B1** | Borden Brook | Weetamoo Woods immediately downstream of tributary originating on east side of livestock area with 100 ft. of buffer. | Background station for Borden Brook. Located in a relatively undeveloped watershed. |
| **B2** | Borden Brook | South side of East Road immediately downstream of confluence with unnamed tributary. | Assesses the impact of an unnamed tributary on Borden Brook and characterizes water quality in Borden Brook upstream of Quaker Creek. |
| **B3** | Borden Brook | At mill dam/footbridge approximately 60 ft. upstream of Main Road. | Assesses impact of Quaker Creek, pasture, and unnamed tributary on main stem of Borden Brook. Also assesses water quality of Borden Brook approximately 700 ft. upstream of Nonquit Pond. |
| **N1** | Unnamed Tributary to Nonquit Pond | Barnswallow Street | Assesses impact of cow pasture. |
| **N2** | Unnamed Tributary to Nonquit Pond | Cul-de-sac of Peaceful Way | Assesses impact of crop field and residential areas. Also assesses water quality of unnamed tributary approximately 350 ft. upstream of Nonquit Pond. |

## 3. DISCUSSION OF SAMPLING PARAMETERS

Below is a brief discussion of conventional sampling parameters and pollutants

**Dissolved Oxygen**

Dissolved oxygen (DO) is essential to aquatic life. As dissolved oxygen levels in water drop below 5.0 mg/l, aquatic life is put under stress. Oxygen levels that remain below 1-2 mg/l for a few hours can result in large fish kills. Low dissolved oxygen can also cause the release of phosphorus from stream and wetland sediments (phosphorus is a critical nutrient involved in eutrophication as discussed in greater detail below). In fact, DO can affect the solubility and availability of many nutrients and pollutants. The solubility of oxygen decreases with increasing water temperature. Stagnant conditions also generally result in lower levels of DO, as bacteria consume oxygen as organic matter decays. Excessive amounts of iron in the water column can also result in low DO, as oxygen binds with iron, taking the oxygen out of solution.

**Specific Conductance**

Specific conductivity is a measure of how well the water can conduct electricity, which is an indirect measure of the amount of ions in solution. Such ions may include sodium, chloride, nitrate, phosphate, calcium, magnesium, and iron. Specific conductance is measured in the field with a hand-held meter, and may give a quick indication of excessive nutrients or metals, dissolved in the water column. Specific conductance is affected by local geology. In addition, runoff and groundwater transport from agricultural and residential areas, roadway runoff, and landfill stormwater runoff and leachate all have the potential to affect specific conductance.

**pH**

pH is a logarithmic scale used to specify the acidity or basicity of an aqueous solution. Solutions with a pH less than seven are acidic and solutions with a pH greater than seven are basic.

Natural factors such as geology affect pH (carbonate rocks can buffer pH changes). Acid precipitation, plant respiration, and the decomposition of organic matter work to lower pH. Photosynthesis by aquatic plants and algae increases pH. Agricultural runoff, wastewater discharge, and landfill leachate can also affect pH. pH affects the solubility and bioavailability of heavy metals and of nutrients such as phosphorus.

**Turbidity**

Turbidity is measured using specialized optical equipment in a laboratory. A light is directed through a water sample, and the amount of light scattered is measured. The amount of scattered light is proportional to the quantity of suspended or dissolved particles present in the sample.

Particulate matter can include sediment (especially clay and silt), fine organic and inorganic matter, soluble colored organic compounds (e.g. tannins), algae, and other microscopic organisms. Sources of turbidity can include erosion from upland areas, and stream bank and stream bed erosion. Tannic acids, often associated with wetland areas, can cause water to be colored resulting in turbidity.

**Total Suspended Solids (TSS)**

Total Suspended Solids (TSS) are solids in water that can be trapped by a filter. TSS can include a wide variety of material, such as silt, decaying plant and animal matter, and sewage. High concentrations of suspended solids can cause many problems for stream health and aquatic life. High TSS in a water body can often mean higher concentrations of bacteria, nutrients, pesticides, and metals in the water. These pollutants may attach to sediment particles on the land and be carried into water bodies with stormwater. In the water, the pollutants may be released from the sediment or travel farther downstream.

High TSS, especially in terminal reservoirs, can block light from reaching submerged vegetation. As the amount of light passing through the water is reduced, photosynthesis slows down. Reduced rates of photosynthesis causes less dissolved oxygen to be released into the water by plants. If light is completely blocked from bottom dwelling plants, the plants will stop producing oxygen and will die. As the plants are decomposed, bacteria will use up even more oxygen from the water. Low dissolved oxygen can lead to fish kills. High TSS can also cause an increase in surface water temperature, because the suspended particles absorb heat from sunlight. This can cause dissolved oxygen levels to fall even further (because warmer waters can hold less DO).

The decrease in water clarity caused by TSS can affect the ability of fish to see and catch food. Suspended sediment can also 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.

The flow rate of the water body is a primary factor in TSS concentrations. Fast running water can carry more particles and larger-sized sediment. Heavy rains can pick up sand, silt, clay, and organic particles (such as leaves and soil) from the land and carry it to surface water. A change in flow rate can also affect TSS; if the speed or direction of the water current increases, particulate matter from bottom sediments may be resuspended.

Most people consider water with a TSS concentration less than 20,000 ug/l to be clear. Water with TSS levels between 40,000 and 80,000 ug/l tends to appear cloudy, while water with concentrations over 150,000 ug/l usually appears dirty.

**Phosphorus**

Total phosphorus is typically the limiting nutrient controlling aquatic plant and algal growth in the freshwater environment. Above a certain threshold level, even small increases in phosphorus can cause eutrophication (excessive aquatic plant and algal growth in addition to low dissolved oxygen conditions) in waterbodies, especially lakes and ponds.

Phosphorus typically is adsorbed onto soil particles and does not easily dissolve in groundwater. Therefore, phosphorus generally enters streams with stormwater runoff. However, some phosphorus can dissolve in groundwater and may enter streams as baseflow. Common sources of phosphorus include eroded sediment from upland areas, streambank erosion, fertilizer, livestock waste, pet waste, human waste, and the atmosphere.

**Ammonia**

Ammonia ($NH_3$) is toxic to fish and other aquatic organisms. Ammonium ($NH_4$), is the predominant form in the pH range of most natural waters, is less toxic to fish and aquatic life as compared to $NH_3$. As the pH increases above 8, the ammonia fraction begins to increase rapidly. In the rare situation that a natural water pH exceeds 9, ammonia and ammonium would be nearly equal. Samples were analyzed for a combination of ammonia and ammonium. The results will be reported as ammonia in this report.

Common sources of ammonia/ammonium include human and animal wastes (including septic systems, leaky sanitary sewers, pet and wildlife waste, livestock, and manure applied to agricultural fields), decaying plant material, decay of soil organic matter (especially in anoxic soils), as well as certain fertilizers. Ammonia and ammonium most commonly enter surface waters through overland runoff or direct discharges from wastewater sources. Ammonia levels in streams are usually only elevated near sources of human or animal waste discharges. Ammonium is also the byproduct when organic matter in soils is mineralized to inorganic-nitrogen. Once in the soil, ammonium binds onto soil particles such as clay and organic matter. For that reason, ammonium is less likely to move vertically through the soil matrix into groundwater, as compared to nitrate. Under the right soil temperature and moisture conditions, ammonium will readily transform into the more mobile form of nitrate.

**Total Kjeldahl Nitrogen (TKN)**

The Total Kjeldahl nitrogen (TKN) laboratory analysis includes nitrogen from Organic-Nitrogen and ammonia+ammonium. Typically, the Organic-Nitrogen fraction of TKN in surface waters is much higher than the ammonia+ammonium fraction. As will be demonstrated in the following pages, the ammonia/ammonium fraction is very low (typically below the detection limit), indicating that TKN values are largely representative of the Organic-Nitrogen fraction.

Organic-Nitrogen includes all substances in which nitrogen is bonded to carbon. It occurs in both soluble and particulate forms. Organic-Nitrogen is found in proteins, amino acids, urea, living or dead organisms (e.g. algae and bacteria), and decaying plant material. Because nitrate is very low in forested and grassland areas, Organic-Nitrogen is typically higher than nitrate in landscapes dominated by these more natural conditions. Soluble Organic-Nitrogen is from wastes excreted by organisms, including livestock manure and human wastes, or from the degradation of particulate nitrogen from plants and plant residues. Some Organic-Nitrogen is attached to soil particles and is associated with sediment losses to water. In nature, Organic-Nitrogen can be biologically transformed to the ammonium form and then to the nitrite and nitrate form. Once in the nitrate or ammonium forms, these nutrients can be used by algae and aquatic organisms and thereby convert back to organic forms of nitrogen. Organic-Nitrogen sometimes makes up a significant fraction of soluble and particulate nitrogen in natural waters.

**Nitrate**

Samples were analyzed for a combination of nitrite plus nitrate. Nitrite ($NO_2$) is typically a short-lived intermediate product when ammonium is transformed into nitrate by microscopic organisms, and is therefore seldom elevated in waters for long periods of time. Nitrite is also an intermediary product as nitrate transforms to nitrogen gas through denitrification. Because nitrate is usually so much higher than nitrite, the combined laboratory concentration of nitrite plus nitrate will be reported as nitrate in this report.

Nitrate (NO3) is very soluble in water and is negatively charged, and therefore moves readily with soil water through the soil profile, where it can reach groundwater. Where groundwater remains oxygenated, nitrate remains stable and can travel in the groundwater until it reaches surface waters. When nitrate encounters low oxygen/anoxic conditions in soils or groundwater it may be transformed to N gasses through a biochemical process called “denitrification.” Therefore, groundwater nitrate is sometimes lost to gaseous N before the nitrate impacted groundwater has enough time to travel to and discharge into streams. Typically, a smaller fraction of nitrate reaches streams in stormwater runoff over the land surface, as compared to subsurface pathways.

Common sources of nitrate include: on-site septic systems, fertilizer, decaying plant material, and precipitation. Much of this nitrate does not initially enter the soils in this form, but results from the biological breakdown of ammonium and organic sources of N which originate as manure, fertilizer and soil organic matter. In the presence of oxygen, moisture, and warm temperatures, other forms of nitrogen will tend to transform into nitrate. Nitrate is the dominant form of nitrogen in groundwater, and is also dominant in rivers and streams with elevated total nitrogen. Where streams originate in areas of agricultural production, the nitrate form of nitrogen is usually substantially higher than Organic-Nitrogen. Concerns about nitrate in our water include: human health effects when found elevated in drinking water supplies, and increased eutrophication and correspondingly low oxygen in downstream waters.

**Dissolved Organic Carbon**

Dissolved organic carbon (DOC) is composed of a diverse array of organic compounds, predominantly humic substances, and is a near ubiquitous component of natural groundwater and surface waters. In general, organic carbon compounds are a result of decomposition processes from dead organic matter such as plants and animals. When water originates from land areas with a high proportion of organic soils and decaying plant material, these components can drain into rivers and lakes as dissolved organic carbon.

DOC can interfere with the effectiveness of drinking water disinfection processes such as chlorination, ultraviolet and ozone sterilization. DOC can also promote the growth of microorganisms by providing a food source. In plants that disinfect with chlorine, DOC concentrations are a primary concern due to the harmful by-products that form when chlorine reacts with organic matter. DOC is also a natural food source for bacteria and elevated DOC levels in surface waters can cause elevated bacteria concentrations.

**Enterococci Bacteria**

Enterococci are an indicator organism, used to predict the presence of pathogens in natural waters. Sources of enterococci are the same as fecal coliform bacteria. According to studies conducted by the EPA, enterococci have a greater correlation with swimming-associated gastrointestinal illness in both marine and fresh waters than other bacterial indicator organisms, and are less likely to "die off", especially in saltwater. As a consequence, enterococci are used to determine risk associated with primary and secondary contact recreation activities in the State’s fresh and salt waters.

**Hardness**

Hardness is a measure of the concentration of cations (largely calcium and magnesium) in solution, with hardness usually measured as calcium carbonate ($CaCO_3$) equivalents. Hardness is largely affected by local geology. The dissolution of rocks increases hardness. Since many of RIDEM metals criteria are hardness-dependent, water samples from stations potentially impacted by the landfill, were analyzed for hardness (discussed in more detail below). 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 to organisms.

**Total Iron**

Iron is a ubiquitous substance, found in rocks and soils. Water percolating through soil and rock can dissolve minerals containing iron and hold it in solution. Anaerobic or acidic conditions can result in enhanced dissolution of iron from rock and soil. High concentrations of iron can be harmful to aquatic life. Iron compounds can also provide energy for bacterial metabolism. Excessive levels of iron can cause a red bacterial slime that can cover streambeds and smother aquatic benthic life.

**Dissolved Metals**

Water samples, from sampling locations potentially impacted by the Tiverton Landfill, were analyzed for dissolved metals. These sampling locations included the landfill swale sampling station (LND), as well as all samples from Quaker Creek (Stations Q1 through Q4), and samples from the terminal sampling station of Borden Brook (Station B3). Samples were analyzed for the following dissolved metals: cadmium, chromium, copper, lead, and selenium.

Heavy metals are known for their toxicity and persistence in the environment. Metals adsorbed in soils or stream sediments may persist for decades. Metals have the tendency to bio-accumulate in living tissues, such as fish, to concentrations that can compromise the normal physiological processes of these organisms, and this provides an introductory pathway into the human food chain. Sources of heavy metals include: industrial activities, paints; wastewater, roadway runoff from automobiles, atmospheric deposition largely from coal combustion, and landfill leachate.

RIDEM's water quality standards for metals 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. In addition, 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)". Criteria for most metals are hardness-dependent, as previously discussed. A summary description of sampling parameters and pollutants is shown in Table 3.

**Table 3. Summary of Sampling Parameters**

| Parameter | General Description | Sources to Surface Waters | Health and Environmental Concerns | Criteria/Guidelines |
|---|---|---|---|---|
| **DO** | Measured in the field by YSI meter. | Atmospheric DO. Decreased by decay of organic matter and high levels of iron. | Aquatic life stressed at 5 mg/l DO. Fish kills at 1-2 mg/l DO. | **RIDEM Criteria:** Instantaneous minimum concentration ≥ 5 mg/l |
| **Specific Conductance** | An indirect measure of the amount of ions in solution. Measured in the field by YSI meter. | Local geology, agricultural and residential runoff and groundwater transport, roadway runoff, and landfill leachate. | Affects osmoregulation of aquatic life. High levels may be indicative of excessive nutrients or metals in solution. | **NHDES Guidance:** 835 µs/cm |
| **pH** | Logarithmic scale used to specify the acidity or basicity of a solution. Measured in the field by YSI meter. | pH affected by geology, photosynthesis and respiration of aquatic plants and algae, decomposition of organic matter, acid rain, agricultural runoff, wastewater discharge, and landfill leachate. | Affects the solubility and bioavailability of heavy metals and of nutrients such as phosphorus | **RIDEM Criteria:** 6.5-9.0 or as naturally occurs. |

| Parameter | General Description | Sources to Surface Waters | Health and Environmental Concerns | Criteria/Guidelines |
|---|---|---|---|---|
| **Turbidity** | Measured indirectly in lab by quantifying amount of scattered light. | Sediment, fine organic and inorganic matter, soluble colored organic compounds (e.g. tannins), algae, and other microscopic organisms. | | **RIDEM Criteria:**<br>Turbidity not to exceed 5 NTU over background.<br>Mean wet-weather turbidity at Station B1 (1.9 NTU) considered background for this study. |
| **Total Suspended Solids** | Water sample is filtered and dry solids weighed. High TSS can often result in high nutrients, bacteria, pesticides, and metals (these pollutants often adsorbed onto soil particles). | Eroded sediment from upland areas, and streambed and streambank erosion. | May be associated with elevated bacteria, pesticides, metals, and organic carbon which may result in disinfection byproducts | **No EPA or RIDEM criteria**<br>EPA guidance 25,000 ug/l for protection of juvenile fish, larvae, and eggs. |
| **Phosphorus** | Does not easily dissolve in groundwater and generally enters streams with stormwater runoff. | Eroded sediment from upland areas, streambank erosion, fertilizer, livestock waste, pet waste, human waste, atmosphere. | Causes eutrophication and hypoxia (low dissolved oxygen) in lakes and reservoirs. | **RIDEM Criteria:** Average Total Phosphorus shall not exceed 0.025 mg/l (25 ug/l) in any lake, pond, kettle hole or reservoir, and average Total P in tributaries at the point where they enter such bodies of water shall not cause exceedance of this phosphorus criteria.<br>**EPA Gold Book Standard:**<br>50 ug/l in any stream at the point where it enters any lake or reservoir; and 100 ug/l in streams not discharging directly to lakes or impoundments. |
| **Ammonia** | Measured in lab together with ammonium. Low levels in most waters. | Septic systems, leaky sanitary sewers, pet and wildlife waste, livestock, manure applied to fields, decaying plant material, decay of soil organic matter, and certain fertilizers. Mostly enters surface waters via overland runoff. | Toxic to aquatic life | **RIDEM Criteria:**<br>Toxicity varies with pH. (more toxic at higher pH). At highest pH toxic to salmonids at 885 ug/l. |

| Parameter | General Description | Sources to Surface Waters | Health and Environmental Concerns | Criteria/Guidelines |
|---|---|---|---|---|
| **Total Kjeldahl Nitrogen (TKN)** | Lab measurement of ammonia/ammonium and Organic-Nitrogen. Organic-Nitrogen is the chief component. | Organic-Nitrogen derived from living or decaying plant material and organisms, soil, and human and animal waste | Can convert to other forms of nitrogen. | **No RIDEM Criteria**<br><br>**EPA Guidance for Northeastern Coastal Zone:**<br>300 ug/l |
| **Nitrate** | Measured in lab together with nitrite. Main form of nitrogen in groundwater and high-nitrogen surface waters. Most nitrogen species can convert to nitrate. | Fertilizer, soil nitrogen, human and animal waste, decaying plant material, , and the atmosphere. | Methemoglobinemia in infants and susceptible adults. Toxic to aquatic life. Eutrophication and hypoxia (low dissolved oxygen), especially in coastal waters. | **No RIDEM Criteria**<br><br>**EPA Guidance for Northeastern Coastal Zone:**<br>310 ug/l |
| **Total Nitrogen** | Sum of TKN, nitrate and nitrite. | See above | See nitrogen parameters above. | **No RIDEM Criteria**<br><br>**EPA Guidance for Northeastern Coastal Zone:**<br>610 ug/l |
| **Dissolved Organic Carbon (DOC)** | Composed of organic compounds, predominantly humic substances. | Decay of organic matter. | Interferes with effectiveness of drinking water disinfection processes. Can cause bacteria growth. Reacts with chlorine to form harmful by-products | No Known In-Stream Criteria or Guidance. |
| **Enterococci** | Quantified in lab as Most Probable Number (MPN) per 100 ml. | Same as above. | Same as above. | **RIDEM Criteria:**<br>Non-Designated Bathing Beach Waters Geometric Mean Density: 54 colonies/100 ml |
| **Hardness** | Amount of dissolved calcium and magnesium in water. | Dissolution of rocks and minerals. Typically high in landfill leachate. | None. However, hardness affects the toxicity of heavy metals (the toxicity of metals decreases with increasing hardness). | No criteria for hardness. However, most RIDEM metals criteria are hardness-dependent. |

| Parameter | General Description | Sources to Surface Waters | Health and Environmental Concerns | Criteria/Guidelines |
|---|---|---|---|---|
| **Total Iron** | Under aerobic conditions, iron complexes with phosphorus, making it unavailable for plant growth. | Rock, minerals, soil. Dissolution of iron-containing materials such as those found in landfills. | High concentrations of iron are harmful to aquatic life. May form a bacterial slime that smothers benthic aquatic life. | **RIDEM Criteria:**<br>1000 ug/l |
| **Dissolved Metals** | Cadmium<br>Chromium<br>Copper<br>Lead<br>Selenium | Industrial activities, paints; wastewater, roadway runoff from automobiles, atmospheric deposition largely from coal combustion, and landfill leachate. | Numerous health concerns. Bioaccumulates in fish and human tissue. Persistent in the environment. | **RIDEM Criteria (Chronic):**<br>Selenium: 5 ug/l<br>RIDEM Criteria for remaining metals are hardness-dependent. |

## 4. STATION BY STATION SAMPLING RESULTS AND POLLUTION SOURCES

Each stream, tributary and source will be discussed separately in the results and pollution section below, beginning with the Tiverton Landfill swale, which discharges to Quaker Creek, followed by Quaker Creek, an unnamed tributary to Borden Brook, Borden Brook, and finally an unnamed tributary to Nonquit Pond.

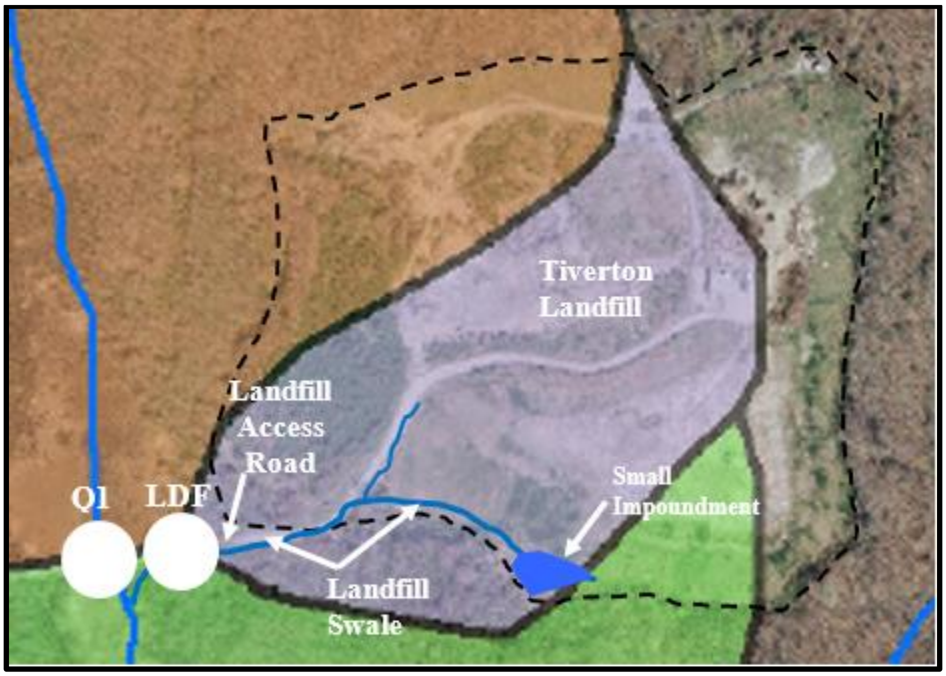
Water quality results are presented in Appendix A. Graphic representations of the water quality results are presented in Appendix B. The result maps in Appendix B depict pollutant concentrations superimposed on an aerial image of the watershed. Results in Appendix B are represented as circles, adjacent to the corresponding sampling stations. Circle sizes are proportional to pollutant concentrations, so that the reader can easily assess pollutant levels in different reaches of the streams. Both dry and wet weather results are depicted for each of the sampled pollutants and other assessed environmental parameters, such as dissolved oxygen. Any sources (e.g. the landfill swale) or tributaries (the unnamed tributary to Borden Brook), were lumped together with the corresponding stream in the result maps in Appendix B. The results section provides links to the appropriate result maps in Appendix B.

Following a discussion of pollutant levels in each watercourse, is a pollutant sources section which includes a discussion of land use, a summary of water quality results, followed by identification of pollutant sources. In the advent that there were multiple sampling stations in the watercourse, each subwatershed is discussed separately to identify pollutant sources local to the subject reach. The land use section presents an aerial image, identifying all land uses in the subwatershed. The land use discussion will focus on land use in close proximity to the stream. The results summary focuses on pollutant concentrations that exceed criteria or guidance levels at headwater stations, or flags significant (> 20%) increases in pollutant concentrations at downstream stations. Pollutant increases are flagged only when the pollutant concentration exceeds criteria or guidance levels. Potential pollutant sources, consistent with exceedances, are then identified. Both dry-weather sources (groundwater sources, direct discharges, and internal sources) and wet-weather sources (mainly stormwater sources) are identified. Potential sources are also identified based on field observations, even when there were no pollutant exceedances of significant increases in pollutants. Links to photographic documentation of land use and potential pollutant sources are provided in the pollution sources section. Photographs are shown in Appendix C. Photographs are grouped according to subwatershed. Each group of photographs are preceded by a key, showing photograph locations and the direction which the photograph was taken.

## 4.1. Landfill Swale, Station LDF

The landfill swale is a stormwater-leachate conveyance structure, and not a Water of the State. Therefore, any exceedances of criteria do not represent a violation of the State's water quality criteria, per se. However, comparing pollutant levels recorded in the swale, with established criteria or guidance, is useful in assessing the significance of the swale as a pollutant source, and whether there is potential for degradation of water quality downstream in Quaker Creek. The location of the landfill swale sampling station (Station LDF) is shown in Figure 2 below.

**Figure 2. Station LDF: Landfill Swale.**




### *4.1.1. Results*

**Dissolved Oxygen**

Mean DO concentrations in the landfill swale (LDF) met criteria, in both dry and wet weather (Figure B-1 and Figure B-2).

**Specific Conductance**

*Dry Weather*

The single dry-weather specific conductance measurement taken in the landfill swale exceeded guidance (835 µs/cm). The dry-weather specific conductance in the swale was 1,161 µs/cm (Figure B-3).

*Wet Weather* The mean wet-weather specific conductance concentration was similar to the dry-weather value, and exceeded guidance (Figure B-4). The mean wet-weather specific conductance concentration in the landfill swale (LDF) was 1,159 µs/cm.

**pH**

*Dry Weather*

Mean dry-weather pH in the landfill ditch exceeded criteria (6.5-9.0). The mean dry-weather pH in the swale was 9.2 (Figure B-5).

*Wet Weather*

The mean wet-weather pH level in the swale met criteria (Figure B-6).

**Turbidity**

*Dry Weather*

The mean dry-weather turbidity concentration in the landfill swale exceeded criteria (6.9 NTU) by almost an order of magnitude (Figure B-7). The mean dry-weather turbidity value in the swale was 63 NTU.

*Wet Weather*

The mean wet-weather turbidity value in the swale (170 NTU) was more than double the dry-weather value (Figure B-8).

**Total Suspended Solids (TSS)**

None of the samples exceeded EPA's suggested guidance of 25,000 ug/l, during either dry or wet weather. (Figure B-9 and Figure B-10)

**Phosphorus**

*Dry Weather*

There were no exceedances of the EPA Gold Book Standard guidance value (100 ug/l), during dry weather. Unlike the Quaker Creek stations, very little of the total phosphorus was in dissolved form (Figure B-11).

*Wet Weather*

The TP concentration exceeded EPA guidance, in the landfill during both wet-weather sampling events. The mean wet-weather TP concentration in the landfill swale was 135 ug/l (Figure B-12).

**Total Nitrogen**

*Dry Weather*

The sole dry-weather total nitrogen sample concentration in the landfill ditch (66,200 ug/l) was more than an order of magnitude higher than the mean dry-weather TN concentration of Quaker Creek (1,703 ug/l). EPA's suggested guidance for TN is 610 ug/l (Figure B-13).

*Wet Weather*

The mean wet-weather total nitrogen concentration in the landfill swale (24,740 ug/l), was significantly lower than that recorded during dry weather (Figure B-14). However, this value still exceeds EPA's suggested guidance by more than an order of magnitude.

**Ammonia**

*Dry Weather*

Unlike Quaker Creek, the vast majority of TN in the landfill was in the form of ammonia (Figure B-13). The single dry-weather ammonia sample from the swale exceeded the acute criteria. The ammonia concentration in the swale was 64,600 ug/l.

*Wet Weather*

The mean wet-weather ammonia concentration in the swale was 19,650 ug/l (Figure B-14). There was a single exceedance of the acute criteria and a single violation of the chronic criteria, during wet weather.

**Organic-N**

*Dry Weather*

The single dry-weather sample of organic-N concentration in the landfill swale was 600 ug/l, which was lower than the mean value for the combined stations of Quaker Creek. EPA's suggested guidance for streams is 300 ug/l (Figure B-13).

*Wet Weather*

The mean wet-weather organic-N concentration in the swale was 1,000 ug/l, which was again lower than the mean wet-weather value for the combined stations of Quaker Creek (Figure B-14).

**Nitrate**

*Dry Weather*

The mean dry-weather nitrate concentration in the landfill ditch was 1,700 ug/l, which was significantly higher than the mean value for the combined stations of Quaker Creek. EPA's suggested guidance for streams is 310 ug/l (Figure B-13).

*Wet Weather*

The mean wet-weather nitrate concentration in the landfill ditch was 4,090 ug/l, which was also significantly higher than the mean value for the combined stations of Quaker Creek (Figure B-14).

**Dissolved Organic Carbon**

*Dry Weather*

The mean dry-weather DOC concentration in the landfill ditch was 26,600 ug/l, which was significantly higher than the mean value for the combined stations of Quaker Creek (Figure B-15).

*Wet Weather*

The mean wet-weather DOC concentration in the landfill ditch was 15,600 ug/l, which was similar to the mean value for the combined stations of Quaker Creek (Figure B-16).

**Enterococci**

*Dry Weather*

The dry-weather enterococci geomean at the landfill swale was 220 MPN/100 ml. The criteria for a freshwater stream is 54 MPN/100 ml (Figure B-17).

*Wet Weather*

The wet-weather enterococci geomean was an order of magnitude higher than during dry weather. The wet-weather enterococci geomean at the landfill swale was 2,666 MPN/100 ml (Figure B-18).

**Total Iron**

*Dry Weather*

Iron levels exceeded the chronic criteria during both dry-weather sampling events (Figure B-19). The mean dry-weather iron concentration in the landfill swale was 6,365 ug/l, which was significantly higher than mean iron levels in Quaker Creek.

*Wet Weather*

Iron levels exceeded the chronic criteria for streams during both wet-weather sampling events (Figure B-20). The mean wet-weather iron concentration was in the landfill swale was 21,515 ug/l, which was significantly higher than mean iron levels in Quaker Creek.

**Dissolved Metals**

There were no violations of criteria for any of the remaining metals [including cadmium (Figure B-21 and (Figure B-22), chromium (Figure B-23 and Figure B-24), copper (Figure B-25 and Figure B-26), lead (Figure B-27 and Figure B-28) or selenium (Figure B-29 and Figure B-30)], during either dry or wet weather.

### ***4.1.2. Pollution Sources***

*Land Use*

Station LDF was located near the terminus of the swale, which captures groundwater seepage and stormwater, exclusively from the Tiverton landfill (Figure 2). An earthen impoundment along the southern boundary of the landfill, traps leachate and stormwater runoff from the landfill. The impounded water is directed to the swale, which merges with a secondary swale that flows along the eastern side of the landfill access road, as the roadway climbs northward up to the top of the landfill. The swale then flows along the southern shoulder of the landfill access road, eventually discharging to Quaker Creek, via sheet flow through a marsh. The lower part of the swale has a series of rip-rapped check dams. A continuous bed of iron flocculent was observed, covering the bottom of the swale. The swale was flowing, even during the three dry-weather sampling events.

*Summary of Pollutant Exceedances and Identification of Potential Sources*

Specific conductance, turbidity, all nitrogen species (particularly ammonia), DOC, enterococci, and total iron concentrations exceed criteria for streams, during both dry and wet weather. pH levels exceed criteria during dry weather only and TP concentrations exceed guidance during wet weather only. Pollutant exceedances, recorded in the landfill swale, during both dry and wet weather, are summarized in Table 4 below. The pollutants, listed in the Table 4 are commonly found in landfill leachate and runoff. These results provide evidence that contaminated groundwater leachate and runoff from the landfill are captured and conveyed via the drainage swale to Quaker Creek.

**Table 4. Station LDF: Landfill Swale. Summary of Pollutant Exceedances.**

| | | | Station Means | |
|---|---|---|---|---|
| | **Units** | **Criteria/Guidance Concentration** | **Dry Weather** | **Wet Weather** |
| **Specific Conductance** | µs/cm | 835 | 1,161 | 1,159 |
| **pH** | --- | 6.5-9.0 | 9.2 | 8.0* |
| **Turbidity** | NTU | 6.9** | 63 | 170 |
| **TP** | ug/l | 100 | 83* | 135 |
| **TN** | ug/l | 610 | 66,200 | 24,740 |
| **Ammonia** | ug/l | --- | 64,600 | 19,650 |
| **Organic-N** | ug/l | 300 | 600 | 1,000 |
| **Nitrate** | ug/l | 310 | 1,700 | 4,090 |
| **Enterococci** | MPN/100 ml | 54 | 220 | 2,666 |
| **Total Iron** | ug/l | 1,000 | 6,365 | 13,940 |

*Meets Applicable Criteria/Guidance.
**Watershed-specific criteria.

*Dry-Weather Exceedances and Potential Sources*

Specific conductivity is a measure of how well the water can conduct electricity, which is an indirect measure of the amount of ions in solution. Elevated specific conductance levels, during dry weather, were likely caused by landfill leachate, which typically has high concentrations of dissolved ions. Such ions may include sodium, chloride, nitrate, phosphate, calcium, magnesium, and iron (iron levels recorded in the swale were extremely high).

The landfill leachate was also characterized by an elevated pH. High pH is common in leachate from older landfills undergoing methanogenesis (the decomposition of organic material under anaerobic conditions).

Turbidity was also elevated during dry weather. Turbidity was probably the result of dissolved inorganic and organic matter, such as iron and tannins.

Elevated nutrients (including both nitrogen and phosphorus) and dissolved organic carbon (DOC) were probably the result of the decomposition of organic matter. The single sample of total nitrogen (66,200 ug/l) was more than an order of magnitude higher than the guidance level. Ammonia made up about 98% of the total nitrogen (high levels of ammonia are typical in landfill leachate). The mean organic-N and nitrate concentrations also significantly exceeded guidance levels, during dry weather.

Enterococci levels were also elevated, during dry weather. Elevated enterococci levels were probably the result of discarded pet waste, diapers, and wildlife feces.

The mean dry-weather total iron concentration in landfill leachate (6,365 ug/l) was also elevated. A bright orange iron flocculent covered the landfill swale as well as the impoundment trapping leachate at the base of the southern end of the landfill (Photo 6). Anaerobic conditions release iron from landfill waste and also from soils, which naturally contain iron. There were no exceedances of dissolved metals (cadmium, chromium, copper, lead, and selenium) in the landfill swale.

*Wet-Weather Exceedances and Potential Sources*

As previously discussed, all pollutants that had elevated levels during dry weather, also had elevated levels during wet weather, with the exception of pH, which met criteria during wet weather. The mean total phosphorus concentration, which met guidance during dry weather, was elevated during wet weather (135 ug/l). Phosphorus is generally adsorbed onto soil particles or metal (e.g. iron) compounds. Stormwater from the landfill area, probably dislodges and transports a significant amount of soil and iron compounds, which result in the elevated levels of TP, recorded during wet weather.

Brown turbid stormwater runoff from the upper portion of the landfill combines with iron flocculent tainted water from the impoundment at the lower portion of landfill (Photos 7-9). Even in wet-weather, iron flocculent from landfill leachate strongly colors the lower swale a bright orange color (Photos 10 and 11).

Turbidity, organic-N, nitrate, enterococci, and total iron concentrations were significantly higher during wet weather, indicating that stormwater runoff from landfill surfaces has significantly higher levels of these pollutants, relative to the landfill leachate, or because increased stormwater flows dislodge pollutants such as iron flocculent. Although still extremely elevated, wet-weather levels of TN, ammonia and to a lesser extent DOC, were lower relative to dry-weather concentrations.

## 4.2. Quaker Creek, Stations Q1 through Q4

There were four sampling stations on Quaker Creek. The first station (Q1) was located at the landfill access road. The second station (Q2) was located downstream of the landfill swale and upstream of a livestock area. The third sampling station (Q3) was located downstream of the livestock area and the final station (Q4) was located immediately upstream of Quaker Creek's confluence with Borden Brook. Sampling station locations are described in Table 2 and shown in Figure 3 below. Results from all stations are summarized below.

### ***4.2.1. Results***

**Dissolved Oxygen**

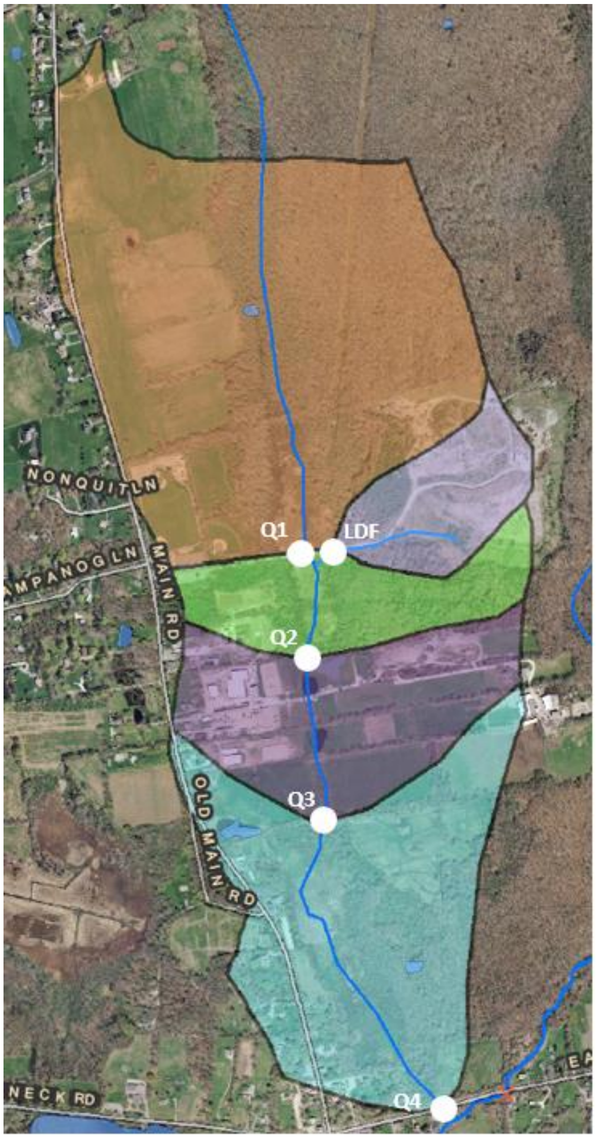
*Dry Weather*

Mean dry-weather DO levels in Quaker Creek met criteria (5.0 mg/l), at all stations, except at the landfill access road (Q1), where mean dry-weather DO was 2.9 mg/l (Figure B-1).

*Wet Weather*

Mean wet-weather DO levels exceeded criteria, at all four Quaker Creek sampling stations ( Figure B-2). The mean wet-weather DO concentration at the access road (Q1) was 3.8 mg/l. There was a significant increase in DO downstream of the landfill at Station Q2. However, the DO concentration at Station Q2 was 4.6 mg/l, which still exceeds the DO criteria. There were no significant changes in DO downstream of the equestrian centers and cattle farm (Station Q3), or at East Road (Station Q4).

**Figure 3. Quaker Creek Sampling Station Locations.**




**Specific Conductance**

*Dry Weather*

Mean dry-weather specific conductance concentrations were below guidance levels at all Quaker Creek sampling stations (Figure B-3).

*Wet Weather*

The mean wet-weather specific conductance concentration met guidance (835 µs/cm) at all stations except Station Q2, located downstream of the landfill. The mean wet-weather specific conductance concentration at Station Q2 was 1,030 µs/cm (Figure B-4).

## pH

*Dry Weather*

Mean dry-weather pH levels exceeded criteria (6.5-9.0) at all but the terminal Quaker Creek station (Station Q4), located at East Road (Figure B-5). The mean pH exceeded 9 at the three upstream stations. The mean pH was highest at the landfill access road (Station Q1). The pH at Station Q1 was 9.4. The pH decreased slightly at each downstream station.

*Wet Weather*

The mean wet-weather pH levels met criteria at all four Quaker Creek stations (Figure B-6).

## Turbidity

*Dry Weather*

Dry-weather turbidity values were low at all stations on Quaker Creek (Figure B-7).

*Wet Weather*

Mean wet-weather turbidity values met criteria at both the landfill access road (Station Q1) and at East Road (Station Q4) (Figure B-8). Mean wet-weather turbidity exceeded criteria (6.9 NTU) downstream of the landfill (Station Q2). The mean wet-weather turbidity at Station Q2 was 9.9 NTU. The turbidity decreased significantly downstream of the equestrian centers and cattle farm (Station Q3). However, the mean turbidity at Station Q3 (7.1 NTU) still exceeded criteria.

## Total Suspended Solids (TSS)

*Dry Weather*

Dry-weather TSS values, recorded in Quaker Creek, were low (Figure B-9). EPA guidance for TSS is 25,000 ug/l for protection of juvenile fish, larvae, and eggs. Most people consider water with a TSS concentration less than 20,000 ug/l to be clear. None of the dry-weather samples exceeded the 20,000 ug/l threshold.

*Wet Weather*

Wet-weather TSS values were below criteria levels at all stations in Quaker Creek (Figure B-10).

## Phosphorus

*Dry Weather*

There were no exceedances of the EPA Gold Book Standard guidance value (100 ug/l), during dry weather (Figure B-11). Approximately 61% of the dry-weather phosphorus was in dissolved form.

*Wet Weather*

Approximately 46% of the wet-weather phosphorus was in dissolved form (Figure B-12). The mean wet-weather TP concentration exceeded EPA guidance at all four Quaker Creek sampling stations. The mean wet-weather TP concentration at station Q1 (located at the Tiverton Landfill access road) was 150 ug/l. There was a significant decrease in TP from the headwaters station to station Q2 (downstream of the Tiverton Landfill), and no significant change at the next downstream station (Q3), located downstream of the equestrian centers and cattle farm. However, there was a 27% increase in mean wet-weather TP from station Q3 to the terminal Quaker Creek station at East Road (Station Q4). The mean wet-weather TP concentration at Station Q4 was 152 ug/l.

**Total Nitrogen**

_Dry Weather_

The mean dry-weather total nitrogen concentration (TN) exceeded EPA's suggested guidance (610 ug/l) at all four Quaker Creek sampling stations (Figure B-13). The mean dry-weather total nitrogen concentration at the landfill access road (Q1) was 1,078 ug/l, which was the lowest mean TN, recorded at any station. There was a 126% increase in TN from Station Q1 to Station Q2, located downstream of the Tiverton Landfill. The mean dry-weather TN at Station Q2 was 2,437 ug/l. The mean TN concentration was little changed at station Q3, located downstream of the equestrian centers and cattle farm. The mean TN concentration decreased by 41% at station Q4, located at East Main Road. The mean dry-weather at station Q4 (located at East Road) was 1,272 ug/l.

_Wet Weather_

The mean wet-weather total nitrogen concentration exceeded EPA's suggested guidance (610 ug/l) at all four Quaker Creek sampling stations(Figure B-14). The mean wet-weather total nitrogen (TN) concentration at the landfill access road (Q1) was 1,525 ug/l. The mean TN concentration doubled from station Q1 to Q2, located downstream of the landfill. The mean wet-weather TN concentration, at Station Q2, was 3,033 ug/l. There was no significant change in wet-weather TP at station Q3, located downstream of the equestrian centers and cattle farm. The mean wet-weather mean TP concentration dropped 60% at station Q4, located at East Road. The mean wet-weather mean TN concentration at East Road was 1,138 ug/l.

**Ammonia**

*Dry Weather*

Ammonia levels are generally below the detection limit at the landfill access road (Station Q1). The mean dry-weather ammonia concentration increased by 866% at station Q2, located downstream of the landfill (Figure B-13). The mean dry-weather ammonia concentration at station Q2 was 863 ug/l. Ammonia levels exceeded chronic criteria levels during all three dry-weather sampling events at station Q2. Ammonia levels decreased significantly at both of the next two downstream stations. The mean dry-weather ammonia concentration at Station Q3 (located downstream of the equestrian centers and cattle farm), was 570 ug/l. However, for one of the two dry-weather sampling events at Station Q3, the ammonia concentration was still above the chronic criteria. Ammonia levels at Station Q4, located at East Road were below the detection limit, during all three dry-weather sampling events.

*Wet Weather*

Wet-weather ammonia levels at the landfill access road (Station Q1), were low (Figure B-14). The mean wet-weather ammonia level increased by 571% at Station Q2, located downstream of the landfill. The mean wet-weather ammonia concentration at Station Q2 was 547 ug/l. The ammonia concentration, at Station Q2 was above the chronic criteria, during one of the three wet-weather sampling events, conducted at this station. Ammonia levels remained relatively unchanged at Station Q3, located downstream of the equestrian centers and cattle farm. The ammonia concentration, during one of the two wet-weather sampling events, conducted Station Q3, was above the chronic criteria. Ammonia levels at Station Q4, located at East Road were below the detection limit, during all three wet-weather sampling events.

## Organic-N

*Dry Weather*

The mean dry-weather organic-N concentration exceeded the EPA suggested guidance (300 ug/l) at all Quaker Creek stations (Figure B-13). In general, organic-N was the dominant form of nitrogen in Quaker Creek. The mean dry-weather organic-N concentration at the landfill access road (Station Q1) was 749 ug/l. There was no significant change in the mean dry-weather organic-N concentration downstream of the landfill (Station Q2) or downstream of the equestrian centers and cattle farm (Station Q3). There was a 50% increase in mean dry-weather organic-N at East Road (Station Q4). The mean dry-weather organic-N concentration at East Road was 1,058 ug/l, which was the highest mean of any station.

*Wet Weather*

The mean wet-weather organic-N concentration exceeded the EPA suggested guidance (300 ug/l) at all Quaker Creek stations (Figure B-14). Wet-weather organic-N means were generally significantly higher than dry-weather means. The mean wet-weather organic-N concentration at the landfill access road (Station Q1) was 1,264 ug/l. There was a 31% increase in the mean wet-weather organic-N concentration downstream of the landfill (Station Q2). The mean wet-weather organic-N concentration at Station Q2 was 1,653 ug/l. There was no significant change in the mean wet-weather organic-N concentration downstream of the equestrian centers and cattle farm (Station Q3). There was a significant decrease in the mean wet-weather organic-N at East Road (Station Q4). The mean wet-weather organic-N concentration at East Road was 977 ug/l, which was the lowest mean of any station.

## Nitrate

*Dry Weather*

The mean dry-weather nitrate at the landfill access road (155 ug/l) was below guidance (310 ug/l) (Figure B-13). The mean nitrate level increased by 390% to 760 ug/l downstream of the landfill (Station Q2). There was little change in the mean nitrate level downstream of the equestrian centers and cattle farm (Station Q3). There was a significant decrease in nitrate at East Road (Station Q4). The mean nitrate concentration at East Road was 163 ug/l, which like the headwater station is below the guidance level.

*Wet Weather*

As in dry weather, the lowest recorded wet-weather mean nitrate levels were recorded at the landfill access road (Station Q1) and at East Road (Station Q4). The mean nitrate levels at both stations (180 ug/l and 112 ug/l) were below guidance (Figure B-14). The mean wet-weather nitrate level increased by 363% from the landfill access road to the station downstream of the landfill (Station Q2). The mean nitrate level at Station Q2 was 833 ug/l. There were significant decreases in nitrate downstream of the equestrian centers and cattle farm (Station Q3) and again at East Road (Station Q4).

## Dissolved Organic Carbon

*Dry Weather*

There were no significant changes in dissolved organic carbon (DOC) levels from the landfill access road (Station Q1) to either the station below the landfill (Station Q2) or the station downstream of the equestrian centers and cattle farm (Station Q3) (Figure B-15). The mean dry-weather DOC concentrations at the three upstream stations on Quaker Creek were in the 14,000-16,000 ug/l range. The DOC concentration at the terminal Quaker Creek station (station Q4) dropped significantly to 12,707 ug/l.

*Wet Weather*

Mean wet-weather DOC values were somewhat higher than dry-weather means at all stations (Figure B-16). The mean wet-weather DOC value at the landfill access road was 16,550 ug/l. There was little change in mean DOC concentration downstream of the landfill (Station Q2). There was a 34% increase in mean wet-weather DOC downstream of the equestrian centers and cattle farm (Station Q3). The mean wet-weather DOC concentration at Station Q3 was 23,800 ug/l. The mean DOC concentration decreased significantly at East Road (Station Q4).

**Enterococci**

*Dry Weather*

The dry-weather enterococci geomeans at all Quaker Creek sampling stations were below the criteria level (54 MPN/100 ml), except at the station downstream of the equestrian centers and cattle farm (Station Q3). The enterococci geomean rose by 74% from Station Q2 to Station Q3, located downstream of the equestrian centers and cattle farm (Figure B-17). The enterococci geomean, downstream of the equestrian centers and cattle farm, was 58 MPN/100 ml. The enterococci geomean decreased significantly at East Road (Station Q4) to 10 MPN/100ml.

*Wet Weather*

Wet-weather enterococci levels were significantly higher than values recorded in dry weather (Figure B-18). The wet-weather enterococci geomeans were significantly greater than the criteria value at all stations. The enterococci geomean at the landfill access road was 1,530 MPN/100 ml. The enterococci geomean increased by 112% to 3,242 MPN/100 ml, downstream of the landfill (Station Q2). There was no significant change in the enterococci geomean, downstream of the equestrian centers and cattle farm (Station Q3). There was a significant decrease in the enterococci geomean at East Road (Station Q4).

**Total Iron**

*Dry Weather*

The mean dry-weather total iron concentration exceeded criteria (1000 ug/l) at the landfill access road (Station Q1) and at the sampling station located downstream of the equestrian centers and cattle farm (Station Q3) (Figure B-19). There were two exceedances of the chronic criteria for iron, at the landfill access road (Station Q1), and downstream of the landfill (Station Q2), during dry weather. There was one exceedance of the chronic criteria downstream of the equestrian centers and cattle farm (Station Q3) and no exceedances at East Road (Station Q4). The mean dry-weather iron concentration was highest at the landfill access road (1,665 ug/l). The mean iron concentration either dropped significantly or experienced no significant change for each of the remaining downstream stations.

*Wet Weather*

The mean wet-weather iron concentrations were significantly higher than those recorded during dry-weather (Figure B-20). Mean wet-weather iron concentrations exceeded criteria at all four Quaker Creek stations. There was a single exceedance of the chronic criteria for iron at the landfill access road (Station Q1). There were two exceedances of the chronic criteria for iron downstream of the landfill swale (Station Q2) and a single exceedance of the criteria downstream of the equestrian centers and cattle farm (Station Q3), and at East Road (Station Q4). The mean wet-weather iron concentration was highest at the landfill access road (2,800 ug/l). The mean iron concentration either dropped significantly or experienced no significant change for each of the remaining downstream stations.

### Dissolved Cadmium

There were no exceedances of criteria for cadmium at any of the four Quaker Creek stations, during dry weather (Figure B-21). There was a single exceedance of the chronic criteria, during wet weather, which occurred at East Road (Q4) (Figure B-22).

### Dissolved Chromium

There were no exceedances of criteria for chromium at any of the four Quaker Creek stations, during either dry or wet weather (Figure B-23 and Figure B-24).

### Dissolved Copper

There were no exceedances of criteria for copper at any of the four Quaker Creek stations, during either dry or wet weather (Figure B-25 and Figure B-26).

### Dissolved Lead

There were no exceedances of criteria for lead at any of the four Quaker Creek stations, during dry weather (Figure B-27). There was a single exceedance of the chronic criteria, during wet weather, which occurred at East Road (Station Q4) (Figure B-28).

### Dissolved Selenium

There were no exceedances of criteria for selenium at any of the four Quaker Creek stations, during either dry or wet weather (Figure B-29 and Figure B-30).

## Targeted Wet-Weather Sampling

Supplementary wet-weather sampling was conducted on Quaker Creek on 1/23/18. The additional sampling was conducted between stations Q2 and Q3, to bracket each equestrian center and cattle farm separately. The stations were located upstream of the first equestrian center (Station Q2), downstream of the first equestrian center and first farm pond (Station Q2a), downstream of the second equestrian center and second farm pond (Station Q2b), and downstream of the cattle farm (Station Q3). The supplementary sampling targeted turbidity, TP, and enterococci bacteria.

### Turbidity

The turbidity level upstream of the first equestrian center (Station Q2) was 7.0 NTU, slightly exceeding the criteria level of 6.9 NTU (Figure B-31). The turbidity level downstream of the first equestrian center (Station Q2a) increased by 271%, to 26 NTU. Turbidity increased again by 146% from Station Q2a to Station Q2b, located downstream of the second equestrian center. The turbidity level at Station Q2b was 64 NTU. There was a slight decrease in turbidity downstream of the cattle farm, at Station Q3.

### TP

Station to station changes in TP largely mimicked changes in turbidity. This was to be expected, since phosphorus is largely absorbed to soil particles. The TP concentration upstream of the first equestrian center (Station Q2) was 53 ug/l, which is below the criteria of 100 ug/l (Figure B-32). The TP concentration downstream of the first equestrian center (Station Q2a) increased by 164%, to 140 ug/l. The TP concentration increased by 100% from Station Q2a to Station Q2b, located downstream of the second equestrian center. The TP concentration at Station Q2b was 280 ug/l. There was a slight decrease in the TP concentration downstream of the cattle farm, at Station Q3.

**Enterococci**

Enterococci concentrations exceeded criteria (54 MPN/100 ml) at all supplementary stations, except for the station downstream of the cattle farm (Station Q3). The enterococci concentration upstream of the first equestrian center (Station Q2) was 960 MPN/100 ml (Figure B-33). The enterococci concentration decreased significantly to 256 MPN/100 ml, downstream of the first equestrian center (Station Q2a). The enterococci concentration increased by 113% from Station Q2a to Station Q2b, located downstream of the second equestrian center. The enterococci concentration at Station Q2b was 546 ug/l. The enterococci concentration was below the detection limit (10 MPN/100 ml) downstream of the cattle farm, at Station Q3.

### ***4.2.2. Pollution Sources***

**Station Q1. Landfill Access Road: Quaker Creek Headwaters**

*Land use*

Despite its depiction as an uninterrupted channel in Figure 4, an inspection of aerial photographs shows no discernable channel north of the Tiverton landfill access road. Instead, the area central to the subwatershed is a wetland. Much of the central portion of the wetland is a marsh, characterized by organic soil, with standing water, most of the year. Forested swamp borders both sides of the marsh area. There are two 12-18-inch culverts that conduct flow under the access road. Iron flocculent was observed in the standing water, upstream of Station Q1 and the landfill access road.

The western portion of the landfill lies within the southeastern portion of the subwatershed of Station Q1. The toe-of-slope of the landfill lies within close proximity to the edge of the wetland corridor. The remaining land to the east of the stream/wetland corridor, consists of upland forest.

Town recreational fields are located on the western side of the subwatershed. There is an 100 ft. vegetative buffer separating the lower baseball field from the wetland corridor associated with Quaker Creek. However, the soccer fields, located in the northeast portion of the park, directly abut the wetland corridor. A large hay field (part of Pardon Gray Preserve) is also present in the western portion of the subwatershed. The hay field also directly abuts the stream/wetland corridor. Part of the southern portion of the pasture area has been recently tilled. Inspection of aerial photographs reveals flow paths from the hayfield towards the wetland corridor.

*Summary of Pollutant Exceedances and Identification of Potential Sources*

Station Q1 was located at the easternmost culvert under the landfill access road, just downstream of the roadway, and upstream any influence from the landfill swale.

*Dry-Weather Exceedances and Potential Sources*

Low levels of dissolved oxygen (DO), as well as elevated levels of pH, TN, organic-N, DOC, and total iron were recorded at Station Q1, during dry weather (Table 5).

Low DO may have been caused by the relatively stagnant conditions in the wetland, and organic wetland soils and decaying organic matter, both of which exert a high biological oxygen demand (BOD). Landfill leachate also may also be high in BOD. Also reduced iron, from the landfill, oxidizes when it seeps out of the ground and hits the atmosphere, consuming oxygen in the process (high levels of total iron were also recorded at Station Q1).

**Figure 4. Station Q1: Landfill Access Road.**


High pH may be associated with leachate from the landfill. High pH is common in leachate from older landfills undergoing methanogenesis (the decomposition of organic material under anaerobic conditions).

Elevated dry-weather TN concentrations at Station Q1 were mostly the result of high levels of organic-N. Decaying nitrogen-rich organic matter from wetland vegetation and soils, may have been the source of the high organic-N concentration. As will be discussed in greater detail later in the document, elevated organic-N concentrations were recorded at the Borden Brook headwater station (Station B1), which is located downstream of a large wetland complex, in a subwatershed that is relatively unimpacted by human development. However, the mean dry-weather organic-N concentration at Station Q1 was significantly higher than the mean value at Station B1, indicating that there may be another source of nitrogen, in addition to the wetland. Nitrate from the landfill, which is readily transported in groundwater, may be a secondary source of organic-N. Nitrate derived nitrogen may combine with decaying organic material, from the wetland, to form organic-N. Nitrogen, may also be transported as nitrate, in groundwater from the pasture and the town's recreational fields, located on the western side of the stream/wetland complex.

**Table 5. Station Q1: Landfill Access Road. Summary of Pollutant Exceedances.**

| | | | Station Means[1] | |
|---|---|---|---|---|
| | Units | Criteria/Guidance Concentration | Dry Weather | Wet Weather |
| **DO** | mg/l | 5 | 2.9 | 3.8 |
| **pH** | --- | 6.5-9.0 | 9.4 | 8.4* |
| **TP** | ug/l | 100 | 26* | 150 |
| **TN** | ug/l | 610 | 1,090 | 1,525 |
| **Organic-N** | ug/l | 300 | 749 | 1,264 |
| **Enterococci** | MPN/100 ml | 54 | 21* | 1,530 |
| **Total Iron** | ug/l | 1,000 | 1,665 | 2,800 |

1. Enterococci value is a geomean.
*Meets applicable criteria/guidance.

Elevated levels of dissolved organic carbon (DOC) were recorded at Station Q1, during dry weather. However, high levels of DOC appear to be ubiquitous in the tributaries to Nonquit Pond. The mean dry-weather DOC concentration at the Borden Brook headwater station (Station B1) was significantly greater than the mean dry-weather value at Station Q1. Decomposing organic material, within the wetlands, may be the principle source of the elevated DOC.

Total mean dry-weather total iron concentration exceeds DEM criteria. Iron floc was apparent in the wetland, upstream of the landfill access road (Photo 1). The source of iron was likely groundwater flow from the Tiverton landfill. Under anaerobic landfill conditions, iron is reduced (including both iron from waste and iron naturally found in soils). The reduced iron is highly soluble and is readily transported by groundwater. Once the reduced iron discharges to the wetland and hits the atmosphere, it oxidizes, producing the rust-colored iron floc.

*Wet-Weather Exceedances and Potential Sources*

Except for pH, all exceedances of criteria/guidance that occurred during dry weather, also occurred during wet weather (Table 5). Mean DO improved somewhat during wet-weather, increasing from 2.9 to 3.8 mg/l. However, the wet-weather DO concentration was still well below the criteria level of 5.0 mg/l. Mean TN and organic-N, as well as total iron were significantly higher during wet weather, probably because the stormwater flow from the surface of the landfill, in addition to groundwater seepage, was contributing to the higher levels. A roadway swale, located on the western edge of the roadway as it climbs northward to the top of the landfill, also discharges stormwater to the wetland, upstream of the access road and Station Q1. Although the swale is not located in an active portion of the landfill, stormwater runoff in the ditch may have high levels of pollutants. Other potential sources of elevated nitrogen levels may include the town's recreational fields and the pasture (part of Pardon Gray Preserve) to the west side of the stream/wetland corridor. Large numbers of seagulls congregate on the Town's baseball fields (Photo 2), and occasionally in the newly tilled portion of the pasture in Pardon Gray Preserve (Photo 3). A swale from the recreational fields flows towards the forested upland buffer, adjacent to the wetland corridor. In addition, the Town's soccer fields directly abut the wetland corridor associated with Quaker Creek (Photo 4 and Photo 5). Several flows paths were observed in aerial photographs, which flow from the pasture to the wetland corridor.

Elevated total phosphorus (TP) concentrations were recorded, during wet weather only. Phosphorus is generally adsorbed onto soil particles or metal (e.g. iron) compounds. Stormwater from the landfill area, probably dislodges and transports a significant amount of soil and iron compounds, which result in the elevated levels of TP.

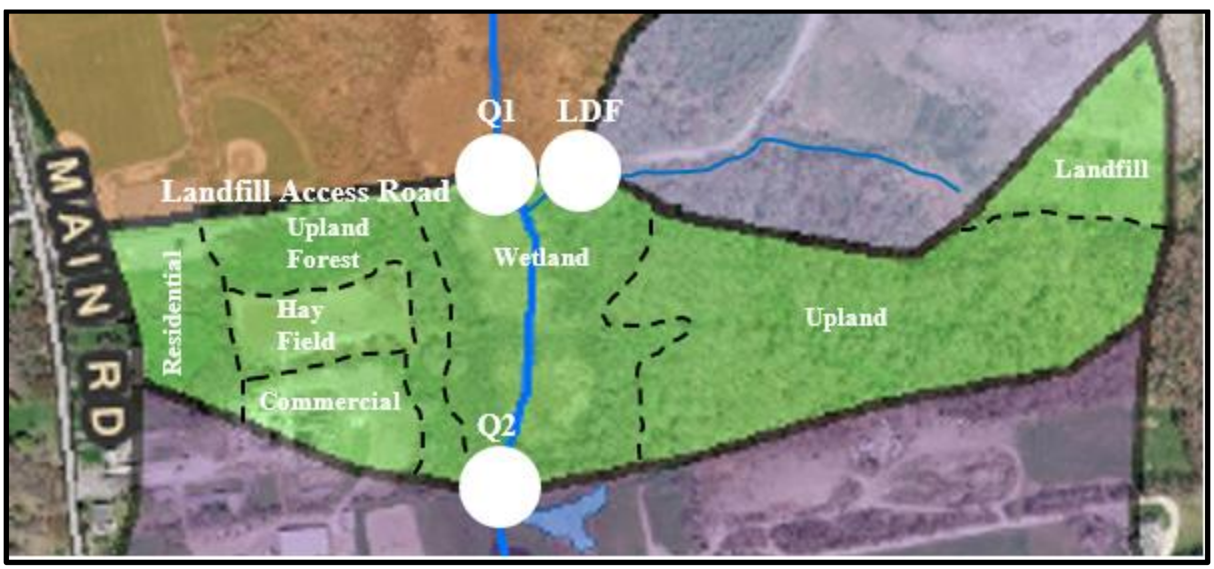
An elevated geomean enterococci concentration was also only recorded during wet weather. The elevated enterococci geomean is probably the result of stormwater flushing bacteria, from diapers and pet and wildlife waste, from the landfill area into the wetland upstream of the access road and Station Q1. A secondary bacteria source may be the town's recreational fields, located to the west of the wetland corridor. Approximately 100 gulls were observed on the fields at various times.

**<u>Station Q2. Downstream of Tiverton Landfill Swale</u>**

*Land use*

The stream corridor, between Stations Q1 and Q2, consists of wetland. Much of the central portion of the wetland is marsh, which is characterized by an organic soil and standing water for much of the year. Despite its depiction as an uninterrupted channel in the base map in Figure 5, an inspection of aerial photographs reveals no discernable channel in this area (except for the immediate area at Stations Q1 and Q2).
The landfill swale, which drains much of the Tiverton landfill, discharges to the Quaker Creek system downstream of Station Q1, and upstream of Station Q2. The remaining area, to the east of the stream-wetland corridor, consists of upland forest.

**Figure 5. Station Q2: Downstream of Landfill Swale.**




There is a 75-100 ft. buffer of upland forest adjacent to the western edge of the stream/wetland corridor. A hayfield (fallow field) and commercial area (artist cooperative; formerly a greenhouse area) are located to the west (upslope of the forested buffer). Residential houses are located along Main St., upslope of the hayfield and commercial property.

*Summary of Pollutant Exceedances and Identification of Potential Sources*

Available data indicates that the landfill swale is responsible for the significant increases in specific conductance, turbidity, TN, ammonia, nitrate, and enterococci bacteria, recorded at Station Q2 (Table 6). Mean concentrations of these pollutants, in the landfill swale, were significantly higher than mean levels recorded at either Stations Q1 or Q2.

*Dry-Weather Exceedances and Potential Sources*

The mean total nitrogen concentration more than doubled from Station Q1 to Station Q2, during dry weather. The increase in TN was caused mainly by significant increases in ammonia and nitrate. There was almost a 4-fold increase in the mean nitrate concentration, during dry weather. The mean ammonia concentration increased by almost 9-fold during dry weather.

*Wet-Weather Exceedances and Potential Sources*

The mean total nitrogen concentration approximately doubled from Station Q1 to Station Q2, during wet weather. Similar to the nitrogen dynamics during dry weather, the wet-weather increase in TN was due largely to significant increases in ammonia and nitrate (an almost 6-fold increase in ammonia and an almost 4-fold increase in nitrate). The dry-weather mean organic-N increased by 31%. The landfill swale is the source of the increase in nitrogen species. The mean wet-weather specific conductance, turbidity and enterococci concentrations more than doubled from Station Q1 to Q2.

**Table 6. Station Q2. Downstream of Landfill Swale: Summary of Significant Pollutant Concentration Increases**

| | | | Station Mean[1] | | % Increase Relative to Upstream Station | |
|---|---|---|---|---|---|---|
| | **Units** | **Criteria/Guidance Concentration** | **Dry Weather** | **Wet Weather** | **Dry Weather** | **Wet Weather** |
| **Specific Conductance** | µs/cm | 835 | 354* | 1,030 | * | 120 |
| **Turbidity** | NTU | 6.9*** | 1.7* | 9.9 | * | 120 |
| **TN** | ug/l | 610 | 2,437 | 3,033 | 126 | 99 |
| **Ammonia** | ug/l | **** | 863 | 547 | 866 | 571 |
| **Organic-N** | ug/l | 300 | 813 | 1,653 | ** | 31 |
| **Nitrate** | ug/l | 310 | 760 | 833 | 390 | 363 |
| **Enterococci** | MPN/100 ml | 54 | 34* | 3,242 | * | 112 |

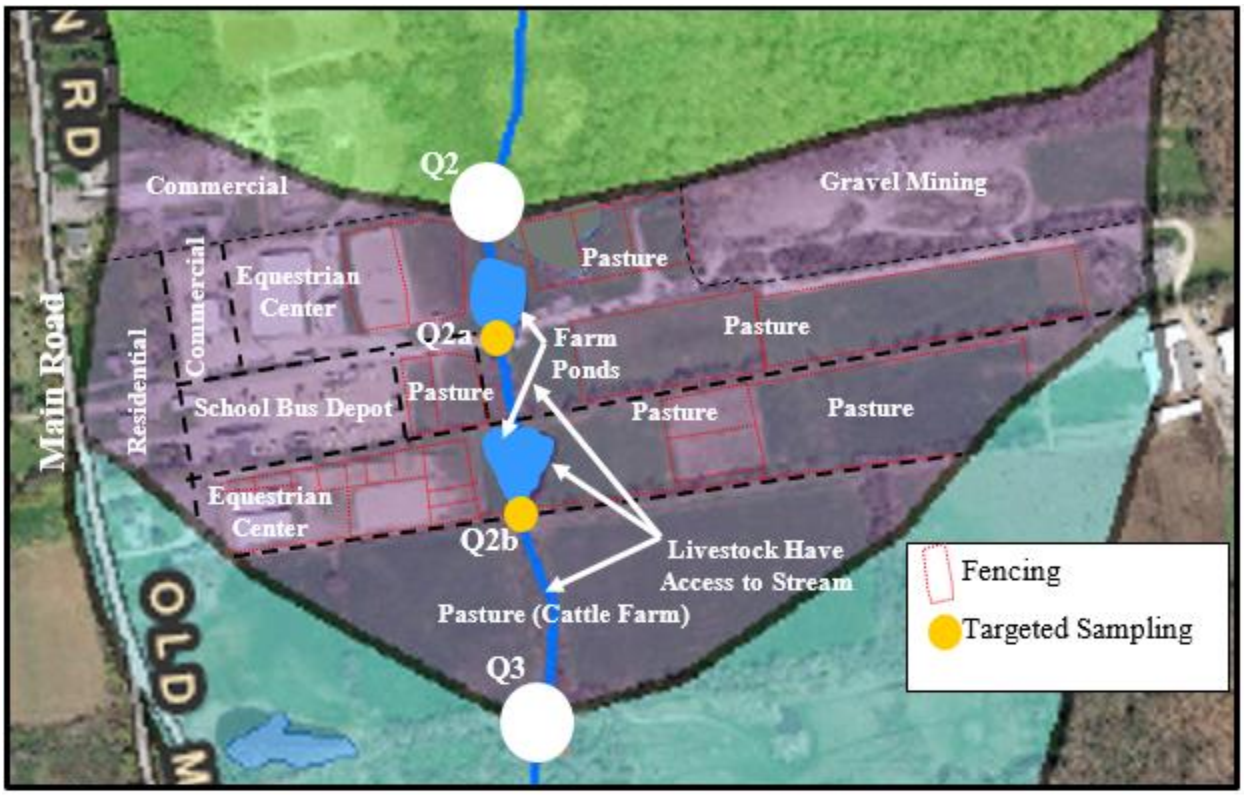
1. Enterococci value is a geomean.
* Meets applicable criteria/guidance.
** No significant change or decrease in pollutant concentration relative to the upstream station.
***Watershed-specific criteria.
**** Criteria is pH-dependent.

**Station Q3. Downstream of Equestrian Centers and Cattle Farm.**

*Land use*

Station Q2 and Q3 bracket a livestock area (Figure 6). There are two equestrian centers located immediately downstream of Station Q2, and a cattle farm located immediately downstream of the equestrian centers. There are two farm ponds, adjacent to each of the equestrian centers. The remainder of the stream corridor consists of a well-defined single channel. There is no significant vegetated buffer along the stream or farm ponds. There are several fenced enclosures, associated with the equestrian centers. Those fenced enclosures, closest to the stream, are characterized by saturated muddy soils, devoid of vegetation, for much of the year.

**Figure 6. Station Q3: Downstream of Livestock Area.**




Although there appears to be no direct livestock access to the stream, adjacent to the upstream farm pond, the fenced enclosure to the west of the farm pond, is sometimes either flooded or characterized by sheet flow, during rain events (Photo 12). The fenced enclosure on the western side of the stream, between the two farm ponds is also saturated or partially flooded, during wet weather (Photos 13-15). Turbid stormwater runoff from the corrals and the dirt parking lot of the bus depot was observed to discolor flow in the stream in this area (Photo 16). A pile of manure was observed, adjacent to the barn and up-gradient of the corrals, associated with the downstream equestrian center (Photo 17). Flooded conditions were also observed in corals located to the east of the upper farm pond. A significant area to the east of the stream, between the two farm ponds, floods periodically. Horses have direct access to this periodically flooded area and a significant amount of manure was observed in this location (Photo 18). Horses also have direct access to the downstream farm pond (Photo 19). In addition, cattle have direct access to the entire length of stream, downstream of the second farm pond (Photos 20-22). There were approximately 40 head of cattle on the farm downstream of the second farm pond.

Other than livestock areas, there are several other land uses, located along the periphery of the subwatershed. There is a 4-acre area of excavated soil, located in the northeast portion of the subwatershed (Photo 23). Although its located over 400 ft. from the upper farm pond, turbid runoff from the excavated area was observed flowing along the northern tree line of the farm, discoloring the eastern side of the farm pond.

There are two commercial areas to the west of the stream, including a small landscaping business to the west of the equestrian center barn, and an artist's cooperative (formerly a greenhouse area) in the northwest corner of the subwatershed. The parking lots and driveways associated with the artist's cooperative, landscaping business, and upper equestrian center have a gravel/seashell surface. Turbid stormwater runoff (milky brown in color) from these areas was observed flowing into a ditch parallel to the main drive accessing the equestrian center (Photos 24 and 25). Runoff from the ditch discharges to the stream south of the upper farm pond, discoloring the water in the stream (Photos 26 and 27).

A school bus depot is located between the two equestrian center barns to the west of the stream (Photo 28). Turbid runoff, from the bus depot's saturated dirt parking area, was observed flowing towards the stream.

*Summary of Pollutant Exceedances and Identification of Potential Sources*

*Dry-Weather Exceedances and Potential Sources*

The dry-weather enterococci geomean at Station Q3 (58 MPN) slightly exceeded the criteria (54 MPN). There was a 74% increase in the enterococci geomean from Station Q2 to Q3 (Table 7). The likely sources are the livestock areas, where horses and cattle have direct access to the stream (this includes all livestock areas to the south of the upstream farm pond).

**Table 7. Station Q3. Downstream of Livestock Area: Summary of Significant Pollutant Concentration Increases.**

| | | | Station Mean[1] | | % Increase Relative to Upstream Main Stem Station | |
|---|---|---|---|---|---|---|
| | **Units** | **Criteria/Guidance Concentration** | **Dry Weather** | **Wet Weather** | **Dry Weather** | **Wet Weather** |
| **DOC** | ug/l | * | 15,850 | 23,800 | ** | 34 |
| **Enterococci** | MPN/100 ml | 54 | 58 | 3,499 | 74 | ** |

1. Enterococci value is a geomean.
*No In-Stream Criteria or Guidance.
** No significant change or decrease in pollutant concentration relative to the upstream station.

*Wet-Weather Exceedances and Potential Sources*

There was a 34% increase in DOC from Station Q2 to Station Q3 (Table 7). The likely source is manure associated with the livestock areas, including both equestrian centers and the cattle farm to the south.

Targeted wet-weather sampling was conducted within the livestock area on 1/23/18 (Table 8). In addition to Stations Q2 and Q3, two additional sampling stations were added to more finely bracket potential sources of pollutants. Station Q2a was located at the outlet of the upstream farm pond, and Station 2Qb was located at the outlet of the downstream farm pond (Figure 6). The targeted wet-weather samples were analyzed for turbidity, TP, and enterococci.

**Table 8. Station Q3. Downstream of Livestock Area: Targeted Wet-Weather Sampling.**

| | | | Q2 | Q2a | Q2b | Q3 |
|---|---|---|---|---|---|---|
| | **Units** | **Criteria/Guidance Concentration** | | | | |
| **Turbidity** | NTU | 6.9 | 7.0 | 26 | 64 | 53 |
| **TP** | ug/l | 100 | 53 | 140 | 280 | 260 |
| **Enterococci** | MPN/100 ml | 54 | 960 | 256 | 546 | <10 |

There were significant increases in turbidity and TP at Station Q2a. As previously discussed, phosphorous is often linked with turbidity, because phosphorus is often adsorbed onto soil particles. The likely sources of the turbidity and phosphorus are the muddy corals to the west of the stream, as well as more distant muddy corals to the east of the stream, and the excavated area located in the northeast portion of the watershed. Sediment plumes were observed entering the stream from these three areas, and both the eastern and western portions of the farm pond were noticeably more turbid than its central portion.

Significant increases in turbidity, TP, and enterococci were documented at Station Q2b. The downstream farm pond was noticeably turbid during wet weather (Photo 29). Increases in turbidity and TP, at this station, were likely caused by stormwater runoff from the northern equestrian center and adjacent commercial areas (artist's cooperative and landscaping business), as well as a dirt parking area associated with the bus depot, and muddy corals located on the western side of the stream. There is a crushed seashell parking area around the upper equestrian area and landscaping business (seashells have a high phosphorus content). As previously discussed, turbid runoff, from the parking area, was observed entering the stream immediately downstream of Station Q2a, via the roadway and a culvert. The enterococci increase was likely caused by manure in close proximity to the stream. Horses have direct access to the eastern side of the stream, along this entire reach. The short reach of stream channel, between the two farm ponds, on the eastern side of the stream, was often flooded during wet weather. A significant amount of manure was observed in the flooded area. In addition, the fenced enclosure to the west of the stream is located in very close proximity to the channel.

There were no pollutant increases, documented by the targeted wet weather sampling, at Station Q3. However, cattle have access to the entire reach of stream, downstream of the second farm pond, and there is the potential for turbidity and TP increases due to animal traffic in the stream and wet adjacent areas. There is also the potential for bacteria increases due to manure in or adjacent to the stream.

**Station Q4. East Road: Immediately Upstream of Borden Brook**

*Land use*

The terminal reach of Quaket Brook (immediately upstream of its confluence with Borden Brook), flows through a broad wetland corridor (Figure 7). Much of the interior of the wetland consists of marsh, with organic soil and standing water in places for much of the year. There are at least two distinct channels in this reach; one in the interior of the marsh and one at its western edge.

There are pastures and a hayfield, located in the northeastern portion of the watershed. Another pasture is located in the southeast corner of the subwatershed. However, there was no evidence of concentrated surface water runoff from the hayfields or pastures to the wetland/stream corridor, in the subject subwatershed. In addition, there was at least a 50-100 ft. buffer between the hay fields and wetland corridor. The remaining land, to the east of the stream/wetland corridor, consisted of upland forest.

Much of the land, to the west of the stream/wetland corridor, directly abuts the wetland, with minimal or no buffer of upland forest. A pasture is located in the northwestern portion of the subwatershed. Cattle in this area, have direct access to a small farm pond that is hydrologically connected to Quaket Creek. Most of the subwatershed, west of the stream corridor, consists of residential land use along Main Road. There is a church in the west-central portion of the watershed and commercial land use, including a sculpture garden, in its southwestern corner.

*Summary of Pollutant Exceedances and Identification of Potential Sources*

*Dry-Weather Exceedances and Potential Sources*

There was a significant increase in organic-N at Station Q4, during dry weather only (Table 9). However, there was a significant decrease in dry-weather TN (dry-weather ammonia and nitrate concentrations dropped significantly at Station Q4). It is likely that the increase in organic-N is due to transformations of N-species occurring in the marsh itself, such as the conversion of nitrate into organic-N.

*Wet-Weather Exceedances and Potential Sources*

There was a significant increase in TP during wet weather at Station Q4. The increase in TP may have been caused by runoff from the pasture (cattle farm), in the northwestern portion of the watershed. Cattle access to the hydrologically connected farm pond is of particular concern (Photo 30). Stormwater runoff from a roadside ditch (Main Rd.) was observed discharging into the farm pond, and was also a potential source of phosphorus (Photo 31).

The increase in wet-weather TP may also be associated with residential and commercial properties along Main Street, including a church (e.g. fertilizer application and potentially failing septic systems). An inspection of records from RIDEM's Onsite Wastewater Treatment System program, from 1990 to present, shows that two of three water tables on record, located east of Main Road, has a water table of 18 in. or less. In addition, many developed properties along Main Road lie in close proximity to the western channel of Quaker Creek (Photos 32 and 33). Phosphorus, ultimately derived from further up in the watershed, may also be released from anaerobic wetland sediments as they become more flooded during rain events.

**Figure 7. Station Q4: East Road.**

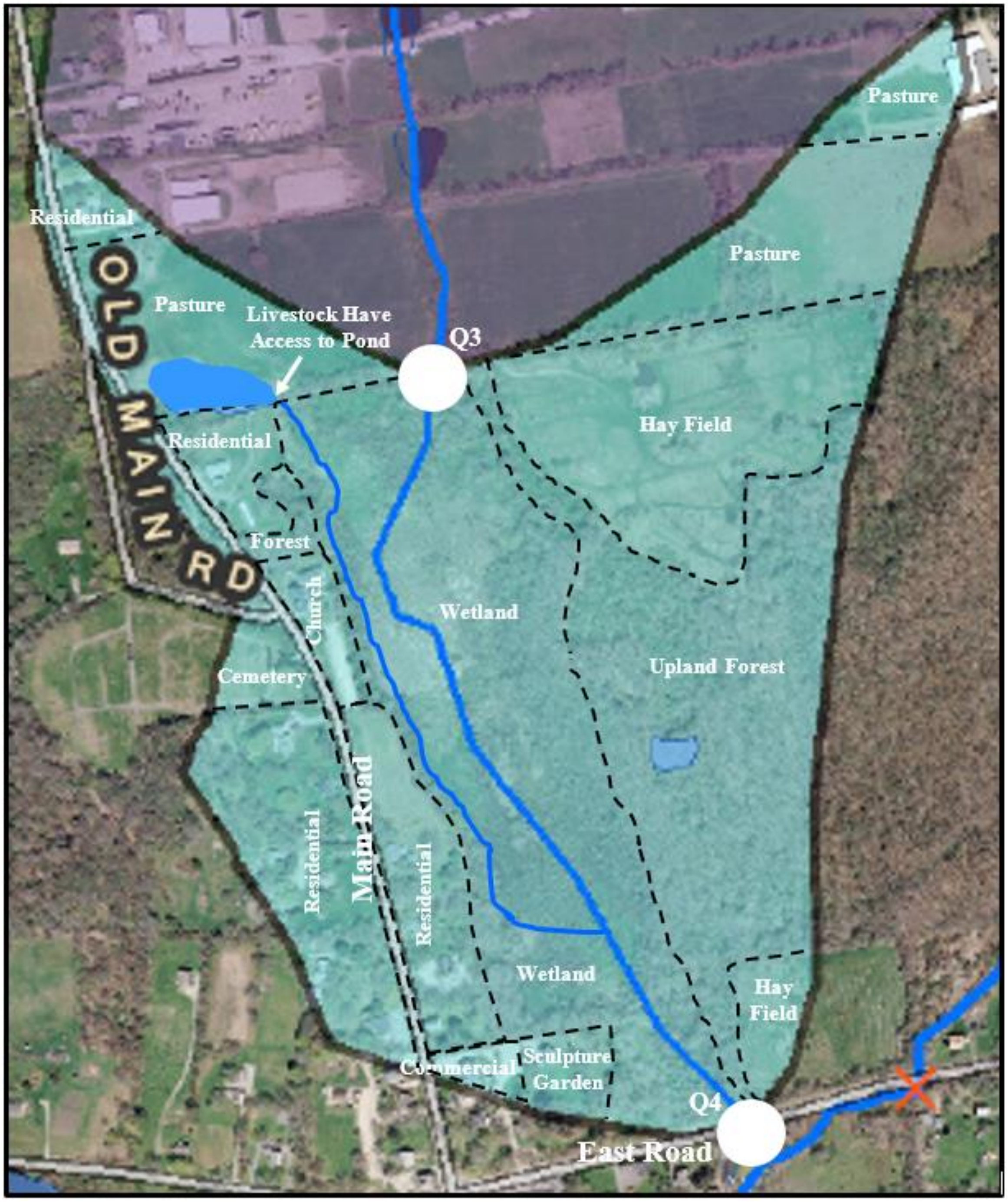


**Table 9. Station Q4. East Road: Summary of Significant Pollutant Concentration Increases.**

| | | | Station Mean | | % Increase Relative to Upstream Main Stem Station | |
|---|---|---|---|---|---|---|
| | **Units** | **Criteria/Guidance Concentration** | **Dry Weather** | **Wet Weather** | **Dry Weather** | **Wet Weather** |
| **TP** | ug/l | 100 | 42** | 152 | * | 27 |
| **Organic-N** | ug/l | 300 | 1,058 | 977 | 50 | * |

* No significant change or decrease in pollutant concentration relative to the upstream station.
** Meets guidance.

## 4.3. Unnamed Tributary to Borden Brook

The sampling station on the unnamed tributary to Borden Brook is located immediately upstream of its confluence with Borden Brook (Figure 8).

### ***4.3.1. Results***

**Dissolved Oxygen**

DO levels met criteria in the unnamed tributary to Borden Brook, during both dry and wet weather. There was not a single DO violation (Figures B-34 and B-35).

**Specific Conductance**

Specific conductance was low, during both dry and wet weather (Figures B-36 and B-37). The highest recorded specific conductance level (151 µs/cm) was well below guidance (835 µs/cm).

**pH**

The mean pH values met criteria, during both dry and wet weather (Figures B-38 and B-39).

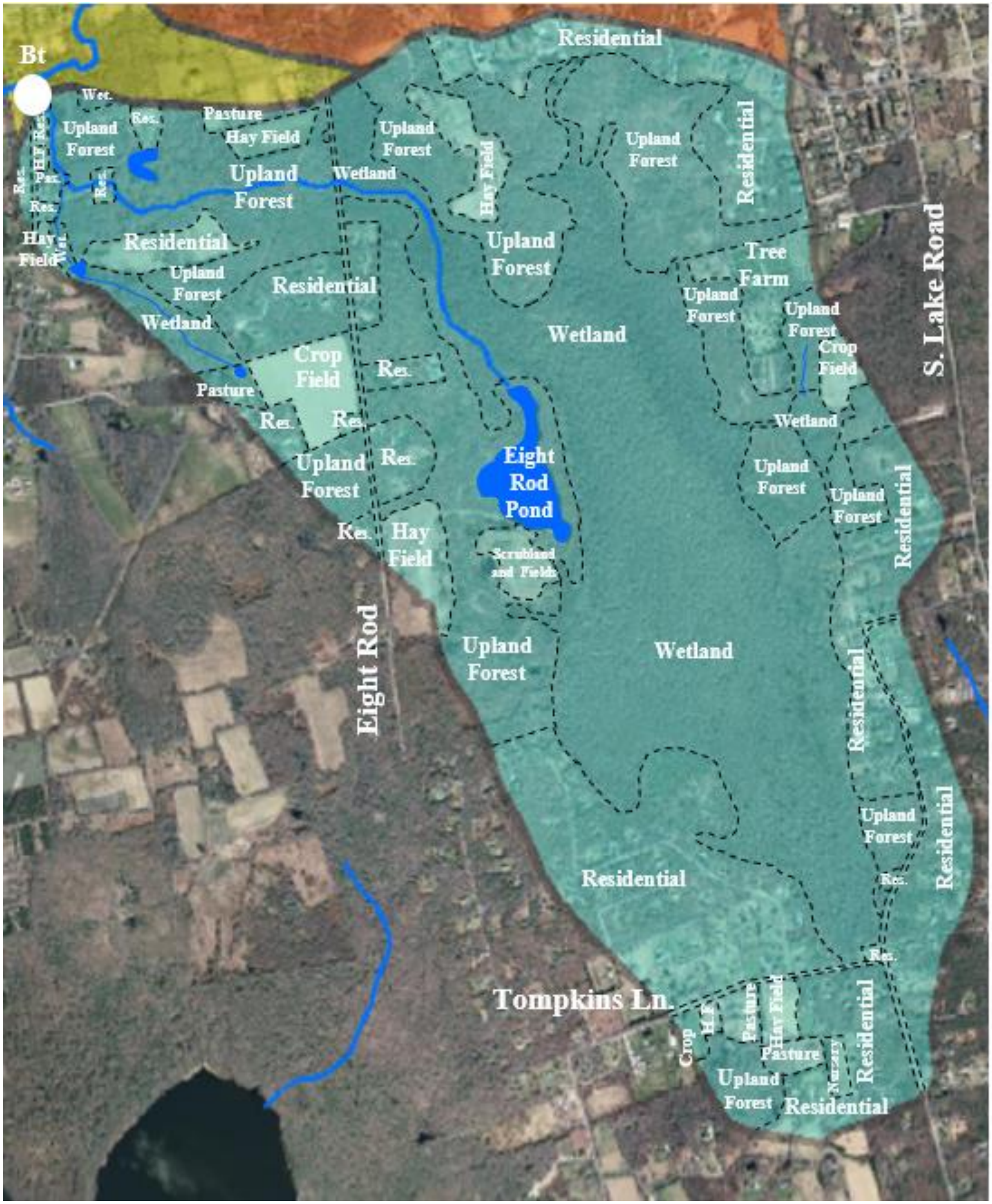
**Turbidity**

There were no violations of the turbidity criteria, during dry or wet weather (Figures B-40 and B-41).

**Total Suspended Solids (TSS)**

There were no violations of the TSS guidance in the unnamed tributary to Borden Brook (Station Bt), during either dry or wet weather (Figures B-42 and B-43).

**Figure 8. Station Bt: Main Road. Unnamed tributary to Borden Brook Immediately Upstream of its Confluence with Borden Brook.**



**Total Phosphorus**

*Dry Weather*

The mean TP concentration at the unnamed tributary, near its confluence with Borden Brook (Station Bt), during dry weather was 64 ug/l (Figure B-44).

*Wet Weather*

The mean TP concentration at the unnamed tributary, near its confluence with Borden Brook (Station Bt), during wet weather was 100 ug/l, just meeting the guidance concentration of the same value (Figure B-45).

**Total Nitrogen**

*Dry Weather*

The mean dry-weather TN concentration in the unnamed tributary to Borden Brook, was 915 ug/l, which exceeded the guidance value of 610 ug/l (Figure B-46).

*Wet Weather*

The mean wet-weather TN concentration in the unnamed tributary to Borden Brook, was 1,205 ug/l (Figure B-47).

**Ammonia**

Ammonia levels were below the criteria levels, during both dry and wet weather. The highest ammonia concentration, recorded in the unnamed tributary to Borden Brook, was 129 ug/l (Figure B-46 and B-47).

**Organic-N**

*Dry Weather*

The mean dry-weather organic-N concentration in the unnamed tributary to Borden Brook (Station Bt), was 778 ug/l, which exceeded guidance (300 ug/l) (Figure B-46).

*Wet Weather*

The mean wet-weather organic-N concentration in the unnamed tributary to Borden Brook (Station Bt), was 1,060 ug/l (Figure B-47).

**Nitrate**

Mean nitrate concentrations, during both dry and wet weather, were well below the guidance level (310 ug/l). The highest nitrate concentration, recorded in the unnamed tributary to Borden Brook, was 120 ug/l (Figures B-46 and B-47).

**Dissolved Organic Carbon**

*Dry Weather*

The mean dry-weather DOC concentration in the unnamed tributary to Borden Brook (Station Bt) was 22,600 ug/l (Figure B-48).

*Wet Weather*

The mean wet-weather DOC concentration in the unnamed tributary to Borden Brook (Station Bt) was 15,700 ug/l (Figure B-49).

**Enterococci**

*Dry Weather*

The dry-weather enterococci geomean in the unnamed tributary to Borden Brook (Station Bt) was 16 MPN/100 ml (well below the criteria value of 54 MPN/100 ml) (Figure B-50).

*Wet Weather*

Wet-weather enterococci values exceeded criteria, during both wet-weather sampling events. The wet-weather geomean in the unnamed tributary to Borden Brook was 2,488 ug/l (Figure B-51).

### ***4.3.2. Pollution Sources***

**Station Bt: Unnamed Tributary Terminus**

*Land use*

Most of the central portion of the subwatershed of Station Bt is wetland. The developed areas in the southern and eastern portions of the subwatershed are located on its periphery, far away from the stream.

This unnamed tributary to Borden Brook arises from Eight Rod Pond in the central portion of the subwatershed. The pond is manmade-the result of a sand or gravel mining operation. The area around the pond is now a DEM management area and is stabilized with vegetation. The stream flows northerly, to Eight Rod Way, through a wetland corridor. The stream continues through an upland forest, and as it nears Main Road it flows along the edge of lawns, associated with two residences (Photo 34). The stream then merges with a smaller stream. There is a pasture, located to the immediate west of the confluence of the streams. The pasture extends to the streambank on both sides of the stream (Photo 35). A few animals (goats and a hog) are kept in a fenced enclosure, approximately 70 ft. from the stream (Photo 36). There is also a large aviary on the property approximately 40 ft. from the stream and a barn and attached fenced enclosure set much further back (Photo 35). Livestock have occasional access to the stream as evidenced by manure near the streambank (Photos 37 and 38). The unnamed tributary then parallels Main Road, flowing behind a hayfield (Photo 39), a residence (Photo 40), and commercial properties (Photo 41). There is little to no vegetated buffer along the western streambank, downstream of the confluence of the two streams.

As discussed above, a smaller stream discharges into the unnamed tributary to Borden Brook. This western fork of the unnamed tributary arises from a wetland. There is a farm pond located within the wetland, that is separated from an adjacent crop field by a 40-ft. vegetative buffer (Photo 42). The wetland is seasonally grazed, as evidenced by closely cropped grass and clumps of old manure (Photos 43 and 44). Apparently, cattle are confined in a fenced enclosure to another part of the farm, during the winter. The pasture is part of a large farm that is mostly located in the subwatershed of an unnamed tributary to Nonquit Pond, located to the west.

There was a large (approximately 130 x 40 x 10 ft.) silage pile located immediately adjacent to the wetland that forms the headwaters of this western fork of the unnamed tributary (Photos 45 through 47). The silage pile is located on a paved drive, immediately adjacent to the wetland. There was a very strong fetid odor emanating from the silage pile. There was heavy growth of filamentous algae in the stream and headwater wetlands, immediately downstream of the silage pile. A white scum covered much of the algae (Photos 48 and 49). The pile was on farm property with approximately a dozen head of cattle (cows apparently do not have access to the silage area during winter, but apparently have access at other times of year). Inspection of aerial photographs of various years shows that the pile is up to 170 ft. long.

The western fork of the tributary then flows through upland forest and into another small farm pond on what is now a 14-acre residential lot. Lawn extends down to the pond's edge at this location (Photo 50). Prior to the confluence with the northeastern fork of the tributary, the stream flows past a hay field and three residential lots (Photos 51 and 52). There is a 10-60 ft. vegetated buffer at the lower end of the stream.

*Summary of Pollutant Exceedances and Identification of Potential Sources*

Mean TN and organic-N concentrations violated guidance levels, during both dry and wet-weather (Table 10). Total phosphorus (TP) met criteria, during dry and wet weather. However, Station Bt is located only 250 ft. upstream of Station B3, where the stricter criteria of 25 ug/l applies. Its appears that it may be difficult to meet criteria at Station B3, with the relatively high TP levels in the unnamed tributary. The Enterococci geomean exceeded criteria, during wet weather only.

**Table 10. Station Bt: Main Road. Summary of Pollutant Exceedances.**

| | | | Station Means[1] | |
|---|---|---|---|---|
| | Units | Criteria/Guidance Concentration | Dry Weather | Wet Weather |
| TP[1] | ug/l | 100 | 64 [2] | 100 [2] |
| TN | ug/l | 610 | 915 | 1,205 |
| Organic-N | ug/l | 300 | 778 | 1,060 |
| Enterococci | MPN/100 ml | 54 | 16 [3] | 2,488 |

1. Enterococci value is a geomean.
2. TP did not exceed the 100 ug/l guidance at this station, but contributed to the exceedance of the stricter criteria of 25 ug/l applied to the terminal Borden Brook Station.
3. Dry-weather enterococci geomean met criteria.

*Dry-Weather Exceedances and Potential Sources*

The mean dry-weather phosphorus concentration was 64 ug/l (the third highest mean TP level of the 11 sampling stations in the study). In general, dry-weather phosphorus levels in any stream tend to be low, as phosphorus is generally adsorbed onto soil particles that are transported by stormwater runoff. A potential source of dry-weather phosphorus could be the large wetland occupying most of the central portion of the subwatershed. The ultimate source of phosphorus, to the wetland, could be phosphorus-rich stormwater runoff from developed areas, adjacent to the wetland. Phosphorus adsorbed onto wetland soils may be released into the water column when the wetland is inundated with standing water and becomes anoxic.

Organic-N was the major form of nitrogen at Station Bt. Although TN and organic-N exceeded guidance levels, the mean TN and organic-N concentrations at Station Bt were similar to those recorded at Station

B1, which is located in Weetamoo Woods in a subwatershed that is relatively undeveloped. Similar to the Weetamoo Woods subwatershed, the subwatershed associated with Station Bt is characterized by extensive wetlands. Elevated dry-weather organic-N and dissolved organic carbon (DOC) are likely the result of the decay of organic material, and to a lesser extent wildlife waste, within the extensive swamp contiguous to the unnamed tributary to Borden Brook.

*Wet-Weather Exceedances and Potential Sources*

The mean wet-weather phosphorus concentration was 100 ug/l (significantly higher than the dry-weather mean value). In addition to the wetland, potential sources of wet-weather phosphorus include any developed areas, adjacent to the stream, which lack an adequate vegetated buffer. Stormwater carrying phosphorus-rich sediment from the crop field, pasture, various hay fields, and residences are potential sources.

The mean wet-weather TN and organic-N concentrations increased significantly, relative to dry-weather values, whereas wet-weather nitrogen concentrations at Station B1 in Weetamoo Woods were similar to dry-weather concentrations. In addition to the extensive wetland bordering the unnamed tributary to Borden Brook, additional potential wet-weather organic nitrogen sources include developed areas near the stream, lacking sufficient vegetative buffers. These areas include the crop field and pasture at the headwaters of the southwest tributary as well as various hay fields, and residences, mostly located along Main Road. The mean DOC concentration was significantly less in wet-weather, indicating that the extensive wetland may be the main source.

The mean wet-weather enterococci concentration exceeded criteria at Station Bt. Potential wet-weather enterococci sources include the extensive wetland and adjacent forested upland (wildlife waste), the pasture and crop field at the headwaters of the southwest fork, and various hayfields (wildlife waste), a small pasture near Main Road (livestock waste), and various residential properties (failing septic systems and pet waste).

## 4.4. Borden Brook

There were three sampling stations located on Borden Brook. The upstream station (B1) was located in Weetamoo Woods, a nature preserve. The middle station (B2) was located at East Road and the downstream station (B3) was located downstream of the confluence of Quaker Creek and the unnamed tributary and immediately upstream of an old mill dam and Main Road. The locations of the Borden Brook sampling stations, as well as the locations of the terminal station on Quaker Creek and the station on the unnamed tributary to Borden Brook, are shown in Figure 9 below.

### ***4.4.1. Results***

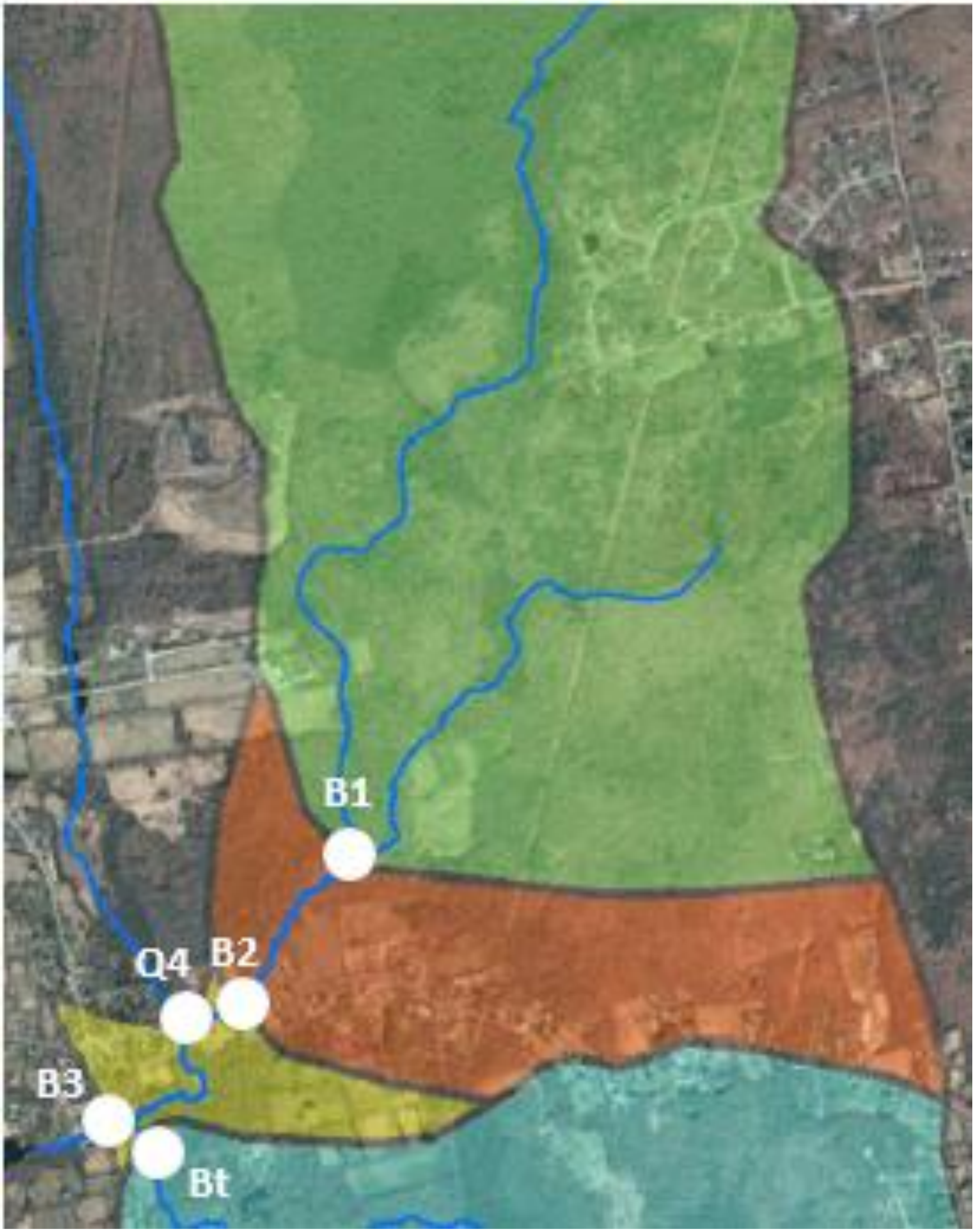
**Dissolved Oxygen**

DO levels met criteria at all stations, during both dry and wet weather (Figures B-34 and B-35). There was not a single DO violation at any of the stations on Borden Brook.

**Specific Conductance**

Specific conductance was low, during both dry and wet weather (Figures B-36 and B-37). The highest recorded specific conductance level (193 µs/cm) was well below guidance (835 µs/cm).

**Figure 9. Borden Brook Sampling Station Locations.**



**pH**

*Dry Weather*

The mean dry-weather pH values met criteria at the Weetamoo Woods sampling station (Station B1) and at Main Street (Station B3) (Figure B-38). The mean dry-weather pH fell outside the criteria range (6.5-9.0) at East Road (Station B2). The mean dry-weather pH at East Road was 9.1.

*Wet Weather*

The mean pH at each Borden Brook station met criteria (Figure B-39). However, the pH values on 11/30/16 and 10/25/17 at all stations were acidic, and fell below the criteria range (6.5-9.0).

**Turbidity**

There were no violations of the turbidity criteria, at any of the three Borden Brook stations, during dry or wet weather (Figures B-40 and B-41).

**Total Suspended Solids (TSS)**

TSS values recorded in Borden brook were low, during both dry and wet weather (Figures B-42 and B-43). All the samples, in both the main stem of the stream and in its tributaries, were well below the 25,000 ug/l EPA guidance.

**Total Phosphorus**

*Dry Weather*

As discussed previously the RIDEM numeric criteria for phosphorus (25 ug/l) is applicable to rivers only at the point where they enter lakes, ponds or in this case, reservoirs. For Borden Brook, this criterion is applied only at the terminal station at Main Street (Station B3), which is located approximately 650 ft. from Nonquit Pond. For the remaining upstream stations, the EPA Gold Book Standard guidance value (100 ug/l) is applied.

Approximately 54-94% of total phosphorus, in the Borden Brook stations, was in dissolved form. The TP concentrations at the two most upstream stations (the Weetamoo Woods and East Rd. stations) were low, during all dry-weather sampling events (the highest TP concentration at these stations was 15 ug/l) (Figure B-44). The mean dry-weather TP concentration at the East Road station of Borden Brook (Station B2), was 11 ug/l. The mean dry-weather TP concentration at Main Street (Station B3) was 71 ug/, which exceeds the 25 ug/l criteria applied to rivers near their discharge point to ponds. The mean of 71 ug/l was largely influenced by a high value (170 ug/l) recorded on 5/4/17. There was a 569% increase in mean dry-weather TP from East Road (Station B2) to Main Street (Station B3). Much of the increase appears due to the two tributaries (Quaker Creek and an unnamed tributary) that merge into Borden Brook between the Borden Brook East Road and Main Street sampling stations (Stations B2 and B3). The TP concentrations in the two tributaries, at their confluence with Borden Brook, was significantly higher than TP concentrations at East Road (Station B2). The mean dry-weather TP concentrations at the terminus of Quaker Creek and the unnamed tributary were 42 and 64 ug/l, respectively.

*Wet Weather*

Mean wet-weather TP at Weetamoo Woods (Station B1) and East Road (Station B2) were 52 and 62 ug/l, respectively (the criteria value applicable to these upstream stations is 100 ug/l). There were only slight increases in mean TP from Weetamoo Woods to East Road and from East Road to Main Street (Figure B-45). The mean wet-weather TP at Main Street (Station B3) was 71 ug/l, which exceeded the criteria applied to this station (25 ug/l). The mean wet-weather TP concentrations at the terminus of Quaker Creek and the unnamed tributary were 152 and 100 ug/l, respectively. This would indicate that the increase at Main Street (Station B3), was caused mainly by the tributaries, entering Borden Brook just upstream.

**Total Nitrogen**

*Dry Weather*

Most of the nitrogen at all the main stem and tributary stations was in the form of organic-N (Figure B-46). The mean dry-weather total nitrogen concentrations at all sampling stations exceeded EPA's suggested guidance (610 ug/l). The mean TN concentration at the headwaters in Weetamoo Woods (Station B1) was 890 ug/l. The mean TN decreased to 624 ug/l at East Road (Station B2). The highest mean TN concentration was recorded at Main Street (1,219 ug/l), which represented a 95% increase from East Road. The increase in mean wet-weather TN, recorded at Main Street (Station B3), was likely due to tributary inflow just upstream (the mean wet-weather TN at the terminus of Quaker Creek and the unnamed tributary was 1,272 ug/l and 915 ug/l, respectively).

*Wet Weather*

The mean wet-weather TN concentration at the headwaters in Weetamoo Woods (Station B1) was 860 ug/l (Figure B-47). The mean TN decreased to 835 ug/l at East Road (Station B2). The highest mean TN concentration was recorded at Main Street (1,170 ug/l), which represented a 40% increase from East Road. The increase in mean wet-weather TN, recorded at Main Street (Station B3), was probably due to tributary inflow just upstream (the mean wet-weather TN at the terminus of Quaker Creek and the unnamed tributary was 1,138 ug/l and 1,205 ug/l, respectively).

**Ammonia**

With only one exception, ammonia levels were below the detection limit at all stations on Borden Brook, during both dry and wet weather (Figures B-46 and B-47).

**Organic-N**

*Dry Weather*

The mean dry-weather organic-N concentration at Weetamoo Woods (Station B1) was 1,093 ug/l (Figure B-46). The suggested guidance for organic-N is 300 ug/l. The organic-N concentration decreased significantly to 504 ug/l, at East Road (Station B2). There was a 117% increase in the mean dry-weather organic-N concentration at Main Street (Station B3). The mean dry-weather organic-N concentration at Main Street was 1,093 ug/l. The mean dry-weather organic-N concentrations at the terminus of Quaker Creek and the unnamed tributary were 1,058 and 778 ug/l, respectively. The increase in mean organic-N at Main Street could have been the result of tributary inflow.

*Wet Weather*

The mean wet-weather organic-N concentration at Weetamoo Woods (Station B1) was 777 ug/l (Figure B-47). The organic-N concentration decreased at East Road (Station B2), to 662 ug/l. There was a 48% increase in the mean wet-weather organic-N concentration at Main Street (Station B3). The mean wet-weather organic-N concentration at Main Street was 977 ug/l. The mean wet-weather organic-N concentrations at the terminus of Quaker Creek and the unnamed tributary were 977 ug/l and 1,060 ug/l respectively. The increase in mean organic-N at Main Street could have been the result of tributary inflow from Quaker Creek and the unnamed tributary.

**Nitrate**

Mean nitrate concentrations, during both dry and wet weather, were below the guidance level (310 ug/l), at all stations on Borden Brook, except for one wet-weather sample taken on 10/25/17 (Figures B-46 and B-47). The nitrate concentration on that date was 320 ug/l.

**Dissolved Organic Carbon**

*Dry Weather*

The highest mean dry-weather DOC concentration (16,467 ug/l) was recorded at Weetamoo Woods (Station B1). Mean DOC concentrations at the other Borden stations were very similar (Figure B-48).

*Wet Weather*

The mean dry-weather DOC concentration, at Weetamoo Woods, was 21,733 ug/l (Figure B-49). The mean DOC concentrations at the other Borden stations were little changed.

**Enterococci**

*Dry Weather*

The dry-weather enterococci geomeans were well below Health criteria (54 MPN/100 ml) (Figure B-50).

*Wet Weather*

Wet-weather enterococci geomeans exceeded criteria at all stations on Borden Brook (Figure B-51). The mean wet-weather enterococci geomean at Weetamoo Woods (Station B1) was 531 MPN/100 ml. The enterococci geomean increased slightly at East Road (Station B2) to 623 MPN/100 ml. There was an 179% increase in the wet-weather enterococci geomean at Main Street (Station B3). The geomean at Main Street was 1,736 MPN/100 ml. The wet-weather geomeans at the terminus of Quaker Creek and the unnamed tributary were 865 and 2,488 MPN/100 ml. The elevated enterococci geomean at Main Street was, at least partially, caused by inflow from the unnamed tributary.

**Metals**

Only samples from the Borden Brook Main Street Station (Station B3), were analyzed for metals. The Main Street station is the only sampling station on Borden Brook, located downstream of Quaker Creek, and the Tiverton Landfill. With the exception of dissolved lead, all dry and wet-weather metals concentrations were below criteria levels.

**Dissolved Lead**

*Dry Weather*

Dissolved lead concentrations at Main Street (Station B3) exceeded criteria, during two of the three dry-weather sampling events (Figure B-27). The mean dry-weather lead concentration at Station B3 was 0.981 ug/l (an 625% increase from the terminal station of Quaker Creek).

*Wet Weather*

Dissolved lead concentrations at Main Street (Station B3) exceeded criteria, during all three wet-weather sampling events, although the 10/25/17 sample did not meet quality assurance (Figure B-28). The mean wet-weather lead concentration at Station B3 was 1.30 ug/l (an 145% increase from the wet-weather mean at the terminal station of Quaker Creek).

**Targeted Wet-Weather Sampling**

A single supplementary wet-weather sample was taken of direct stormwater runoff impacted by a manure pile. The manure pile was located at the end of a short paved drive accessing a pasture (Station Bm, Figure 11). The manure pile is located on the north side of East Road, between telephone pole Nos. 100 and 101. Stormwater from this location eventually flows into Borden Brook, just upstream of the East Road sampling station (Station B2). The sample was analyzed for enterococci only. The enterococci concentration of the sample was 10,700 MPN/100 ml, which is more than two orders of magnitude higher than the criteria (54 MPN/100 ml).

***4.4.2. Pollution Sources***

**Station B1. Weetamoo Woods**

*Land use*

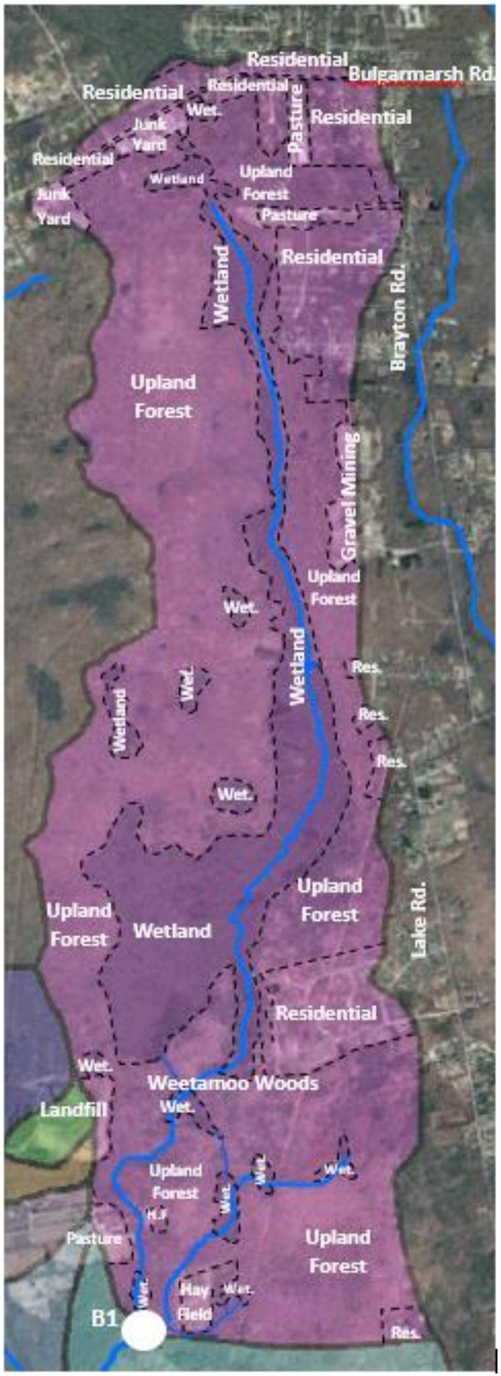
Borden Brook arises from an extensive linear swamp, which stretches from south of Bulgarmarsh Road to Weetamoo Woods in the southern portion of the subwatershed. Despite its depiction as an uninterrupted channel in the base map in Figure 10, an inspection of aerial photographs reveals that there are extensive areas where there is no discernable channel and where there are likely broad areas of standing water.

Most of the development in the Upper Borden Brook area is located on the periphery of the watershed, with a significant vegetated buffer adjacent to the stream in most places. The extreme eastern portion of the Tiverton Landfill, as well as a pasture and hayfield are located on the southwestern edge of the watershed.

However, the pasture and hay field are located about 100 feet from the stream channel and the landfill is located at least 300 feet from the channel.

At the northern edge of the watershed, on Bulgarmarsh Road, are residential areas, a pasture, and two junk yards. The easternmost junkyard is located within close proximity to the wetland, comprising the headwaters of Borden Brook. The remaining developed areas, at the northern end of the subwatershed, are located far from the stream or any contiguous wetland areas.

**Figure 10. Station B1: Weetamoo Woods.**



There are residential areas along the eastern side of the subwatershed, as well as a pasture, and a gravel mining operation. However, there is a significant vegetated buffer (> 100 ft.) near developed areas, adjacent to the stream and any contiguous wetlands.

There is a hay field in Weetamoo Woods, at the southern end of the subwatershed, which lies in close proximity to Borden Brook and tributary (within 50 ft.). Unlike pastures, which are associated with livestock, there does not appear to any grazing associated with this field.

*Summary of Pollutant Exceedances and Identification of Potential Sources*

Sampling at Station B1, located at the southern end of Weetamoo Woods, revealed elevated levels of total nitrogen (TN) and DOC during both dry and wet weather (Table 11). Total nitrogen was largely comprised of organic-N. Enterococci levels were elevated during wet weather only.

Although the extensive swamp contiguous to Borden Brook, is likely a source of the elevated pollutant concentrations, recorded at Station B1, developed areas on the periphery of the subwatershed that border the wetland, may also contribute to the high pollutant levels. These areas may include the Tiverton Landfill, residential areas, and pastures. It is noted that the Tiverton Landfill is located 340-700 ft. from the stream channel and there was no evidence of concentrated surface flow.

*Dry-Weather Exceedances and Potential Sources*

Elevated dry-weather organic-N and dissolved organic carbon are likely the result of the decay of organic material, and to a lesser extent wildlife waste, within the extensive swamp contiguous to Borden Brook. The swamp is characterized by large areas of standing water, for much of the year, which results in the accumulation of organic material and the development of an organic soil.

*Wet-Weather Exceedances and Potential Sources*

Wet-weather TN and organic-N means were similar to those documented during dry weather. The mean DOC concentration was significantly higher during wet weather.

Elevated enterococci concentrations, recorded in wet weather, were possibly the result of wildlife waste, generated within the wetland, contiguous to the stream. Bacteria from previously drier areas, may have been transported to the stream once the edges of the swamp were inundated from the rainfall.

**Table 11. Station B1: Weetamoo Woods. Summary of Pollutant Exceedances.**

| | | | Station Means[1] | |
|---|---|---|---|---|
| | Units | Criteria/Guidance Concentration | Dry Weather | Wet Weather |
| TN | ug/l | 610 | 890 | 860 |
| Organic-N | ug/l | 300 | 786 | 777 |
| Enterococci | MPN/100 ml | 54 | 4 [2] | 531 |

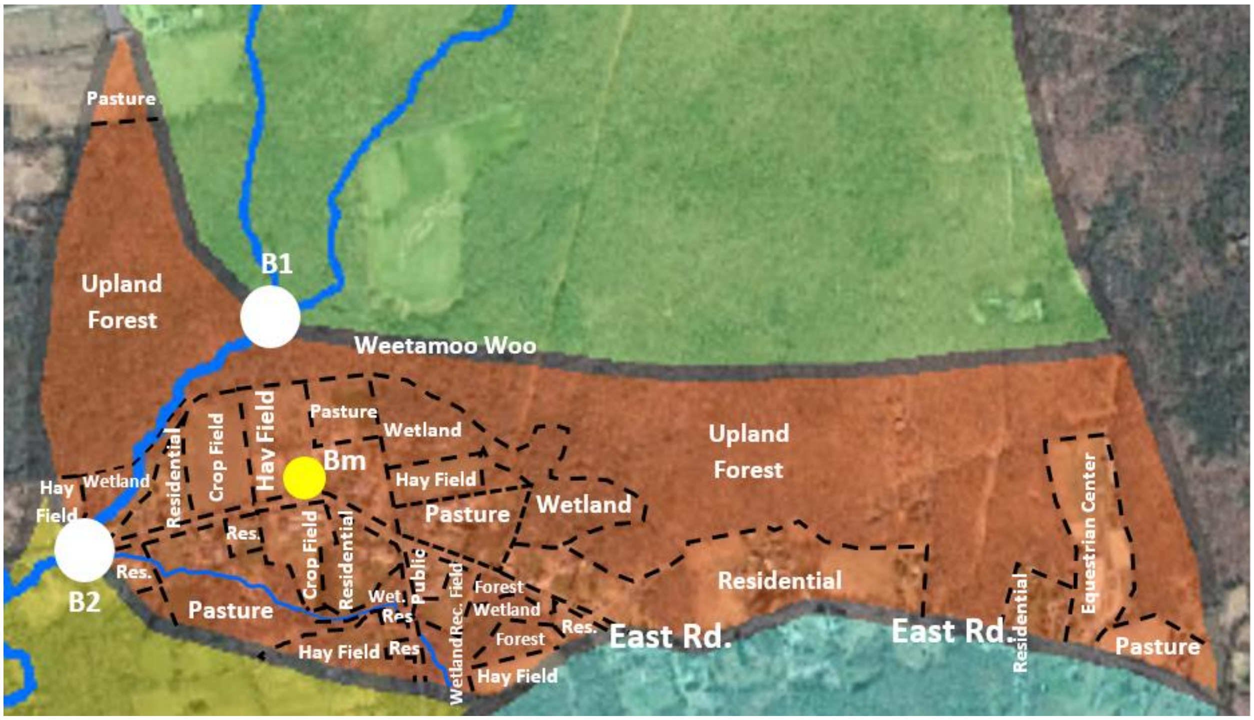
1. Enterococci value is a geomean.
2. Meets Applicable Criteria/Guidance.

## Station B2. East Road.

*Land use*

There are few developed properties, on the main stem of Borden Brook, adjacent to the short reach of stream, between Stations B1 and B2 (Figure 11). A hay field and two residential properties are located adjacent to Borden Brook, immediately north of East Road. There is at least a 20-40 ft. vegetative buffer along the stream at these properties (Photos 53 and 54). The remaining properties, north of East Road have at least a 100-ft. vegetated buffer along the stream.

**Figure 11. Station B2: East Road.**




There are several different land uses in the central and western portions of the subwatershed, including pastures, an equestrian center, residential areas, hay fields, and a crop field. Although these properties are distant to Borden Brook, the road could potentially provide a pathway for polluted stormwater runoff, to reach the stream. An example of this is a manure pile, located next to a hayfield, adjacent to the north side of East Road. The manure pile is located at the end of a short paved sunken drive, near the roadway (Photo 55). Another example is a chicken pen at the top-of-bank of a roadway ditch on the southern shoulder of East Road (Photo 56).

The manure pile on the north side of East Road is a source of bacteria and likely nutrients to the stream. Stormwater runoff was observed entering a roadside ditch from the manure pile, which discharges to Borden Brook just upstream of Station B2. As previously discussed, stormwater from the manure pile was sampled and the enterococci concentration was 10,700 MPN/100 ml, which is more than two orders of magnitude higher than the criteria (54 MPN/100 ml).

A small tributary discharges to Borden Brook, south of East Road, where Borden Brook crosses the roadway, immediately upstream of Station B2. It appears that most of the land, south of East Road, drains to the tributary. Downstream of Eight Road Way, the tributary flows, past a residence (Photo 57) and crop field (Photos 58 and 59), through another residence (Photo 60), and through a pasture (Photos 61 through 64), with no vegetated buffer in places. The tributary then flows past a couple of residential properties, where there is again no significant vegetated buffer (Photo 65).

*Summary of Pollutant Exceedances and Identification of Potential Sources*

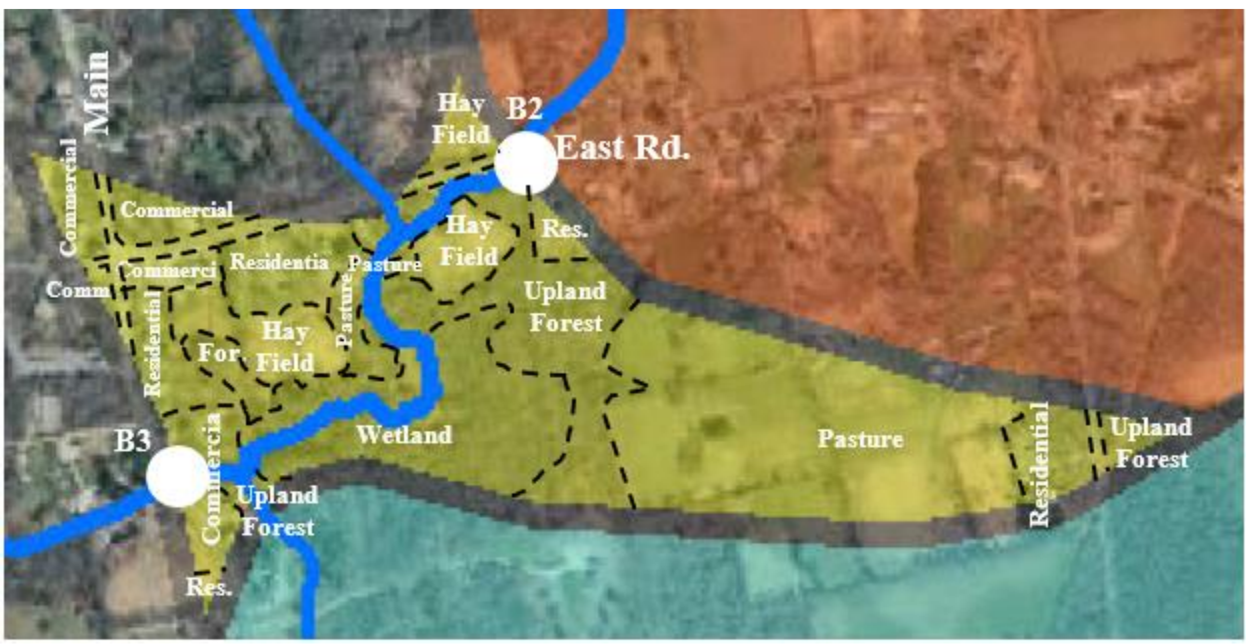
There were no significant increases in pollutant concentrations exceeding criteria/guidance at Station B2, during either dry or wet weather. However, potential pollution sources were visually observed. The tributary flows through a pasture, where cattle appear to have access to the stream. The pasture is a potential dry and wet-weather source of nutrients, bacteria, and turbidity. There was also an inadequate buffer along the stream as it flowed past a crop field, and residential properties, although the area adjacent to the stream at the crop field was grassed and not actively tilled.

**<u>Station B3 Main Road</u>**

*Land use*

Borden Brook flows through a wetland corridor through much of the subwatershed, between Stations B2 and B3 (Figure 12). As the stream bends away from Station B2 and East Road, it flows past a hay field on its southern bank, where there is little to no vegetated buffer. Inspection of aerial photographs reveals that the hay field was actively grazed until at least 2011. Immediately downstream of the hayfield, Quaker Brook crosses East Road, and discharges into Borden Brook.

**Figure 12. Station B3: Main Road.**



There is a pasture (i.e. actively grazed area) that straddles the stream, between the confluence with Quaker Creek and a sharp bend in the river. Much of the pasture directly abuts the stream, with no vegetated buffer, and with clumps of manure in close proximity to the stream (Photos 66 and 67). A bridge allows animal access from barns on the west side of the river to its eastern bank (Photo 68). A manure pile was observed approximately 30 ft. from the river's western bank (Photo 69). Much of the pasture is seasonally wet and mucky, especially areas immediately adjacent to the stream.

The stream flows through a broad wetland corridor, downstream of the pasture. A hayfield borders the wetland corridor to the north of the stream. An unnamed tributary discharges to Borden Brook to the rear of commercial properties on Main Road. There is a small pond immediately downstream of the confluence of Borden Brook and the tributary (Photo 70). Station B3 was located at an old mill dam, at the downstream end of the pond, approximately 700 ft. upstream of Nonquit Pond (Photos 71 and 72). The flow over the mill dam had a strong orange tinge, which may be the result of natural acids coloring the water. There are commercial properties on Main Road, adjacent to Station B3, including offices and several small retail shops, including a metal working shop. Several of these commercial properties have lawns that extend to the top of the streambank (Photo 73). There are also several commercial and residential properties in the northwest part of the subwatershed, in the Four Corners area, near the intersection of Main Road and East Road.

*Summary of Pollutant Exceedances and Identification of Potential Sources*

The mean total nitrogen (TN) increased significantly, during both dry and wet weather. Total phosphorus (TP) increased significantly during dry weather only (Table 12).

**Table 12. Station B3. Main Road: Summary of Significant Pollutant Concentration Increases.**

| | | | Station Mean | | % Increase Relative to Upstream Main Stem Station | |
|---|---|---|---|---|---|---|
| | **Units** | **Criteria/Guidance Concentration** | **Dry Weather** | **Wet Weather** | **Dry Weather** | **Wet Weather** |
| **TP** | ug/l | 25 [1] | 71 | 74 | 569 | * |
| **TN** | ug/l | 610 | 1,219 | 1,170 | 95 | 40 |
| **Organic-N** | ug/l | 300 | 1,093 | 977 | 117 | 48 |
| **Lead** | ug/l | ** | 0.981 | 1.300 | *** | *** |

* No significant change or decrease in pollutant concentration relative to the upstream station.
** Criteria is hardness dependent.
***Station B3 was the only station on Borden Brook that was sampled for dissolved lead.

*Dry-Weather Exceedances and Potential Sources*

The mean dry-weather TP concentration increased from 11 ug/l at East Road (Station B2) to 71 ug/l at Main Street (Station B3). The increase in mean dry-weather TP at the Main Street Station was probably due in part to elevated levels in the two tributaries that discharge into Borden Brook just upstream of Main Street. The mean dry-weather TP concentrations at the terminus of Quaker Creek and the unnamed tributary were

42 ug/l and 64 ug/l, respectively. The pasture adjacent to Borden Brook, located between Stations B2 and B3, may also be a source of phosphorus. Livestock have direct access to the stream at this location, and manure and physical disturbance of stream and wetland sediments may be responsible for at least some of the increase in TP. Finally, phosphorus may be released from anoxic wetland sediments, from the swamp located upstream of Main Road.

The mean dry-weather TN concentration nearly doubled from Station B2 to Station B3. The increase was caused by a doubling of organic-N. The mean dry-weather TN concentration increased from 624 ug/l at East Road (Station B2) to 1,219 ug/l at Main Street (Station B3). The increase in mean dry-weather TN at the Station B3 was probably due in part to elevated levels in the two tributaries that discharge into Borden Brook just upstream of Main Street. The mean dry-weather TN concentrations at the terminus of Quaker Creek and the unnamed tributary were 1,272 ug/l and 915 ug/l, respectively. Other potential sources of nitrogen include livestock in the pasture, failing septic systems and fertilizer from nearby businesses and residences, and the decay of organic material in the wetland.

The lead concentration at Station B3 exceeded criteria, during two of the three dry-weather sampling events. The source of lead causing these exceedances is unknown; potential sources include an unknown legacy source, illegal dumping into the stream channel or small run-of-the river pond immediately upstream of Station B3, or an unidentified active source.

*Wet-Weather Exceedances and Potential Sources*

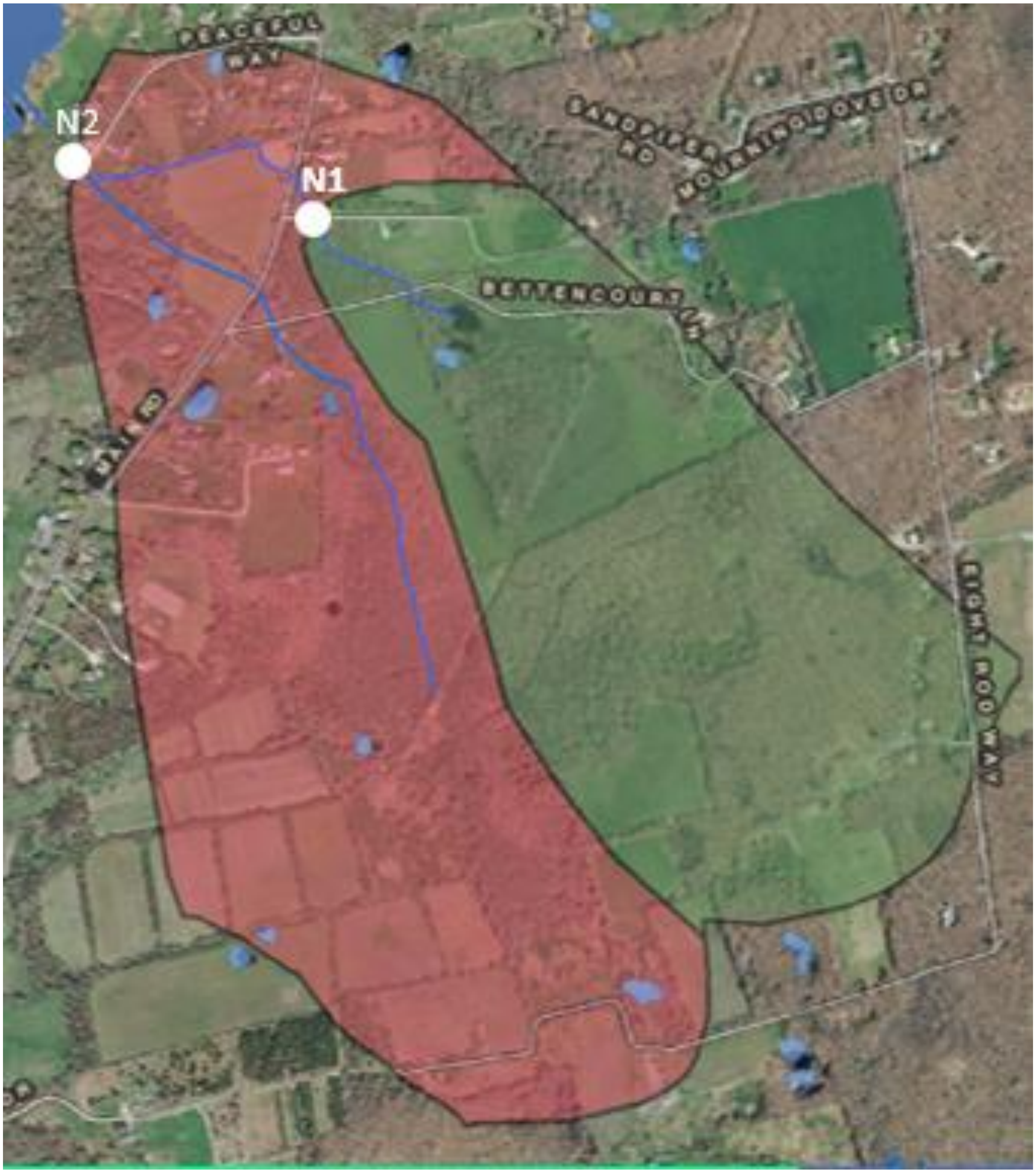
Wet-weather TN and organic-N mean concentrations were similar to those recorded during dry weather Although there was a significant increase in wet-weather nitrogen from Stations B2 to B3, the percent increase was not as pronounced as that recorded during dry weather. The mean wet-weather TN concentration increased from 835 ug/l at East Road (Station B2) to 1,170 ug/l at Main Street (Station B3). The increase in mean wet-weather TN at the Station B3 was again probably due in part to elevated levels in the two tributaries that discharge into Borden Brook. The mean wet-weather TN concentrations at the terminus of Quaker Creek and the unnamed tributary were 1,138 ug/l and 1,205 ug/l, respectively. Other potential wet weather sources include stormwater runoff from the pasture, failing septic systems, fertilizers, runoff from commercial and residential properties, and stormwater runoff from East Road.

The dissolved lead concentration at Station B3 exceeded criteria, during three of the three wet-weather sampling events (although the third wet-weather sample did not meet quality assurance). Potential sources are the same as the dry-weather sources, discussed above.

## 4.5. Unnamed Tributary to Nonquit Pond

There were two sampling stations located on the unnamed tributary to Nonquit Pond. One station (Station N1) is located near the headwaters of the northeast fork of the stream, immediately downstream of a dairy farm. The other sampling station (Station N2) is located at the cul-de-sac of Peaceful Way, immediately downstream of the confluence of the northeast fork and the southwest forks of the stream. Station N2 is located downstream of a crop field. The locations of the sampling stations on the unnamed tributary to Nonquit Pond are shown in Figure 13 below.

**Figure 13. Unnamed Tributary to Nonquit Pond Sampling Station Locations.**



### *4.5.1. Results*

**Dissolved Oxygen**

DO levels met criteria in the unnamed tributary to Nonquit Pond, during both dry and wet weather (Figures B-52 and B-53). There was not a single DO violation.

**Specific Conductance**

Specific conductance was low, during both dry and wet weather (Figures B-54 and B-55). The highest recorded specific conductance level (177 µs/cm) was well below guidance (835 µs/cm).

**pH**

The mean pH values met criteria, during both dry and wet weather; (Figures B-56 and B-57).

**Turbidity**

*Dry-Weather*

The mean dry-weather turbidity concentration met criteria at both stations of the unnamed tributary to Nonquit Pond (Figure B-58). There was a single exceedance of the turbidity criteria, during dry weather, at Barnswallow Street (Station N1). Turbidity was 10.0 NTU on 5/4/17 at Station N1.

*Wet-Weather*

The mean wet-weather turbidity concentration met criteria (6.9 NTU) at the Barnswallow Street (station N1), but exceeded criteria at Peaceful Way (Station N2) (Figure B-59). The mean wet-weather turbidity at Peaceful Way was 8.6 NTU.

**Total Suspended Solids (TSS)**

*Dry-Weather*

The mean dry-weather TSS concentration met criteria at both stations of the unnamed tributary to Nonquit Pond (Figure B-60). There was a single exceedance of the TSS (30,000 ug/l), at Barnswallow Street (Station N1), which occurred on the same date as the turbidity exceedance (5/4/17).

*Wet-Weather*

There were no violations of the TSS guidance, during wet weather, at either station on the unnamed tributary to Nonquit Pond (Figure B-61).

**Total Phosphorus**

*Dry Weather*

The mean dry-weather TP concentration at Barnswallow Street (Station N1) was 333 ug/l, exceeding the EPA guidance applied to this upstream station (100 ug/l) (Figure B-62). The mean dry-weather TP concentration decreased significantly at the downstream station (Station N2), to 21 ug/l.

***Wet Weather***

The mean wet-weather TP concentrations exceeded criteria at both stations on the unnamed tributary to Nonquit Pond (Figure B-63). The mean wet-weather TP concentration at Barnswallow Street (Station N1) was 310 ug/l exceeding the EPA guidance applied to this upstream station (100 ug/l). Although the mean wet-weather TP concentration decreased significantly at the downstream station (Station N2), it was still elevated (197 ug/l). Since the Peaceful Way station (Station N2) is located only 300 feet from Nonquit Pond, the stricter RIDEM criteria (25 ug/l) was applied to results from this station.

**Total Nitrogen**

*Dry Weather*

The mean dry-weather TN concentration at Barnswallow Street (Station N1) was 1,363 ug/l (exceeding the guidance value of 610 ug/l). The mean dry-weather TN concentration downstream at Peaceful Way (Station N2) increased to 1,620 ug/l (Figure B-64).

*Wet Weather*

The mean wet-weather TN concentration at the Barnswallow Street (Station N1) was 848 ug/l (Figure B-65). There was a 52% increase in mean wet-weather TN concentration downstream at Peaceful Way (Station N2), where mean wet-weather TN was 1,287 ug/l.

**Ammonia**

Ammonia levels at both stations on the unnamed tributary to Nonquit Pond, were below the criteria levels, during both dry and wet weather. The highest ammonia concentration, recorded in the unnamed tributary to Nonquit, was 461 ug/l (Figures B-64 and B-65).

**Organic-N**

*Dry Weather*

The mean dry-weather organic-N concentration at the Barnswallow Street (Station N1), was 1,142 ug/l (Figure B-64). The mean dry-weather organic-N concentration decreased significantly to 868 ug/l at Peaceful Way (Station N2.) The mean dry-weather organic-N concentrations exceeded EPA guidance (300 ug/l) at both stations of the unnamed tributary to Nonquit Pond.

*Wet Weather*

The mean wet-weather organic-N concentration at the Barnswallow Street (Station N1), was 720 ug/l (Figure B-65). The mean wet-weather organic-N concentration increased by 37% to 989 ug/l at Peaceful Way (Station N2.)

**Nitrate**

*Dry Weather*

The mean dry-weather nitrate concentration, at Barnswallow Street (33 ug/l), was well below the EPA guidance of 310 ug/l (Figure B-64). The mean nitrate concentration increased by 1,595% to 565 ug/l at Peaceful Way (Station N2).

*Wet Weather*

The mean wet-weather nitrate concentration, at both stations of the unnamed tributary, were below EPA guidance (Figure B-65).

**Dissolved Organic Carbon**

*Dry Weather*

The mean dry-weather DOC concentration at Barnswallow Street (Station N1) was 22,300 ug/l (Figure B-66). The mean dry-weather DOC concentration decreased significantly at Peaceful Way (Station N2).

*Wet Weather*

The mean wet-weather DOC concentration at Barnswallow Street (Station N1) was 17,300 ug/l (Figure B-67). There was no significant change in the mean wet-weather DOC concentration at Peaceful Way (Station N2).

**Enterococci**

*Dry Weather*

The geomean dry-weather enterococci levels at both stations of the unnamed tributary to Nonquit Brook were below criteria levels (Figure B-68).

*Wet Weather*

The single wet-weather enterococci sample exceeded criteria (54 MPN/100 ml) at Barnswallow Street (Figure B-69). The wet-weather enterococci concentration at Barnswallow Street on 4/26/17 was 4,350 MPN/100ml. The enterococci concentration at Peaceful Way (Station N2) decreased significantly on this date. There was no flow at Barnswallow Street during the 10/25/17 sampling event. However, the wet-weather enterococci concentration at Peaceful Way was 15,500 MPN/100 ml.

**Targeted Wet-Weather Sampling**

Supplementary wet-weather samples were taken of direct stormwater runoff, at two locations in the watershed of the unnamed tributary to Nonquit Pond. One sample (Nw) was taken in the wetland headwaters of the eastern fork of the unnamed tributary, near a cattle farm (Figure 14). This sample was analyzed for bacteria only. The enterococci concentration at this location was 54,800 MPN/100 ml, which is three orders of magnitude higher than the criteria (54 MPN/100 ml).

The second sample (Nc) was collected from runoff from a cornfield (not from the stream directly), located to the west side of Main Road (Figure 15). This sample was taken near the east fork of the unnamed tributary, downstream of Station N1, and upstream Station N2 and the confluence of the eastern and western forks of the unnamed tributary. This sample was analyzed for turbidity and TP. The turbidity of the stormwater sample was 140 NTU, which is significantly higher than the criteria value of 6.9 NTU. The TP concentration of the sample was 790 ug/l, which also is significantly higher than the criteria value.

#### ***4.5.2. Pollution Sources***

**Station N1. Barnswallow Street**

*Land use*

Station N1 is located at Barnswallow Street, on the northeast fork an unnamed tributary to Nonquit Pond (Figure 14). The stream originates from a wetland, south of Bettencourt Lane. It flows past the northeast corner of a pasture, just south of Bettencourt Lane. It then flows through a small wetland area and upland forest.

Inspection of aerial photographs as well as field observations revealed that cows graze within the wetland at the headwaters of the stream. Cattle have access to saturated and flooded areas along much of the perimeter of the wetland. However, it appears that during the winter, cattle are restricted to a fenced area at least 50 ft. east of the wetland (Photos 75 and 76). There is an earthen berm, along the perimeter of the corner of the wetland, where it lies closest to the eastern pasture (Photo 77). At other times of year, cattle graze within the wetland, particularly in a significant area of standing water to the north of the forested portion of the wetland (Photos 78 and 79), including a small farm pond (Photo 80). Cows also graze in wet meadows on the southeastern side of the wetland (Photo 81). A pasture area to the west of the wetland appears to have a better-quality forage (Photo 82). However, the southern portion of the pasture, adjacent to the forested wetland is seasonally saturated, and cattle have direct access to the stream at the northeast corner of the pasture (Photo 83).

There are a few 2-3-acre residential lots (former farm land) located to the north of Bettencourt Lane. All but one lot have sufficient vegetative buffers. There is a single residential lot, to the immediate north of Bettencourt lane, where there is no vegetative buffer in place.

The subwatershed, to the southeast of the wetland and surrounding pasture areas, consists largely of forested area. Pastures and a residential area, located at the southeastern end of the subwatershed are located far from the headwaters of the stream, and any surface waters.

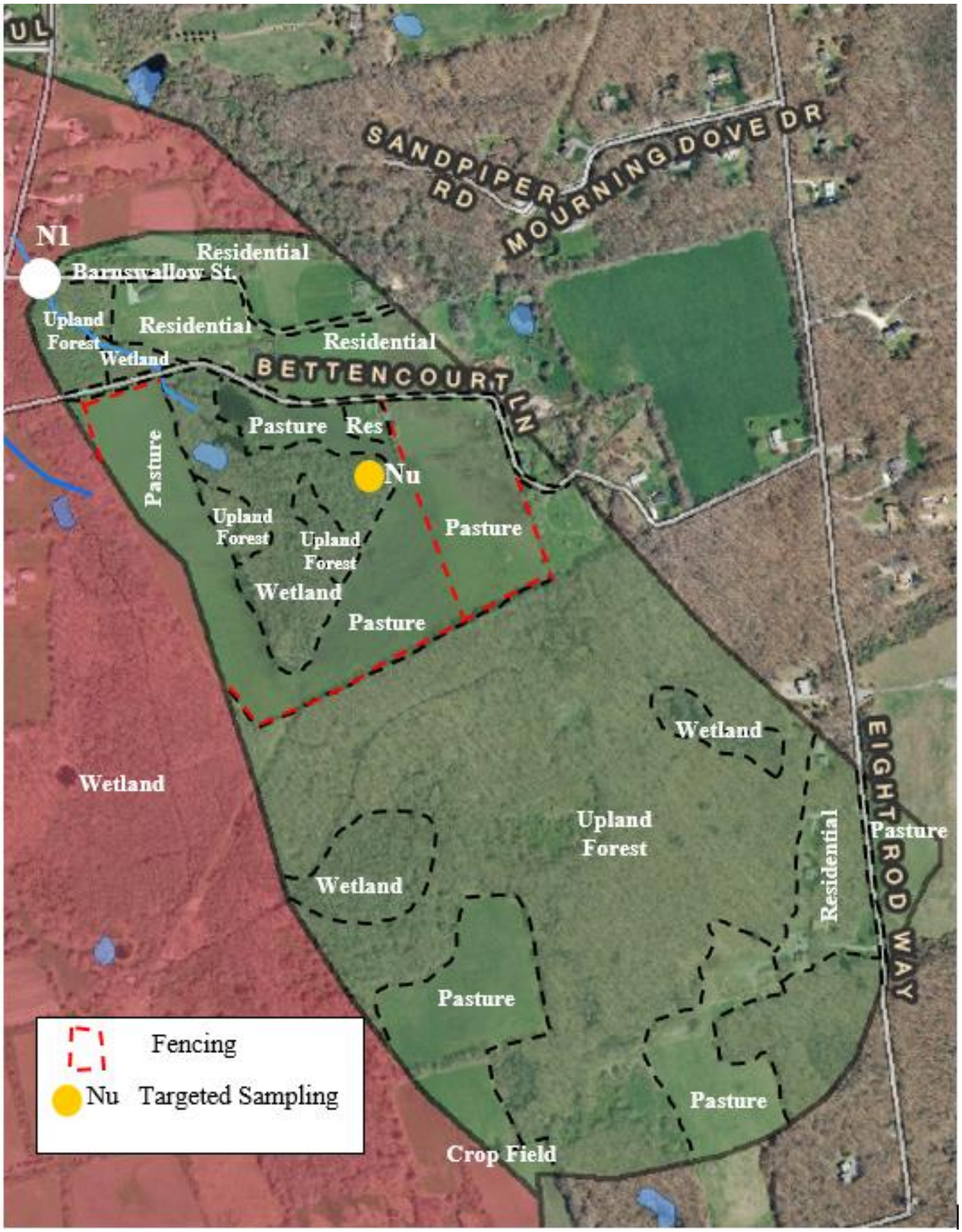
*Summary of Pollutant Exceedances and Identification of Potential Sources*

Elevated mean concentrations of total phosphorus (TP), total nitrogen (TN), organic-N, and dissolved organic carbon (DOC) were documented at Station N1, during both dry and wet weather. The mean enterococci concentration exceeded criteria, during wet weather only.

*Dry-Weather Exceedances and Potential Sources*

The mean dry-weather TP concentration (333 ug/l) was more than three times higher than the EPA guidance value (Table 13). The probable source was cows grazing in the wetland, which forms the headwaters of the northeastern fork of the unnamed tributary to Nonquit Pond (Figure 14). As previously discussed, cows have access to most of the perimeter of the wetland, including flooded areas adjacent to the stream. Inspection of historic aerial photographs shows cattle in the flooded area. Cattle were observed in the subject area, during at least one field inspection.

**Figure 14. Station N1: Barnswallow Street: Northeast Fork of Unnamed Tributary to Nonquit Pond.**




The mean dry-weather TN concentration (1,363 ug/l) was more than twice as high as the guidance value. TN was largely in the form of organic-N. As previously discussed, organic-N was also elevated at Station B1 (890 ug/l), in a relatively undeveloped subwatershed of Borden Brook, with significant areas of hydrologically connected wetlands. It seems likely that some of the organic-N originates from the wetland at the headwaters of the unnamed tributary to Nonquit Pond. However, the mean dry-weather organic-N concentration at Station N1 is significantly higher than the value documented at the upstream station of Borden Brook (located in a mostly undeveloped watershed). It is therefore likely that a significant amount of organic-N results from cattle in the flooded pasture area.

**Table 13. Station N1: Barnswallow Street. Summary of Pollutant Exceedances.**

| | | | Station Means[1] | |
|---|---|---|---|---|
| | **Units** | **Criteria/Guidance Concentration** | **Dry Weather** | **Wet Weather** |
| **TP[1]** | ug/l | 100 | 333 | 310 |
| **TN** | ug/l | 610 | 1,363 | 848 |
| **Organic-N** | ug/l | 300 | 1,142 | 720 |
| **Enterococci** | MPN/100 ml | 54 | 37[2] | 4,350 |

1. Enterococci value is a geomean.
2. Meets Criteria/Guidance

The mean dry-weather DOC level at Station N1 was elevated. As previously discussed, DOC levels were elevated at all stations, even in relatively undeveloped watersheds. The source of the elevated DOC levels were probably cattle in the flooded area, as well as decomposition of organic matter within the wetland itself.

*Wet-Weather Exceedances and Potential Sources*

The mean wet-weather TP concentration was similar to the dry-weather value (Table 13). In addition to cattle in the flooded area on the north side of the wetland, cattle have access to a wet meadow area to the southeast of the forested portion of the wetland, and also wet areas in the western pasture area, bordering the forested wetland (Figure 14). Contaminated stormwater runoff from this area, probably was discharged to the wetland and tributary.

Although the mean wet-weather TN, organic N, and DOC concentrations were elevated, they were significantly less than those documented during dry weather. The wet-weather source of both nitrogen and DOC was probably cattle in the seasonally flooded area, as well as contaminated stormwater from grazed areas further afield.

The wet-weather enterococci geomean was elevated, relative to DEM's criteria. The likely source may have been contaminated runoff, from areas grazed by cattle. However, wildlife waste from the forested wetland area, may also have contributed to the high wet-weather bacteria concentration. Targeted wet-weather sampling was conducted on January 23, 2018, at the most upstream possible area within the forested wetland. The enterococci, at this location, was 54,800 MPN/100 ml, more than three orders of magnitude higher than the criteria value. There was an earthen berm wrapped around the perimeter of the wetland, upslope of the sampling location (Station Nu; Figure 14). It appeared that stormwater from pasture areas, discharged to the wetland downstream of the berm and sampling point. Although the extreme variability of bacteria samples makes it difficult to identify sources, it appears that the wetland itself may have been a significant source of bacteria, in addition to stormwater contaminated by cattle.

**Station N2. Peaceful Way**

*Land use*

The southwest fork of the unnamed tributary to Nonquit Pond arises from a large linear wetland. With the exception of a residential area, to the immediate south of Bettencourt Lane, the stream flows through a wetland corridor, which is bordered mainly by upland forest.

Agricultural areas at the southern end of the wetland, are distant (>500 ft.) to the stream headwaters. Agricultural land bordering the southern end of the wetland consists of hay field, and is not actively tilled. The hay field area is largely fallow, and is infrequently mowed. There is a small sliver of pasture, located within the subwatershed, to the east of the wetland, on the south side of Bettencourt Lane. However, there is at least a 70-ft. buffer of upland forest between the pasture and wetland.

There are crop fields located to the west of the headwaters of the stream. However, the crop fields are separated from the wetland, by a stone wall and hedgerow and a buffer of closely cropped grass and trees. A small farm pond is located more than 200 ft. from the crop fields, and there was no indication of concentrated surface runoff to the farm pond, during a rain event. Further north is another area of crop field, but it is separated from the wetland by upland forest, which is a least 100 ft. wide. Immediately south of Bettencourt Lane, the stream flows along the edge of a six-acre residential lawn (Photo 84), and past an old farm pond on the residential property, which is hydrologically connected to the stream by two short swales (Photo 85). Downstream (west) of Main Road, the southwest fork of the unnamed tributary flows through a crop field, with an approximately 15 ft. wide vegetated buffer along the stream (Photo 86).

The lower portion of the northeast fork of the unnamed tributary, downstream of Station N1, flows along the edge of a residential lawn. Downstream of Main Road, the northeast fork flows along the northern edge of the crop field, discussed above, with 0-15 ft. of vegetated buffer. The northeast fork then flows across a stone wall, forming a property boundary between the crop field and residential lots. The tributary then flows parallel to the stone wall, at the rear of five residential lots. With the exception of one residential lot with a 50-ft. vegetative buffer, the remaining lots have lawns that extend to the top-of-bank of the tributary (Photo 87). Turbid runoff was observed in an erosional swale at the northern edge of the cornfield, which discharges to the tributary near the confluence of its two forks (Photo 88). The two forks of the unnamed tributary converge just upstream of Station N2, which is located approximately 400 ft. upstream of Nonquit Pond.

*Dry-Weather Exceedances and Potential Sources*

Nitrate was the only pollutant, which had significant increase in concentration, during dry weather, the nitrate concentration at Station N2 (565 ug/l) was greater than that recorded at Station N1, by a factor of about 16-fold (Table 14). As previously discussed nitrate is highly soluble. Nitrate can travel long distances in groundwater, even in areas with significant vegetated buffers. The source of nitrate could be any agricultural area or residential area in the subwatershed (many residential properties in the area were recently developed from agricultural lands and are serviced by on-site sewage disposal systems). The crop field, located to the west of Main Road, is a more proximal potential source of nitrate.

*Wet-Weather Exceedances and Potential Sources*

There was a significant increase in mean wet-weather turbidity (Table 14). As previously discussed, a significant vegetated buffer is associated with the stream, along most of its length (Figure 15). The likely source of turbidity is the crop field, located immediately downstream of Main Road. Bare soil and relatively steep gradients in this area create favorable conditions for soil transport to the stream.

**Table 14. Station N2. Peaceful Way: Summary of Significant Pollutant Concentration Increases.**

| | | | Station Mean | | % Increase Relative to Upstream Main Stem Station | |
|---|---|---|---|---|---|---|
| | Units | Criteria/Guidance Concentration | Dry Weather | Wet Weather | Dry Weather | Wet Weather |
| Turbidity | NTU | 6.9 | 2.5 [1] | 8.6 | * | 56 |
| TN | ug/l | 610 | 1,620 | 1,287 | * | 52 |
| Organic-N | ug/l | 310 | 868 | 989 | * | 37 |
| Nitrate | ug/l | 300 | 565 | 147 [1] | 1,595 | * |
| Enterococci | MPN/100 ml | 54 | 19 [1] | 4,204 | * | ** |

1. Meets criteria/guidance.
2. The enterococci concentration at Peaceful Way on 10/25/17 was 15,500 MPN. There was no flow upstream at Barnswallow Street (Station N1) on this date.

* No significant change or decrease in pollutant concentration relative to the upstream station.

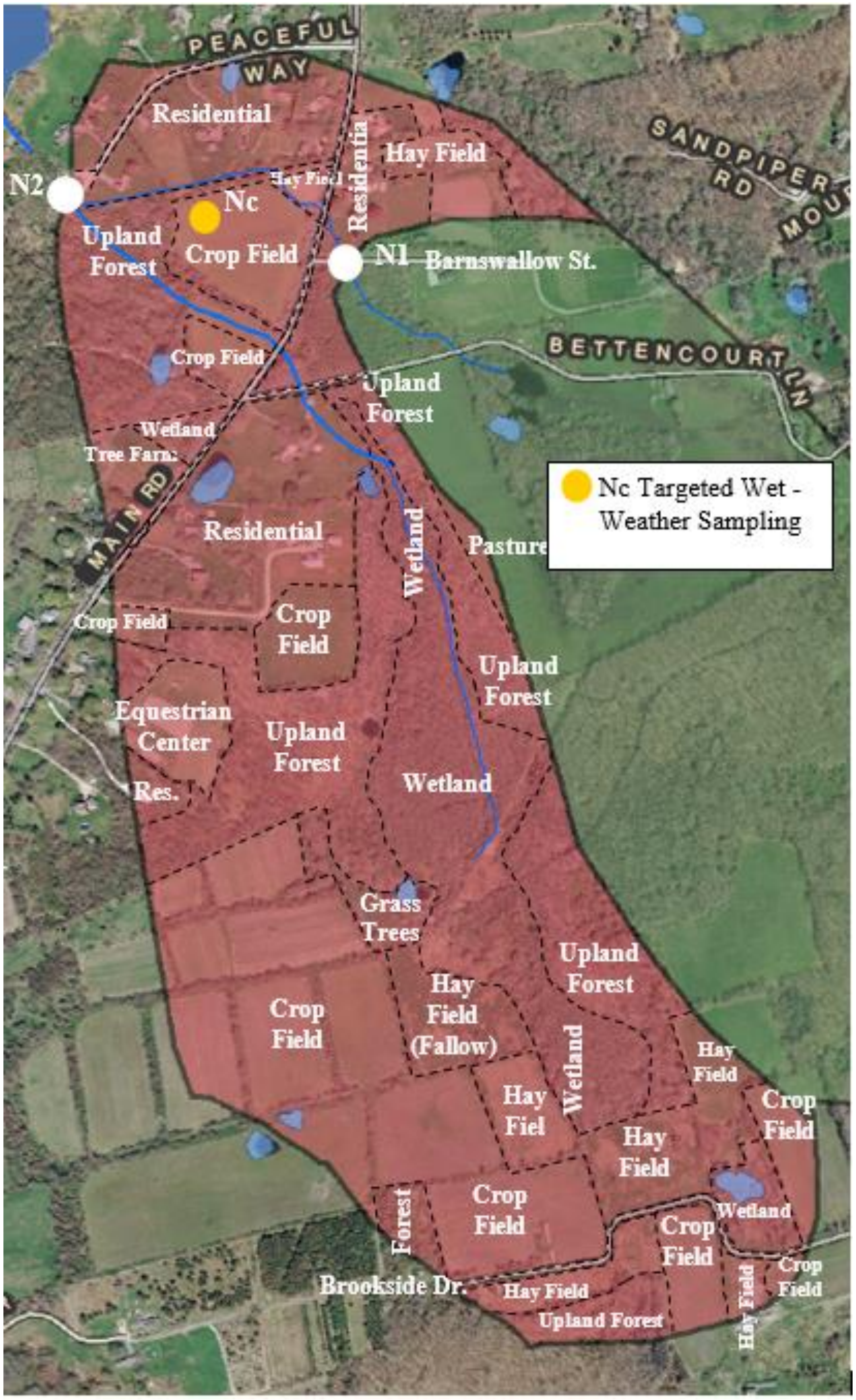
** The enterococci concentration was 15,500 MPN/100 ml on 10/25/17, when there was no flow upstream at Station N1.

As previously discussed, a targeted wet-weather sample (Nc) was collected from runoff from the subject crop field discussed above (not directly from the stream). This sample was taken near the east fork of the unnamed tributary, downstream of Station N1, and upstream Station N2 and the confluence of the eastern and western forks of the unnamed tributary (Figure 15). The turbidity of the stormwater sample was 140 NTU, which is significantly higher than the site-specific criteria value of 6.9 NTU. The TP concentration of the sample was 790 ug/l, which also is significantly higher than the criteria value. The targeted sampling confirmed that the crop field is a source of turbidity and TP.

There was also a significant wet-weather increase in mean TN at Station N2. Nitrogen was mainly in the form of organic-N. Probable sources include the crop field, located downstream of Main Road, and the residential lawn located south of Bettencourt Lane. Both areas have an inadequate vegetated buffer, adjacent to the stream. Another potential source is the decay of organic material, and to a lesser extent wildlife waste, within the extensive swamp associated with the upper reaches of the stream.

Although there was no increase in the mean wet-weather enterococci concentration at Station N2, there was no flow at the upstream Station N1 on 10/25/17, when the concentration at Station N2 was 15,500 MPN/100 ml. Potential sources of enterococci bacteria, include the single residential property south of Bettencourt Lane (pet and wildlife waste and potentially a failing septic system), and the crop field downstream of Main Road (wildlife waste). The extensive wetland corridor, along the upper reaches of the stream, is another potential source (wildlife waste).

**Figure 15. Station N2: Peaceful Way.**



# APPENDIX A. WATER QUALITY RESULTS

(return to document)

**Figure A-1. Quaker Creek and Landfill Swale Water Quality Results.**

| Quaker Creek (RI0010031R-04) and Landfill Swale Sampling Results | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Dry-Weather Results | | | | | Wet-Weather Results | | | | | All-Weather Results | |
| Parameter | Units | Criteria/ Guidance[1] | Sampling Station | 3/22/2017 | 5/4/2017 | 6/1/2017 | Station Mean[2] | Stream Mean[2,3] | 11/30/2016 | 4/26/2017 | 10/25/2017 | Station Mean[2] | Stream Mean[2,3] | Station Mean[2] | Stream Mean[2,3] |
| | | | Q1 | 2.5 | 11.3 | 14.4 | | | 9.6 | 11.9 | 15.8 | | | | |
| | | | LDF | | 9.1 | 14.1 | | | | 12.4 | 17.0 | | | | |
| **Temperature** | °C | | Q2 | 2.7 | 10.6 | 14.7 | | | | 11.9 | 17.0 | | | | |
| | | | Q3 | | 13.6 | 15.7 | | | | 12.2 | 16.8 | | | | |
| | | | Q4 | 3.0 | 11.1 | 14.6 | | | 9.6 | 12.4 | 17.2 | | | | |
| | | | Q1 | 5.6 | **1.5** | **1.5** | **2.9** | | | **4.8** | **2.7** | **3.8** | | **3.2** | |
| | | | LDF | | 8.5 | 7.7 | 8.1 | | | 9.2 | **4.8** | 7.0 | | **7.6** | |
| **DO** | mg/l | Instantaneous minimum conc. ≥ 5 mg/l | Q2 | 8.5 | **3.8** | **3.5** | 5.3 | 5.2 | **4.2** | 6.0 | **3.6** | **4.6** | **4.3** | **4.9** | 5.0 |
| | | | Q3 | | 8.9 | 6.3 | 7.6 | | | 8.0 | **0.1** | **4.1** | | 5.8 | |
| | | | Q4 | 8.9 | 5.7 | **3.4** | 6.0 | | 5.5 | 6.1 | **1.7** | **4.4** | | 5.2 | |
| | | | Q1 | 301 | 295 | 244 | 280 | | | 321 | 617 | 469 | | 356 | |
| | | | LDF | | | **1,161** | **1,161** | | | **1,038** | **1,279** | **1,159** | | **1,159** | |
| **Specific Conductance** | µs/cm | 835 µs/cm | Q2 | 363 | 346 | 353 | 354 | 303 | 356 | 328 | **2,406** | **1,030** | 544 | 692 | 495 |
| | | | Q3 | | 350 | 337 | 344 | | | 304 | 349 | 327 | | 335 | |
| | | | Q4 | 246 | 276 | 224 | 249 | | 347 | 184 | 231 | 254 | | 251 | |
| | | | Q1 | 8.9 | **9.9** | **9.5** | **9.4** | | | **9.9** | 6.9 | 8.4 | | 9.0 | |
| | | | LDF | | **9.3** | **9.1** | **9.2** | | | 8.8 | 7.1 | 8.0 | | 8.6 | |
| **pH** | | 6.5-9.0 | Q2 | 8.7 | **10.0** | 8.9 | **9.2** | **9.2** | 6.3 | 8.9 | 7.1 | 7.4 | 7.7 | 8.3 | 8.4 |
| | | | Q3 | | **9.7** | 8.6 | **9.2** | | | 8.7 | 6.8 | 7.8 | | 8.5 | |
| | | | Q4 | 8.6 | **9.6** | 8.6 | 8.9 | | 6.7 | 8.6 | 6.6 | 7.3 | | 8.1 | |

## Quaker Creek (RI0010031R-04) and Landfill Swale Sampling Results (cont.)

| Parameter | Units | Criteria/ Guidance[1] | Sampling Station | Dry-Weather Results | | | | | Wet-Weather Results | | | | | All-Weather Results | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 3/22/2017 | 5/4/2017 | 6/1/2017 | Station Mean[2] | Stream Mean[2,3] | 11/30/2016 | 4/26/2017 | 10/25/2017 | Station Mean[2] | Stream Mean[2,3] | Station Mean[2] | Stream Mean[2,3] |
| | | | Q1 | 0.73 | 1.7 | 1.7 | 1.4 | | | 1.1 | **7.9** | 4.5 | | 2.6 | |
| | | | *Q1 Dup.* | | *1.8* | | | | | | | | | | |
| | | | LDF | | **85** | **40** | **63** | | | **20** | **320** | **170** | | **116** | |
| | | | *LDF Dup.* | | | | | | | 20.0 | | | | | |
| **Turbidity** | NTU | 6.9 NTU (≤ 5 NTU over background) | Q2 | 0.78 | 1.5 | 2.7 | 1.7 | 1.8 | 6.7 | **11.0** | **12.0** | **9.9** | 6.7 | 5.8 | 3.8 |
| | | | *Q2 Dup.* | *0.77* | | | | | | | | | | | |
| | | | Q3 | | 1.9 | 5.1 | 3.5 | | | **9.9** | 4.3 | **7.1** | | 5.3 | |
| | | | Q4 | 0.3 | 1.3 | 1.8 | 1.1 | | 2.6 | 2.3 | **9.5** | 4.8 | | 3.0 | |
| | | | *Q4 Dup.* | | | *1.8* | | | 2.6 | | | | | | |
| | | | Q1 | 8,000 | 2,800 [4] | 3,200 | 5,600 | | | 3,600 | 8,000 | 5,800 | | 5,700 | |
| | | | *Q1 Dup.* | | *2,000* | | | | | | | | | | |
| | | | LDF | | 19,000 | 17,000 | 18,000 | | | 16,000 | 24,000 | 20,000 | | 19,000 | |
| | | | *LDF Dup.* | | | | | | | 16,000 | | | | | |
| **TSS** | ug/l | 25,000 ug/l | Q2 | 8000 [4] | 2,000 | 3,600 | 2,800 | 5,200 | 6,000 | 5,200 | 7,200 | 6,133 | 5,711 | 4,800 | 5,373 |
| | | | *Q2 Dup.* | *12,000* | | | | | | | | | | | |
| | | | Q3 | | 3,200 | 6,400 | 4,800 | | | 11,000 | 4,000 | 7,500 | | 6,150 | |
| | | | Q4 | 16,000 | 1,600 | 2,800 | 6,800 | | 1,600 [4] | 1,600 | 4,800 | 3,200 | | 5,360 | |
| | | | *Q4 Dup.* | | | *2,800* | | | <1000 | | | | | | |
| | | | Q1 | < 10 | 38 | 35 | 26 | | | 20 [5] | **280** | **150** | | 76 | |
| | | | *Q1 Dup.* | | *39* | | | | | | | | | | |
| | | | LDF | | 73 | 92 | 83 | | | **130** | **140** | **135** | | **109** | |
| | | | *LDF Dup.* | | | | | | | 140 | | | | | |
| **TP** | ug/l | 100 ug/l | Q2 | < 10 | 42 | 52 | 33 | 39 | 70 | **110** | **160** | **113** | **135** | 73 | 77 |
| | | | *Q2 Dup.* | *< 10* | | | | | | | | | | | |
| | | | Q3 | | 52 | 73 | 63 | | | **130** | **110** | **120** | | 91 | |
| | | | Q4 | < 10 | 56 | 66 | 42 | | **120** [6] | 46 | **290** | **152** | | 97 | |
| | | | *Q4 Dup.* | | | *67* | | | 95 | | | | | | |

## Quaker Creek (RI0010031R-04) and Landfill Swale Sampling Results (cont.)

| | | | | Dry-Weather Results | | | | | Wet-Weather Results | | | | | All-Weather Results | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Units** | **Criteria/ Guidance[1]** | **Sampling Station** | **3/22/2017** | **5/4/2017** | **6/1/2017** | **Station Mean[2]** | **Stream Mean[2,3]** | **11/30/2016** | **4/26/2017** | **10/25/2017** | **Station Mean[2]** | **Stream Mean[2,3]** | **Station Mean[2]** | **Stream Mean[2,3]** |
| | | | Q1 | < 10 | 21 | 29 | 18 | | | 30[5] | 24 | 27 | | 22 | |
| | | | *Q1 Dup.* | | *23* | | | | | | | | | | |
| | | | LDF | | 11 | 16 | 14 | | | 54[6] | < 10 | 30 | | 15 | |
| | | | *LDF Dup.* | | | | | | | 67 | | | | | |
| **DP** | ug/l | | Q2 | < 10 | 25 | 33 | 21 | 24 | 32 | 62 | 58 | 51 | 63 | 36 | 39 |
| | | | *Q2 Dup.* | | | | | | | | | | | | |
| | | | Q3 | | 30 | 33 | 32 | | | 71 | 61 | 66 | | 49 | |
| | | | Q4 | < 10 | 39 | 35 | 26 | | 67 | 33 | **190** | 97 | | 62 | |
| | | | *Q4 Dup.* | | | *37* | | | *66* | | | | | | |
| | | | Q1 | <100 | <100 | 168 | 89 | | | 113 | < 100 | 82 | | 86 | |
| | | | *Q1 Dup.* | | *<100* | | | | | | | | | | |
| | | | LDF | | 64,600 | 51,900[7] | 64,600 | | | 11,600 | 27,700 | 19,650 | | 34,633 | |
| | | | *LDF Dup.* | | | | | | | | | | | | |
| **Ammonia** | ug/l | Acute: 1,320-48,800 ug/l Chronic:389-6,670 ug/l (pH and temperature dependent) | Q2 | **800** | **570** | **1,220** | 863 | 377 | < 100 | **1,490** | 100 | 547 | 295 | 705 | 338 |
| | | | *Q2 Dup.* | *900* | | | | | | | | | | | |
| | | | Q3 | | 270 | **869** | 570 | | | **946** | < 100 | 498 | | 534 | |
| | | | Q4 | <100 | <100 | <100 | 50 | | < 100 | < 100 | < 100 | 50 | | 50 | |
| | | | *Q4 Dup.* | | | *<100* | | | *< 100* | | | | | | |

| Quaker Creek (RI0010031R-04) and Landfill Swale Sampling Results (cont.) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **Dry-Weather Results** | | | | | **Wet-Weather Results** | | | | | **All-Weather Results** | |
| **Parameter** | **Units** | **Criteria/ Guidance[1]** | **Sampling Station** | **3/22/2017** | **5/4/2017** | **6/1/2017** | **Station Mean[2]** | **Stream Mean[2,3]** | **11/30/2016** | **4/26/2017** | **10/25/2017** | **Station Mean[2]** | **Stream Mean[2,3]** | **Station Mean[2]** | **Stream Mean[2,3]** |
| | | | Q1 | **1,000** | 1,090 [4] | **715** | **858** | | | **1,590** | **1,100** | **1,345** | | **1,101** | |
| | | | *Q1 Dup.* | | *1,520* | | | | | | | | | | |
| | | | LDF | | **65,200** | **24,500 [7]** | **65,200** | | | **11,600** | **29,700** | **20,650** | | **35,500** | |
| | | | *LDF Dup.* | | | | | | | *12,800* | | | | | |
| **TKN** | ug/l | 300 ug/l | Q2 | **1,800** | **2,010** | **1,220** | **1,677** | **1,262** | **900** | **4,500** | **1,200** | **2,200** | **1,692** | **1,938** | **1,477** |
| | | | *Q2 Dup.* | *1,700* | | | | | | | | | | | |
| | | | Q3 | | **1,450** | **1,100** | **1,275** | | | **3,850** | **700** | **2,275** | | **1,775** | |
| | | | Q4 | **1,200** | **1,260** | **865** | **1,108** | | **600** | **1,580** | **900** | **1,027** | | **1,068** | |
| | | | *Q4 Dup.* | | | *955* | | | *700* | | | | | | |
| | | | Q1 | **950** | 589 [4] | **547** | **749** | | | **1,477** | **1,050** | **1,264** | | **1,006** | |
| | | | *Q1 Dup.* | | *1,470* | | | | | | | | | | |
| | | | LDF | | **600** | | **600** | | | 0 | **2,000** | **1,000** | | **867** | |
| | | | *LDF Dup.* | | | | | | | | | | | | |
| **Organic N** | ug/l | 300 ug/l | Q2 | **1,000** | **1,440** | 0 | **813** | **852** | **850** | **3,010** | **1,100** | **1,653** | **1,397** | **1,233** | **1,125** |
| | | | *Q2 Dup.* | | | | | | | | | | | | |
| | | | Q3 | | **1,180** | 231 | **706** | | | **2,904** | **650** | **1,777** | | **1,241** | |
| | | | Q4 | **1,150** | **1,210** | **815** | **1,058** | | **550** | **1,530** | **850** | **977** | | **1,018** | |
| | | | *Q4 Dup.* | | | *905* | | | | | | | | | |

| Quaker Creek (RI0010031R-04) and Landfill Swale Sampling Results (cont.) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Dry-Weather Results | | | | | Wet-Weather Results | | | | | All-Weather Results | |
| Parameter | Units | Criteria/ Guidance[1] | Sampling Station | 3/22/2017 | 5/4/2017 | 6/1/2017 | Station Mean[2] | Stream Mean[2,3] | 11/30/2016 | 4/26/2017 | 10/25/2017 | Station Mean[2] | Stream Mean[2,3] | Station Mean[2] | Stream Mean[2,3] |
| | | | Q1 | 310 | < 50 | 130 | 155 | | | 300 | 60 | 180 | | 165 | |
| | | | *Q1 Dup.* | | *< 50* | | | | | | | | | | |
| | | | LDF | | **1,000** | **2,400** | **1,700** | | | **7,150** | **1,030** | **4,090** | | **2,895** | |
| | | | *LDF Dup.* | | | | | | | *7,100* | | | | | |
| **Nitrate** | ug/l | 310 ug/l | Q2 | **1,060** | **490** | **730** | **760** | **457** | **970** | **1,450** | 80 | **833** | **1,417** | **797** | **428** |
| | | | *Q2 Dup.* | *1,030* | | | | | | | | | | | |
| | | | Q3 | | **850** | **940** | **895** | | | **1,140** | < 50 | **583** | | **739** | |
| | | | Q4 | **440** | < 50 | < 50 | 163 | | 190 | 120 | < 50 | 112 | | 118 | |
| | | | *Q4 Dup.* | | | *< 50* | | | *200* | | | | | | |
| | | | Q1 | **1,310** | **1115** [4] | **845** | **1,078** | | | **1,890** | **1,160** | **1,525** | | **1,301** | |
| | | | *Q1 Dup.* | | *1,545* | | | | | | | | | | |
| | | | LDF | | **66,200** | **26,900** [7] | **66,200** | | | **18,750** | **30,730** | **24,740** | | **38,560** | |
| | | | *LDF Dup.* | | | | | | | *19,900* | | | | | |
| **TN** | ug/l | 610 ug/l | Q2 | **2,860** | **2,500** | **1,950** | **2,437** | **1,762** | **1,870** | **5,950** | **1,280** | **3,033** | **2,128** | **2,735** | **1,945** |
| | | | *Q2 Dup.* | *2,730* | | | | | | | | | | | |
| | | | Q3 | | **2,300** | **2,040** | **2,170** | | | **4,990** | **725** | **2,858** | | **2,514** | |
| | | | Q4 | **1,640** | **1,285** | **890** | **1,272** | | **790** | **1,700** | **925** | **1,138** | | **1,205** | |
| | | | *Q4 Dup.* | | | *980* | | | *900* | | | | | | |

## Quaker Creek (RI0010031R-04) and Landfill Swale Sampling Results (cont.)

| Wet-Weather Results | | | | Wet-Weather Results | | | | | Wet-Weather Results | | | | | Wet-Weather Results | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Units** | **Criteria/ Guidance[1]** | **Sampling Station** | **3/22/2017** | **5/4/2017** | **6/1/2017** | **Station Mean[2]** | **Stream Mean[2,3]** | **11/30/2016** | **4/26/2017** | **10/25/2017** | **Station Mean[2]** | **Stream Mean[2,3]** | **Station Mean[2]** | **Stream Mean[2,3]** |
| | | | Q1 | **9,720** | **18,500** | **14,300** | **14,173** | | | **10,600** | **22,500** | **16,550** | | **15,124** | |
| | | | *Q1 Dup.* | | *18,300* | | | | | | | | | | |
| | | | LDF | | **24,900** | **28,300** | **26,600** | | | **16,800** [4] | **15,600** | **15,600** | | **22,933** | |
| | | | *LDF Dup.* | | | | | | | *20,500* | | | | | |
| **DOC** | ug/l | 4,000 ug/l | Q2 | **10,100** | **18,800** | **16,800** | **15,233** | **14,367** | **16,900** | **14,300** | **22,100** | **17,767** | **17,860** | **16,500** | **16,030** |
| | | | *Q2 Dup.* | *10,000* | | | | | | | | | | | |
| | | | Q3 | | **17,900** | **13,800** | **15,850** | | | **13,400** | **34,200** | **23,800** | | **19,825** | |
| | | | Q4 | **7,920** | **17,000** | **13,200** | **12,707** | | **12,500** | **12,700** | **19,400** | **14,867** | | **13,787** | |
| | | | *Q4 Dup.* | | | *13,600* | | | 12,500 | | | | | | |
| | | | Q1 | 10 | 10 | **89** | 21 | | | **1,500** | **1,560** | **1,530** | | **116** | |
| | | | *Q1 Dup.* | | *10* | | | | | | | | | | |
| | | | LDF | | 20 | **> 2420** | **220** | | | **14,100** [6] | **504** | **2,666** | | **766** | |
| | | | *LDF Dup.* | | | | | | | *17,300* | | | | | |
| **Enterococci** | MPN/100 ml | Geometric Mean Density: 54 MPN/100 ml | Q2 | < 10 | 10 | **756** | 34 | 28 | | **1,620** | **6,490** | **3,242** | **2,092** | **209** | **167** |
| | | | *Q2 Dup.* | *10* | | | | | | | | | | | |
| | | | Q3 | | 10 | **1,990** | 141 | | | **1,590** | **7,700** | **3,499** | | **703** | |
| | | | Q4 | < 10 | < 10 | 44 | 10 | | | **243** | **3,080** | **865** | | **61** | |
| | | | *Q4 Dup.* | | | *42* | | | | | | | | | |

1. Criteria/guidance apply to all stations except LDF (landfill swale), which is a management control structure and not a Water of the State.
2. All averages expressed as means except enterococci, which is expressed as geometric mean.
3. Stream averages include all main stem stations but not landfill swale (LDF).
4. Sample did not meet quality control/quality assurance parameters and was not used to calculate means.
5. TP less than DP. Values still used to calculate averages, because of low P values.
6. Sample did not meet quality control/quality assurance parameters, but was used to calculate averages because duplicate was relatively similar.
7. Ammonia greater than TKN (ammonia & organic-N). Values not used to calculate means.

**Yellow shading indicates that sampling station is not on main stem of the river and was not used to calculate stream averages.**

**Black bold font indicates an exceedance of water quality criteria**

**Orange font indicates an exceedance of chronic aquatic life criteria.**

**Red font indicates an exceedance of acute aquatic life criteria.**

**Figure A-2. Quaker Creek, Landfill Swale, and Terminal Borden Brook Sampling Station Metals Results**

| Quaker Creek (RI0010031R-04), Terminal Borden Brook Station (RI0010031R-04), and Landfill Swale Sampling Results (Metals) | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Dry-Weather Results | | | | | | | | Wet-Weather Results | | | | | | | | All-Weather Results | |
| **Parameter** | **Units** | **Sampling Station** | **3/22/17 Criteria[1]** | **3/22/17** | **5/4/17 Criteria[1]** | **5/4/17** | **6/1/17 Criteria[1]** | **6/1/17** | **Station Mean** | **Stream Mean[2]** | **11/30/16 Criteria[1]** | **11/30/16** | **4/26/17 Criteria[1]** | **4/26/17** | **10/25/17 Criteria[1]** | **10/25/17** | **Station Mean** | **Stream Mean[2]** | **Station Mean[2]** | **Stream Mean[2]** |
| | | Q1 | | 85,100 | | 93,400 | | 95,600 | 91,367 | | | | | 97,700 | | 141,000 | 119,350 | | 102,560 | |
| | | Q1 Dup. | | | | 93,800 | | | | | | | | | | | | | | |
| | | LDF | | | | 288,000 | | 249,000 | 268,500 | | | | | 177,000 | | 189,000 | 183,000 | | 225,750 | |
| | | LDF Dup. | | | | | | | | | | | | 171,000 | | | | | | |
| | | Q2 | | 78,500 | | 95,800 | | 75,200 | 83,167 | | | 73,800 | | 74,200 | | 88,000 | 78,667 | | 80,917 | |
| **Hardness** | ug/l | Q2 Dup. | | 78,300 | | | | | | 79,800 | | | | | | | | 77,810 | | 72,092 |
| | | Q3 | | | | 90,200 | | 71,300 | 80,750 | | | | | 64,200 | | 57,500 | 60,850 | | 70,800 | |
| | | Q4 | | 49,700 | | 79,400 | | 63,600 | 64,233 | | | 88,900 | | 45,300 | | 47,500 | 60,567 | | 62,400 | |
| | | Q4 Dup. | | | | | | 64,600 | | | | 90,000 | | | | | | | | |
| | | B3 | | 19,300 | | 36,800 | | 18,200 | 24,767 | | | 42,600 | | 18,000 | | 31,900 [3] | 30,300 | | 26,980 | |
| | | B3 Dup. | | | | | | | | | | | | | | 24,300 | | | | |

## Quaker Creek (RI0010031R-04), Terminal Borden Brook Station (RI0010031R-04), and Landfill Swale Sampling Results (Metals) (cont.)

| | | | Dry-Weather Results | | | | | | | | Wet-Weather Results | | | | | | | | All-Weather Results | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | Units | Sampling Station | 3/22/17 Criteria[1] | 3/22/17 | 5/4/17 Criteria[1] | 5/4/17 | 6/1/17 Criteria[1] | 6/1/17 | Station Mean | Stream Mean[2] | 11/30/16 Criteria[1] | 11/30/16 | 4/26/17 Criteria[1] | 4/26/17 | 10/25/17 Criteria[1] | 10/25/17 | Station Mean | Stream Mean[2] | Station Mean[2] | Stream Mean[2] |
| | | Q1 | 1,000 | 654 | 1,000 | **2,840** | 1,000 | **1,500** | **1,665** | | | | 1,000 | 400 | 1,000 | **5,200** | **2,800** | | **2,119** | |
| | | Q1 Dup. | | | | 2,270 | | | | | | | | | | | | | | |
| | | LDF | | | 1,000 | **5,450** | 1,000 | **7,280** | **6,365** | | | | 1,000 | **2,530** | 1,000 | **40,500** | **21,515** | | **13,940** | |
| | | LDF Dup. | | | | | | | | | | | | 2,570 | | | | | | |
| | | Q2 | 1,000 | 389 | 1,000 | **1,230** | 1,000 | **1,300** | 973 | | 1,000 | **1,120** | 1,000 | 747 | 1,000 | **6,170** | **2,679** | | **1,826** | |
| **Total Iron** | ug/l | Q2 Dup. | | 348 | | | | | | 1,104 | | | | | | | | **2,112** | | **1,443** |
| | | Q3 | | | 1,000 | 982 | 1,000 | **1,140** | **1,061** | | | | 1,000 | 1,000 | 1,000 | **1,710** | **1,355** | | **1,208** | |
| | | Q4 | 1,000 | 163 | 1,000 | 949 | 1,000 | 992 | 701 | | 1,000 | 456 | 1,000 | 426 | 1,000 | **3,890** | **1,591** | | **1,146** | |
| | | Q4 Dup. | | | | | | 1,050 | | | | 468 | | | | | | | | |
| | | B3 | 1,000 | 191 | 1,000 | 723 | 1,000 | 458 | 457 | | 1,000 | 412 | 1,000 | 327 | 1,000 | 949 | 563 | | 510 | |
| | | B3 Dup. | | | | | | | | | | | | | | 945 | | | | |
| | | Q1 | 0.22 | 0.090 | 0.23 | < 0.054 | 0.24 | < 0.046 | 0.047 | | | | 0.24 | < 0.054 | 0.31 | < 0.046 | 0.025 | | 0.038 | |
| | | Q1 Dup. | | | | < 0.054 | | | | | | | | | | | | | | |
| | | LDF | | | 0.512 | < 0.054 | 0.463 | 0.057 | 0.042 | | | | 0.366 | 0.094 | 0.383 | < 0.046 | 0.059 | | 0.050 | |
| | | LDF Dup. | | | | | | | | | | | | 0.101 | | | | | | |
| | | Q2 | 0.21 | < 0.054 | 0.24 | < 0.054 | 0.20 | < 0.046 | 0.026 | | 0.20 | < 0.054 | 0.20 | < 0.054 | 0.23 | 0.127 | 0.060 | | 0.043 | |
| **Dissolved Cadmium** | ug/l | Q2 Dup. | | < 0.054 | | | | | | 0.031 | | | | | | | | 0.058 | | 0.042 |
| | | Q3 | | | 0.23 | < 0.054 | 0.19 | < 0.046 | 0.025 | | | | 0.18 | < 0.054 | 0.17 | < 0.046 | 0.025 | | 0.025 | |
| | | Q4 | 0.15 | < 0.054 | 0.21 | < 0.054 | 0.18 | < 0.046 | 0.026 | | 0.23 | < 0.054 | 0.14 | **0.253** | 0.15 | < 0.046 | 0.101 | | 0.063 | |
| | | Q4 Dup. | | | | | | < 0.046 | | | | < 0.054 | | | | | | | | |
| | | B3 | 0.08 | < 0.054 | 0.12 | < 0.054 | 0.08 | < 0.046 | 0.026 | | 0.14 | 0.059 | 0.07 | < 0.054 | 0.11 | 0.062 [3] | 0.043 | | 0.033 | |
| | | B3 Dup. | | | | | | | | | | | | | | < 0.046 | | | | |

## Quaker Creek (RI0010031R-04), Terminal Borden Brook Station (RI0010031R-04), and Landfill Swale Sampling Results (Metals) (cont.)

| | | | Dry-Weather Results | | | | | | | | Wet-Weather Results | | | | | | | | All-Weather Results | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Units** | **Sampling Station** | **3/22/17 Criteria[1]** | **3/22/17** | **5/4/17 Criteria[1]** | **5/4/17** | **6/1/17 Criteria[1]** | **6/1/17** | **Station Mean** | **Stream Mean[2]** | **11/30/16 Criteria[1]** | **11/30/16** | **4/26/17 Criteria[1]** | **4/26/17** | **10/25/17 Criteria[1]** | **10/25/17** | **Station Mean** | **Stream Mean[2]** | **Station Mean[2]** | **Stream Mean[2]** |
| | | Q1 | 64.94 | < 0.57 | 70.08 | < 0.57 | 71.43 | 1.3 | 0.62 | | | | 72.72 | < 0.57 | 98.20 | 1.9 | 1.09 | | 0.8 | |
| | | Q1 Dup. | | | | < 0.57 | | | | | | | | | | | | | | |
| | | LDF | | | 176.26 | 0.85 | 156.46 | 4.9 | 2.88 | | | | 118.30 | 1.3 | 124.8 | 4.5 | 2.9 | | 2.9 | |
| | | LDF Dup. | | | | | | | | | | | | 1.3 | | | | | | |
| | | Q2 | 60.79 | < 0.57 | 71.56 | < 0.57 | 58.68 | 1.3 | 0.62 | | 57.79 | < 1.0 | 58.04 | < 0.57 | 66.75 | 1.0 | 0.60 | | 0.6 | |
| **Dissolved Chromium** | ug/l | Q2 Dup. | | | | | | | | 0.60 | | | | | | | | 0.58 | | 0.59 |
| | | Q3 | | | 68.11 | < 0.57 | 56.18 | 1.3 | 0.79 | | | | 51.56 | < 0.57 | 47.11 | 0.48 | 0.38 | | 0.6 | |
| | | Q4 | 41.80 | < 0.57 | 61.36 | < 0.57 | 51.16 | 0.75 | 0.44 | | 67.3 | < 1.0 | 38.75 | < 0.57 | 40.28 | 0.55 | 0.45 | | 0.4 | |
| | | Q4 Dup. | | | | | | 0.69 | | | | < 1.0 | | | | | | | | |
| | | B3 | 19.27 | < 0.57 | 32.68 | < 0.57 | 18.36 | 0.93 | 0.50 | | 36.85 | < 1.0 | 18.20 | < 0.57 | 29.07 | 0.59 | 0.46 | | 0.5 | |
| | | B3 Dup. | | | | | | | | | | | | | | 0.56 | | | | |
| | | Q1 | 7.80 | 1.18 | 8.45 | 0.607 | 8.62 | 0.939 | 0.909 | | | | 8.78 | 0.839 | 12.01 | 4.28 | 2.56 | | 1.57 | |
| | | Q1 Dup. | | | | 0.657 | | | | | | | | | | | | | | |
| | | LDF | | | 22.11 | 4.42 | 19.53 | 9.05 | 6.74 | | | | 14.59 | 11.8 | 15.43 | 5.36 | 8.58 | | 7.66 | |
| | | LDF Dup. | | | | | | | | | | | | 11.6 | | | | | | |
| | | Q2 | 7.28 | 1.36 | 8.63 | 1.180 | 7.02 | 1.69 | 1.410 | | 6.91 | 2.91 | 6.94 | 2.50 | 8.03 | 3.42 | 2.94 | | 2.18 | |
| **Dissolved Copper** | ug/l | Q2 Dup. | | 1.30 | | | | | | 1.230 | | | | | | | | 2.27 | | 4.07 |
| | | Q3 | | | 8.20 | 1.520 | 6.71 | 1.91 | 1.715 | | | | 6.13 | 2.32 | 5.58 | 1.72 | 2.02 | | 1.87 | |
| | | Q4 | 4.93 | 1.12 | 7.35 | 1.140 | 6.08 | 0.886 | 1.049 | | 8.10 | 1.62 | 4.55 | 1.70 | 4.74 | 1.43 | 1.58 | | 1.32 | |
| | | Q4 Dup. | | | | | | 0.963 | | | | 1.59 | | | | | | | | |
| | | B3 | 2.20 | 0.627 | 3.81 | 1.930 | 2.09 | 1.24 | 1.266 | | 4.32 | 1.81 | 2.07 | 1.30 | 3.37 | 2.84[3] | 1.56 | | 1.38 | |
| | | B3 Dup. | | | | | | | | | | | | | | 1.81 | | | | |

| Quaker Creek (RI0010031R-04), Terminal Borden Brook Station (RI0010031R-04), and Landfill Swale Sampling Results (Metals) (cont.) | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Dry-Weather Results** | | | | | | | | **Wet-Weather Results** | | | | | | | | **All-Weather Results** | |
| **Parameter** | **Units** | **Sampling Station** | **3/22/17 Criteria[1]** | **3/22/17** | **5/4/17 Criteria[1]** | **5/4/17** | **6/1/17 Criteria[1]** | **6/1/17** | **Station Mean** | **Stream Mean[2]** | **11/30/16 Criteria[1]** | **11/30/16** | **4/26/17 Criteria[1]** | **4/26/17** | **10/25/17 Criteria[1]** | **10/25/17** | **Station Mean** | **Stream Mean[2]** | **Station Mean[2]** | **Stream Mean[2]** |
| | | Q1 | 2.11 | 0.168 | 2.34 | 0.156 | 2.40 | 0.134 | 0.153 | | | | 2.45 | 0.183 | 3.65 | 0.260 | 0.222 | | 0.18 | |
| | | Q1 Dup. | | | | 0.171 | | | | | | | | | | | | | | |
| | | LDF | | | 7.790 | < 0.142 | 6.69 | 0.288 | 0.180 | | | | 4.660 | 1.38 | 5.00 | 0.430 | 0.905 | | 0.542 | |
| | | LDF Dup. | | | | | | | | | | | | 1.22 | | | | | | |
| | | Q2 | 1.93 | 0.149 | 2.40 | 0.187 | 1.84 | 0.199 | 0.178 | | 1.81 | 0.283 | 1.82 | 0.361 | 2.19 | 0.465 | 0.370 | | 0.27 | |
| **Dissolved Lead** | ug/l | Q2 Dup. | | 0.172 | | | | | | 0.170 | | | | | | | | 0.37 | | 0.356 |
| | | Q3 | | | 2.25 | 0.183 | 1.74 | 0.286 | 0.235 | | | | 1.55 | 0.236 | 1.37 | 0.353 | 0.295 | | 0.26 | |
| | | Q4 | 1.17 | < 0.142 | 1.96 | 0.182 | 1.53 | 0.153 | 0.135 | | 2.21 | < 0.142 | 1.05 | 0.368 | 1.11 | **1.15** | 0.530 | | 0.33 | |
| | | Q4 Dup. | | | | | | 0.148 | | | | 0.146 | | | | | | | | |
| | | B3 | 0.40 | **0.745** | 0.83 | 0.518 | 0.38 | **1.680** | 0.981 | | 0.98 | **1.49** | 0.37 | **1.11** | 0.71 | **1.93** [3] | 1.300 | | 1.11 | |
| | | B3 Dup. | | | | | | | | | | | | | | 1.31 | | | | |
| | | Q1 | 5 | 0.52 | 5 | 0.63 | 5 | 0.76 | 0.64 | | | | 5 | 0.45 | 5 | 1.2 | 0.83 | | 0.71 | |
| | | Q1 Dup. | | | 5 | 0.56 | | | | | | | | | | | | | | |
| | | LDF | | | 5 | 2.7 | 5 | 1.8 | 2.3 | | | | 5 | 0.76 [3] | 5 | 2.6 | 2.6 | | 2.4 | |
| | | LDF Dup. | | | | | | | | | | | | 0.97 | | | | | | |
| | | Q2 | 5 | 0.064 | 5 | 0.72 | 5 | 0.58 | 0.45 | | 5 | <1.0 | 5 | 0.61 | 5 | 1.1 | 0.74 | | 0.60 | |
| **Dissolved Selenium** | ug/l | Q2 Dup. | | | | | | | | 0.55 | | | | | | | | 0.60 | | 0.55 |
| | | Q3 | | | 5 | 0.64 | 5 | 0.81 | 0.73 | | | | 5 | 0.37 | 5 | < 0.49 | 0.37 | | 0.58 | |
| | | Q4 | 5 | 0.22 | 5 | 0.56 | 5 | 0.52 | 0.43 | | 5 | < 1.0 | 5 | 0.43 | 5 | 0.62 | 0.52 | | 0.48 | |
| | | Q4 Dup. | | | | | | 0.52 | | | | < 1.0 | | | | | | | | |
| | | B3 | 5 | 0.24 | 5 | 0.44 | 5 | < 0.49 | 0.31 | | 5 | < 1.0 | 5 | 0.28 | 5 | < 0.49 | 0.39 | | 0.33 | |
| | | B3 Dup. | | | | | | | | | | | | | | < 0.49 | | | | |

1. With the exception of iron and selenium, criteria varies with hardness. All criteria values apply to chronic aquatic life criteria. There were no violations of acute criteria, which are higher values. Criteria apply to all stations except LDF (landfill swale), which is a management control structure and not a Water of the State.

2. Stream mean includes data from all stations on the main stem of Quaker Creek, and not LDF (landfill swale) and B3 (terminal station of Borden Brook).

3. Sample did not meet quality control/quality assurance parameters and was not used to calculate means.

**Data shown in bold exceeded water quality criteria or guidance.**

Yellow shading indicates that sampling station(LDF) is a management control structure and was not used to calculate stream averages.

Blue shading indicates that sampling station B3 is a single Borden Brook station and was not used to calculate stream averages.

**Figure A-3. Borden Brook and Unnamed Tributary Water Quality Results.**

| Borden Brook and Unnamed Tributary (RI0010031R-01) Sampling Results | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Dry-Weather Results | | | | | Wet-Weather Results | | | | | All-Weather Results | |
| Parameter | Units | Criteria/ Guidance | Sampling Station | 3/22/2017 | 5/4/2017 | 6/1/2017 | Station Mean[1] | Stream Mean[1,2] | 11/30/2016 | 4/26/2017 | 10/25/2017 | Station Mean[1] | Stream Mean[1,2] | Station Mean[1] | Stream Mean[1,2] |
| **Temperature** | °C | | B1 | 3.9 | 12.2 | 13.3 | | | 9.6 | 11.3 | 16.8 | | | | |
| | | | B2 | 4.1 | 12.0 | 13.4 | | | 9.3 | 11.3 | 17.1 | | | | |
| | | | Bt | | 13.6 | 13.9 | | | | 11.7 | 17.1 | | | | |
| | | | B3 | 3.9 | 12.3 | 13.7 | | | 9.5 | 11.7 | 17.2 | | | | |
| **DO** | mg/l | Instantaneous minimum conc. ≥ 5 mg/l | B1 | 15.0 | 11.4 | 8.5 | 11.6 | 11.4 | 10.3 | 9.4 | 8.3 | 9.3 | 9.0 | 10.5 | 10.2 |
| | | | B2 | 13.1 | 11.9 | 8.6 | 11.2 | | 10.8 | 9.9 | 8.0 | 9.6 | | 10.4 | |
| | | | Bt | | 10.2 | 8.9 | 9.6 | | | 8.9 | 7.3 | 8.1 | | 8.8 | |
| | | | B3 | 13.6 | 11.6 | 8.6 | 11.3 | | 9.6 | 9.3 | 5.6 | 8.2 | | 9.7 | |
| **Specific Conductance** | µs/cm | 835 µs/cm | B1 | 89 | 76 | 72 | 79 | 96 | 135 | 69 | 107 | 104 | 124 | 91 | 110 |
| | | | B2 | 117 | 85 | 91 | 98 | | 135 | 79 | 158 | 124 | | 111 | |
| | | | Bt | | 104 | 109 | 107 | | | 98 | 151 | 124 | | 115 | |
| | | | B3 | 112 | 112 | 106 | 110 | | 193 | 99 | 145 | 146 | | 128 | |
| **pH** | | **6.5-9.0** | B1 | 8.6 | 8.1 | 6.7 | 7.8 | 8.4 | **6.3** | 7.9 | **6.2** | 6.8 | 6.7 | 7.3 | 7.5 |
| | | | B2 | 8.5 | **9.6** | **9.3** | **9.1** | | **5.6** | 8.4 | **6.3** | 6.8 | | 8.0 | |
| | | | Bt | | 7.9 | 8.9 | 8.4 | | | 7.5 | **5.9** | 6.7 | | 7.6 | |
| | | | B3 | 8.2 | 7.8 | 8.5 | 8.2 | | **5.5** | 7.6 | **6.3** | 6.5 | | 7.3 | |
| **Turbidity** | NTU | 6.9 NTU (≤ 5 NTU over background) | B1 | 0.2 | 0.3 | 0.3 | 0.3 | 0.8 | 0.9 | 1.2 | 3.7 | 1.9 | 2.1 | 1.1 | 1.4 |
| | | | B2 | 0.2 | 0.4 | 0.4 | 0.4 | | 0.9 | 1.6 | 3.4 | 2.0 | | 1.2 | |
| | | | Bt | | 0.5 | 0.7 | 0.6 | | | 2.0 | 2.6 | 2.3 | | 1.5 | |
| | | | B3 | 0.5 | 4.1 | 0.6 | 1.7 | | 1.4 | 1.6 | 3.9 | 2.3 | | 2.0 | |
| | | | *B3 Dup.* | | | | | | | | *3.8* | | | | |

| Borden Brook and Unnamed Tributary (RI0010031R-01) Sampling Results (cont.) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Dry-Weather Results | | | | | Wet-Weather Results | | | | | All-Weather Results | |
| Parameter | Units | Criteria/ Guidance | Sampling Station | 3/22/2017 | 5/4/2017 | 6/1/2017 | Station Mean[1] | Stream Mean[1,2] | 11/30/2016 | 4/26/2017 | 10/25/2017 | Station Mean[1] | Stream Mean[1,2] | Station Mean[1] | Stream Mean[1,2] |
| TSS | ug/l | 25,000 ug/l | B1 | 8,000 | < 1,000 | 1,600 | 3,367 | 4,244 | 2,400 | 1,600 | 8,400 | 4,133 | 4,067 | 3,750 | 4,156 |
| | | | B2 | 8,000 | 1,200 | < 1,000 | 3,233 | | < 1,000 | 5,200 | 12,000 | 5,900 | | 4,567 | |
| | | | Bt | | 2,400 | 1,200 | 1,800 | | | 6,000 | 6,400 | 6,200 | | 4,000 | |
| | | | B3 | 12,000 | 5,200 | 1,200 | 6,133 | | < 1,000 | 2,800 | 3,200 | 2,167 | | 4,150 | |
| | | | *B3 Dup.* | | | | | | | | *2,800* | | | | |
| TP | ug/l | 100 ug/l except at Station B3 where 25 ug/l applies[4] | B1 | < 10 | < 10 [3] | 11 | 8 | 33 | 24 | 23 | 110 | 52 | 63 | 35 | 49 |
| | | | B2 | < 10 | 12 | 15 | 11 | | 27 | 30 | 130 | 62 | | 37 | |
| | | | Bt | | 62 | 65 | 64 | | | 99 | 100 | 100 | | 82 | |
| | | | B3 | < 10 | 170 | 39 | 71 | | 52 | 49 | 120 | 74 | | 73 | |
| | | | *B3 Dup.* | | | | | | | | *120* | | | | |
| DP | ug/l | | B1 | < 10 | 56 [3] | 10 | 8 | 27 | 18 | 20 | 78 | 39 | 45 | 26 | 36 |
| | | | B2 | < 10 | < 10 | 11 | 7 | | 21 | 20 | 86 | 42 | | 25 | |
| | | | Bt | | < 10 | 63 | 34 | | | 99 | 76 | 88 | | 61 | |
| | | | B3 | < 10 | 140 | 31 | 59 | | 34 | 40 | 86 | 53 | | 56 | |
| | | | *B3 Dup.* | | | | | | | | *87* | | | | |
| Ammonia | ug/l | Acute: 1,320-48,800 ug/l Chronic: 389-6,670 ug/l (pH and temperature dependent) | B1 | < 100 | < 100 | 137 | 79 | | < 100 | < 100 | < 100 | 50 | 100 | 65 | 55 |
| | | | B2 | < 100 | < 100 | < 100 | 50 | | < 100 | < 100 | < 100 | 50 | | 50 | |
| | | | Bt | | < 100 | 129 | 90 | | | < 100 | < 100 | 50 | | 70 | |
| | | | B3 | < 100 | < 100 | < 100 | 50 | | < 100 | < 100 | < 100 | 50 | | 50 | |
| | | | *B3 Dup.* | | | | | | | | *< 100* | | | | |
| TKN | ug/l | 300 ug/l | B1 | 1,100 | 970 | 525 | 865 | 854 | 600 | 780 | 1,100 | 827 | 855 | 846 | 855 |
| | | | B2 | 300 | 441 | 920 | 554 | | 600 | 335 | 1,200 | 712 | | 633 | |
| | | | Bt | | 1,150 | 585 | 868 | | | 1,220 | 1,000 | 1,110 | | 989 | |
| | | | B3 | 1,000 | 1,390 | 1,040 | 1,143 | | 700 | 1,380 | 1,000 | 1,027 | | 1,085 | |
| | | | *B3 Dup.* | | | | | | | | *1,000* | | | | |

**Borden Brook and Unnamed Tributary (RI0010031R-01) Sampling Results (cont.)**

| | | | | Dry-Weather Results | | | | | Wet-Weather Results | | | | | All-Weather Results | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Units** | **Criteria/ Guidance** | **Sampling Station** | **3/22/2017** | **5/4/2017** | **6/1/2017** | **Station Mean[1]** | **Stream Mean[1,2]** | **11/30/2016** | **4/26/2017** | **10/25/2017** | **Station Mean[1]** | **Stream Mean[1,2]** | **Station Mean[1]** | **Stream Mean[1,2]** |
| Organic N | ug/l | 300 ug/l | B1 | 1,050 | 920 | 388 | 786 | 794 | 550 | 730 | 1,050 | 777 | 805 | 781 | 800 |
| | | | B2 | 250 | 391 | 870 | 504 | | 550 | 285 | 1,150 | 662 | | 583 | |
| | | | Bt | | 1,100 | 456 | 778 | | | 1,170 | 950 | 1,060 | | 919 | |
| | | | B3 | 950 | 1,340 | 990 | 1,093 | | 650 | 1,330 | 950 | 977 | | 1,035 | |
| | | | *B3 Dup.* | | | | | | | | *950* | | | | |
| Nitrate | ug/l | 310 ug/l | B1 | < 50 | < 50 | < 50 | 25 | 60 | < 50 | < 50 | 50 | 33 | 100 | 29 | 80 |
| | | | B2 | 160 | < 50 | < 50 | 70 | | < 50 | < 50 | 320 | 123 | | 97 | |
| | | | Bt | | < 50 | 70 | 48 | | | 70 | 120 | 95 | | 71 | |
| | | | B3 | 150 | 51 | 50 | 84 | | 140 | 60 | 230 | 143 | | 114 | |
| | | | *B3 Dup.* | | | | | | | | *230* | | | | |
| TN | ug/l | 610 ug/l | B1 | 1,125 | 995 | 550 | 890 | 911 | 625 | 805 | 1,150 | 860 | 955 | 875 | 933 |
| | | | B2 | 460 | 466 | 945 | 624 | | 625 | 360 | 1,520 | 835 | | 729 | |
| | | | Bt | | 1,175 | 655 | 915 | | | 1,290 | 1,120 | 1,205 | | 1,060 | |
| | | | B3 | 1,150 | 1,441 | 1,065 | 1,219 | | 840 | 1,440 | 1,230 | 1,170 | | 1,194 | |
| | | | *B3 Dup.* | | | | | | | | *1,230* | | | | |
| DOC | ug/l | 4,000 ug/l | B1 | 11,700 | 17,500 | 20,200 | 16,467 | 16,100 | 28,500 | 14,500 | 22,200 | 21,733 | 21,433 | 19,100 | 18,767 |
| | | | B2 | 10,600 | 18,800 | 17,800 | 15,733 | | 27,700 | 14,900 | 19,500 | 20,700 | | 18,217 | |
| | | | Bt | | 23,800 | 21,400 | 22,600 | | | 14,200 | 17,200 | 15,700 | | 19,150 | |
| | | | B3 | 11,000 | 18,500 | 18,800 | 16,100 | | 26,500 | 15,900 | 23,200 | 21,867 | | 18,983 | |
| | | | *B3 Dup.* | | | | | | | | *24,000* | | | | |
| Enterococci | MPN/100 ml | Geometric Mean Density: 54 MPN/100 ml | B1 | < 10 | < 10 | 2 | 4 | 7 | | 41 | 6,870 | 531 | 831 | 27 | 48 |
| | | | B2 | < 10 | < 10 | 15 | 7 | | | 75 | 5,170 | 623 | | 43 | |
| | | | Bt | | 10 | 26 | 16 | | | 439 | 14,100 | 2,488 | | 200 | |
| | | | B3 | < 10 | 20 | 31 | 15 | | | 262 | 11,500 [5] | 1,736 | | 99 | |
| | | | *B3 Dup.* | | | | | | | | *15,000* | | | | |

1. All averages expressed as means except enterococci, which is expressed as geometric mean.

2. Stream averages include all main stem stations on Borden Brook, and not the Borden Brook tributary station (Bt).

3. TP less than DP. Values were not used to calculate averages.

4. EPA guidance for phosphorus in streams is 100 ug/l, which applies to stations B1 and B2. RIDEM applies a criterion of 25 ug/l to lakes and regulations state that average TP in tributaries at the point where they enter such bodies of water shall not cause exceedance of this phosphorus criteria. The 25 ug/l criteria was applied to Station B3 because of its proximity to Nonquit Pond.

5. Sample did not meet quality control/quality assurance parameter, but was used to calculate averages because duplicate was relatively similar and because of the typical variability of bacteria analysis.

Black bold font indicates an exceedance of water quality criteria or guidance.

Blue shading indicates that sampling station Bt is a tributary to Borden Brook and was not used to calculate stream averages.

**Figure A-4. Unnamed Tributary to Nonquit Pond Water Quality Results.**

| Unnamed Tributary to Nonquit Pond (RI0010031R-20) Sampling Results | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Dry-Weather Results | | | | | Wet-Weather Results | | | | | All-Weather Results | |
| **Parameter** | **Units** | **Criteria/ Guidance** | **Sampling Station** | **3/22/2017** | **5/4/2017** | **6/1/2017** | **Station Mean[1]** | **Stream Mean[1]** | **11/30/2016** | **4/26/2017** | **10/25/2017** | **Station Mean[1]** | **Stream Mean[1]** | **Station Mean[1]** | **Stream Mean[1]** |
| **Temperature** | °C | | N1 | | 13.6 | 16.8 | | | 10.1 | 13.2 | | | | | |
| | | | N2 | | 11.6 | 14.6 | | | 10.1 | 12.3 | 17.5 | | | | |
| **DO** | mg/l | Instantaneous minimum conc. ≥ 5 mg/l | N1 | | 9.3 | 7.3 | 8.3 | 8.9 | 8.6 | 8.2 | | 8.4 | 9.0 | 8.4 | 9.0 |
| | | | N2 | | 10.4 | 8.6 | 9.5 | | 10.4 | 9.7 | 8.1 | 9.4 | | 9.4 | |
| **Specific Conductance** | µs/cm | 835 µs/cm | N1 | | 93 | 90 | 92 | 95 | 177 | 90 | | 134 | 127 | 113 | 112 |
| | | | N2 | | 109 | 86 | 98 | | 175 | 70 | 122 | 122 | | 112 | |
| **pH** | | 6.5-9.0 | N1 | | 7.9 | 7.1 | 7.5 | 7.6 | **5.6** | 7.3 | | 6.5 | 6.6 | 7.0 | 7.1 |
| | | | N2 | | 8.0 | 7.3 | 7.7 | | **6.1** | 7.4 | 6.8 | 6.8 | | 7.1 | |
| **Turbidity** | NTU | 6.9 NTU (≤ 5 NTU over background) | N1 | 5.3 | **10.0** | 0.2 | 5.2 | 3.8 | 2.5 | **8.5** | | 5.5 | **7.4** | 5.3 | 5.4 |
| | | | N2 | 1.6 | 0.6 | 5.3 | 2.5 | | **9.6** | **9.9** | 6.3 | **8.6** | | 5.5 | |
| **TSS** | ug/l | 25,000 ug/l | N1 | 24,000 | **30,000** | 1,000 | 18,333 | 11,567 | 3,200 | 22,000 | | 12,600 | 8,433 | 16,040 | 10,909 |
| | | | N2 | 6,000 | 1,600 | 6,800 | 4,800 | | 2,400 | 19,000 | 4,000 | 8,467 | | 6,633 | |
| **TP** | ug/l | 100 ug/l except at Station N2 where 25 ug/l applies[2] | N1 | **170** | **820** | 10 | **333** | 177 | 49 | **570** [3] | | **310** | **242** | **324** | **207** |
| | | | N2 | 14 | **32** | 18 | 21 | | **250** | **150** | **190** | **197** | | **109** | |
| **DP** | ug/l | | N1 | **130** | **660** | 10 | **267** | **141** | 24 | **730** [3] | | **377** | **243** | **206** | **133** |
| | | | N2 | < 10 | **28** | 14 | 16 | | **170** | **140** | **150** | **153** | | **85** | |
| **Ammonia** | ug/l | Acute: 8,400-48,800 ug/l Chronic: 1,940-6,670 ug/l (pH and temperature-dependent) | N1 | < 100 | 159 | 354 | 188 | 187 | < 100 | < 100 | | 50 | 110 | 133 | 152 |
| | | | N2 | < 100 | < 100 | 461 | 187 | | < 100 | 352 | < 100 | 151 | | 169 | |
| **TKN** | ug/l | 300 ug/l | N1 | **1,300** | **1,820** | **870** | **1,330** | **1,193** | **600** | **940** | | **770** | **992** | **1,106** | **1,101** |
| | | | N2 | **1,300** | **1,080** | **785** | **1,055** | | **600** | **1,920** | **900** | **1,140** | | **1,098** | |

## Unnamed Tributary to Nonquit Pond (RI0010031R-20) Sampling Results

| | | | | Dry-Weather Results | | | | | Wet-Weather Results | | | | | All-Weather Results | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Units** | **Criteria/ Guidance** | **Sampling Station** | **3/22/2017** | **5/4/2017** | **6/1/2017** | **Station Mean[1]** | **Stream Mean[1]** | **11/30/2016** | **4/26/2017** | **10/25/2017** | **Station Mean[1]** | **Stream Mean[1]** | **Station Mean[1]** | **Stream Mean[1]** |
| **Organic N** | ug/l | 300 ug/l | N1 | **1,250** | **1,661** | **516** | **1,142** | **1,005** | **550** | **890** | | **720** | **882** | **973** | **949** |
| | | | N2 | **1,250** | **1,030** | **324** | **868** | | **550** | **1,568** | **850** | **989** | | **929** | |
| **Nitrate** | ug/l | 310 ug/l | N1 | < 50 | < 50 | 50 | 33 | 299 | < 50 | 130 | | 78 | 119 | 51 | 217 |
| | | | N2 | **1,230** | < 50 | **440** | **565** | | 250 | 130 | 60 | 147 | | **356** | |
| **TN** | ug/l | 610 ug/l | N1 | **1,325** | **1,845** | **920** | **1,363** | **1,492** | **625** | **1,070** | | **848** | **1,111** | **1,157** | **1,319** |
| | | | N2 | **2,530** | **1,105** | **1,225** | **1,620** | | **850** | **2,050** | **960** | **1,287** | | **1,453** | |
| **DOC** | ug/l | 4,000 ug/l | N1 | **16,700** | **27,700** | **22,500** | **22,300** | **19,037** | **17,700** | **16,900** | | **17,300** | **16,300** | **20,300** | **17,793** |
| | | | N2 | **7,820** | **21,500** | **18,000** | **15,773** | | **18,700** | **11,100** | **17,100** | **15,633** | | **15,703** | |
| **Enterococci** | MPN/100 ml | Geometric Mean Density: 54 MPN/100 ml | N1 | 31 | 20 | **81** | 37 | 27 | | **4,350** | | **4,350** | **4,252** | **121** | **144** |
| | | | N2 | 10 | < 10 | **140** | 19 | | | **1,140** | **15,500** | **4,204** | | **165** | |

1. All averages expressed as means except enterococci, which is expressed as geometric mean.

2. EPA guidance for phosphorus in streams is 100 ug/l, which applies to stations N1. RIDEM applies a criterion of 25 ug/l to lakes and regulations state that average TP in tributaries at the point where they enter such bodies of water shall not cause exceedance of this phosphorus criteria. The 25 ug/l criteria was applied to Station N2 because of its proximity to Nonquit Pond.

3. TP less than DP. Values were still used to calculate averages, because values were relatively similar and both TP and DP concentrations were extremely elevated.

**Black bold font indicates an exceedance of water quality criteria or guidance.**

## APPENDIX B. WATER QUALITY RESULT MAPS

(return to document)

**Figure B-1. Quaker Creek Dry Weather Dissolved Oxygen (mg/l) (return to: [landfill swale] or [Quaker Creek]).**

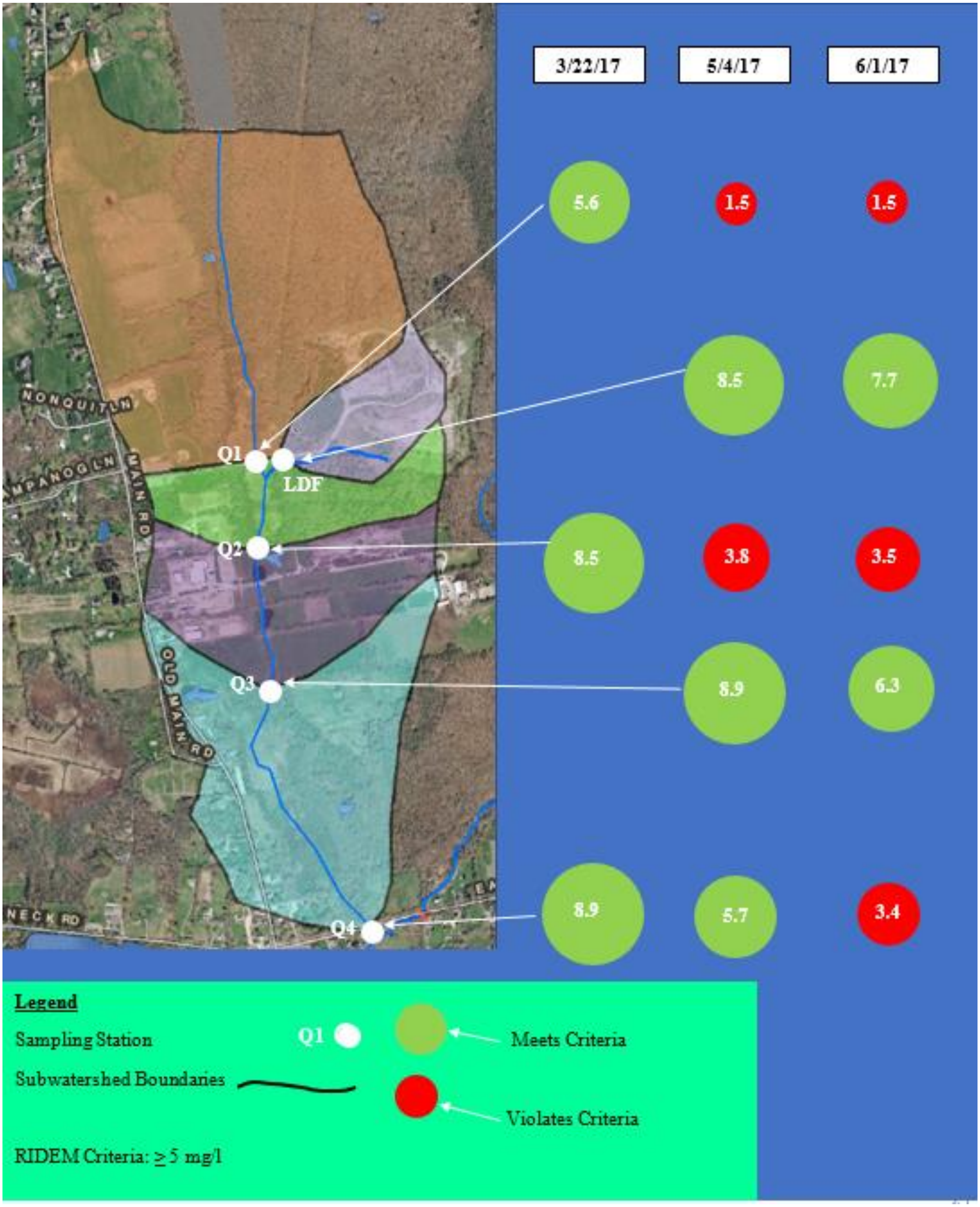


**Figure B-2. Quaker Creek Wet Weather Dissolved Oxygen (mg/l) (return to: landfill swale or Quaker Creek).**

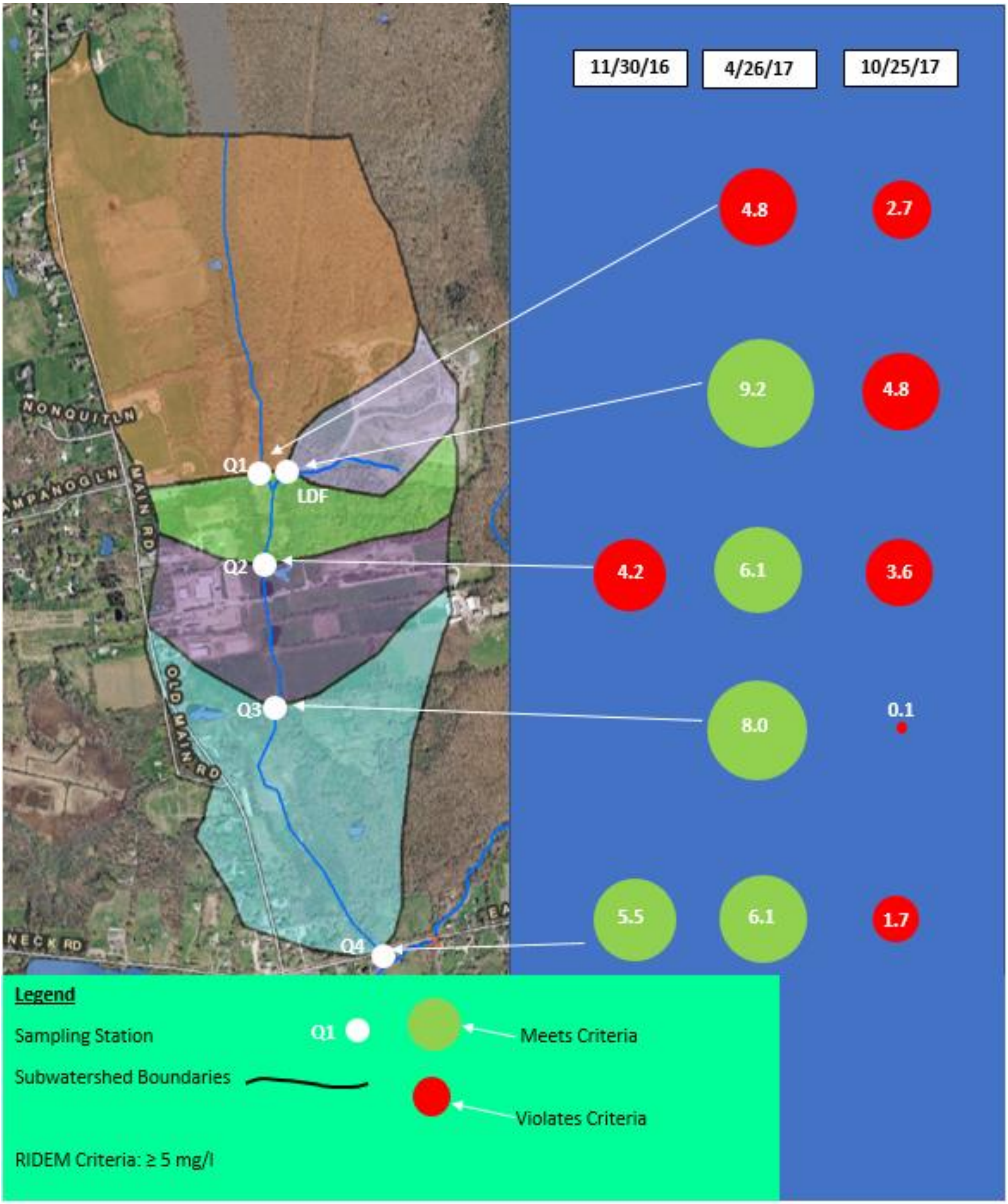


**Figure B-3. Quaker Creek Dry Weather Specific Conductance (µs/cm) (return to: [landfill swale]() or [Quaker Creek]()).**

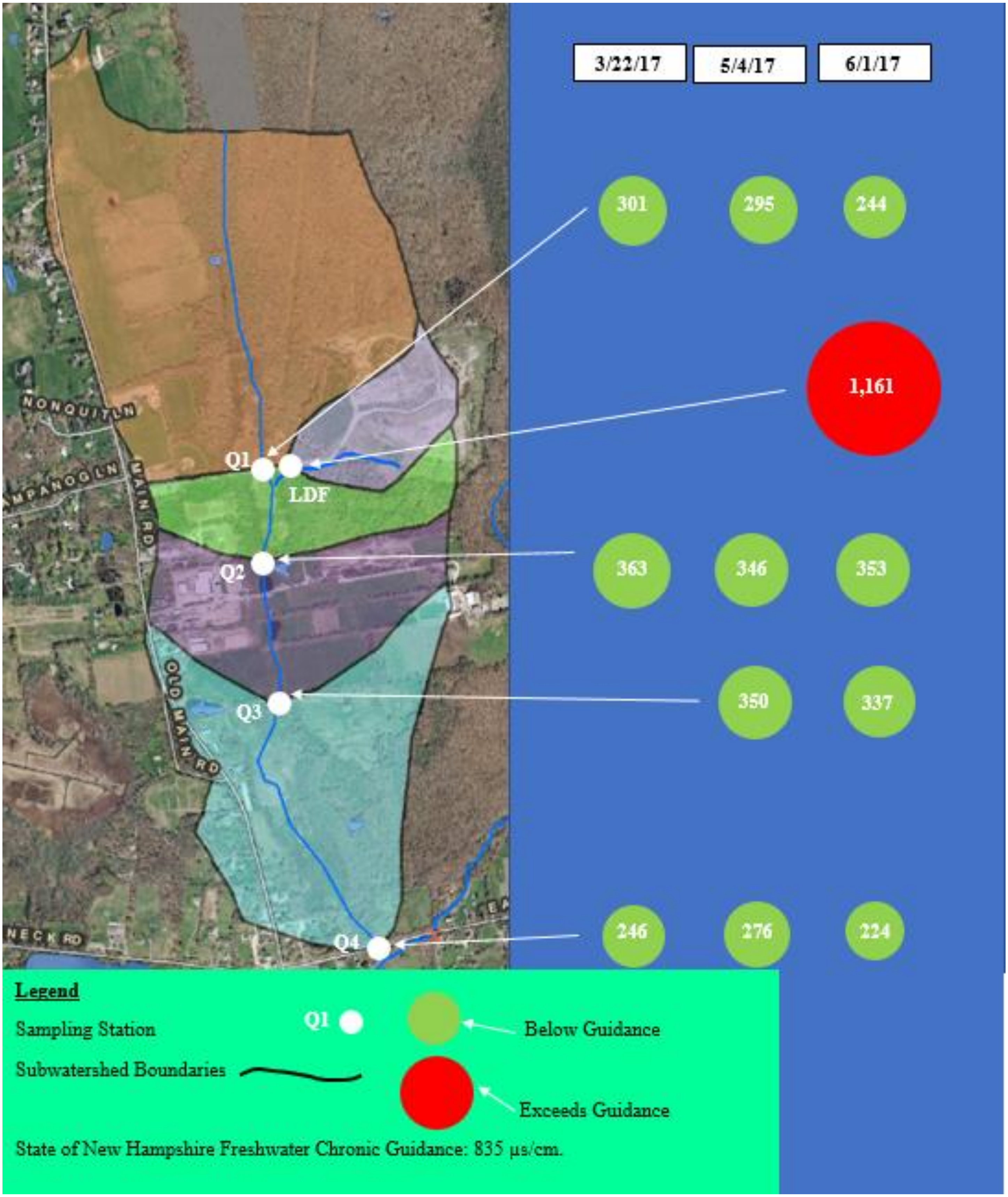


**Figure B-4. Quaker Creek Wet Weather Specific Conductance (µs/cm) (return to: landfill swale or Quaker Creek).**

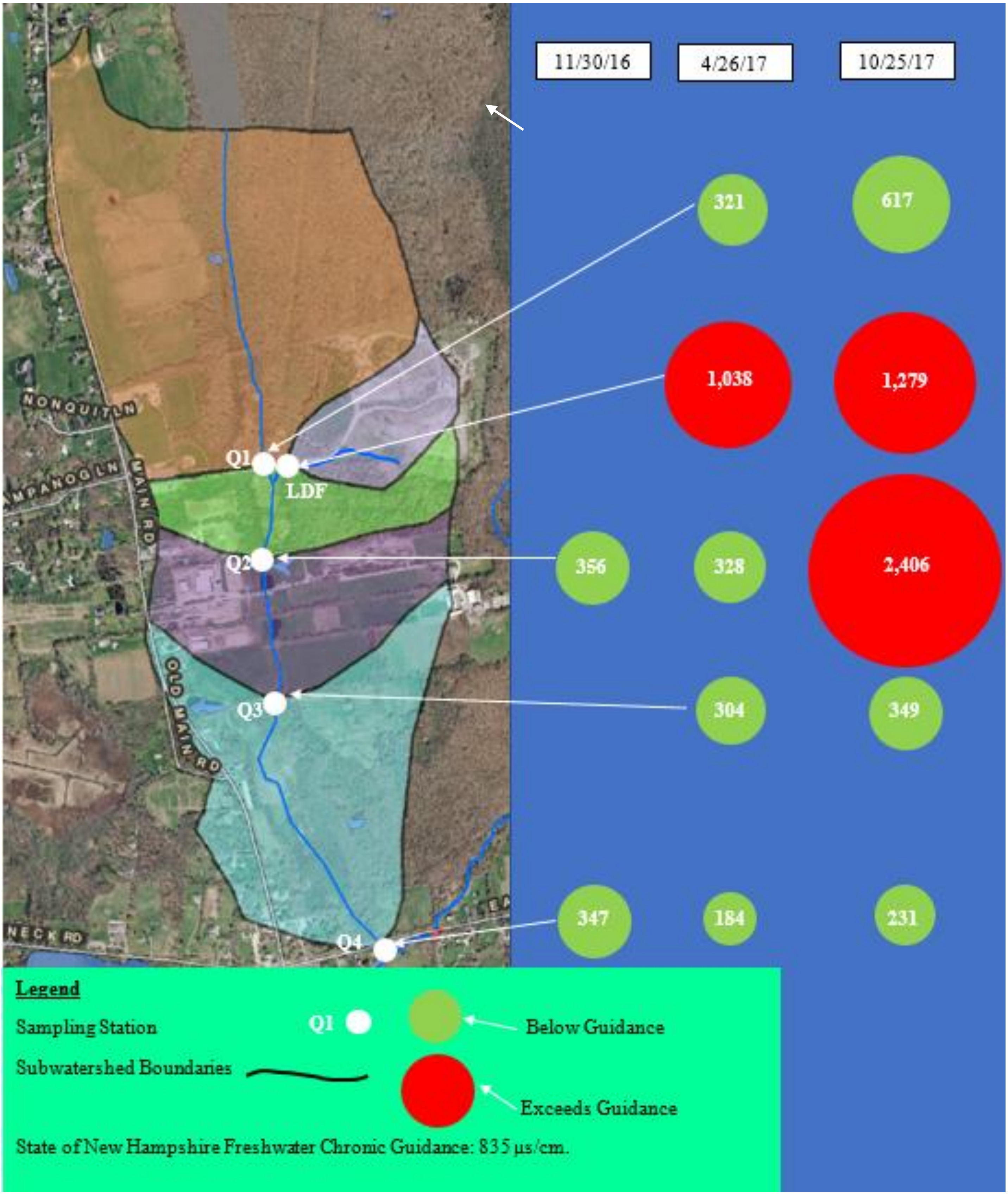


**Figure B-5. Quaker Creek Dry Weather pH (return to: landfill swale or Quaker Creek).**

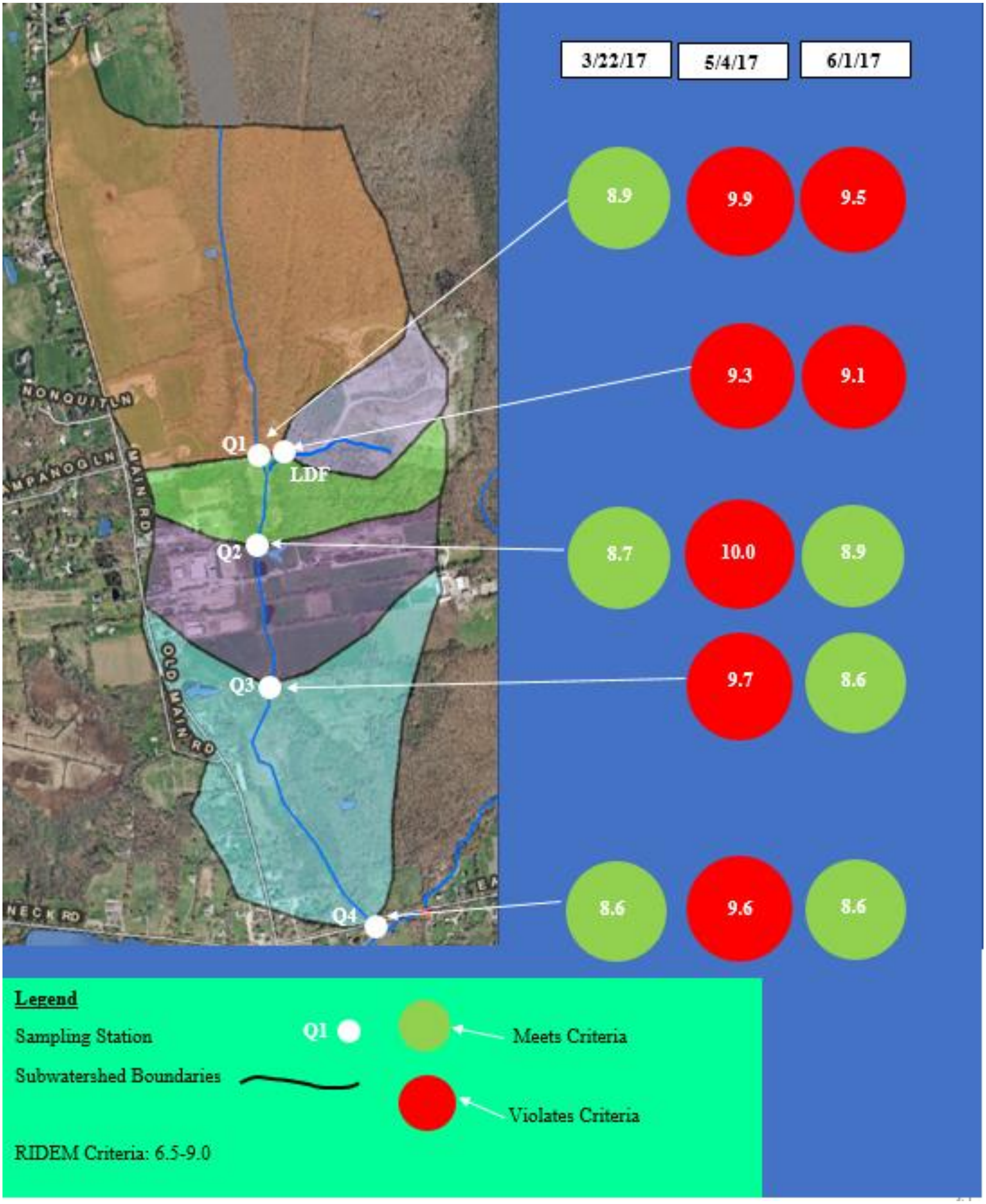


**Figure B-6. Quaker Creek Wet Weather pH (return to: landfill swale or Quaker Creek).**

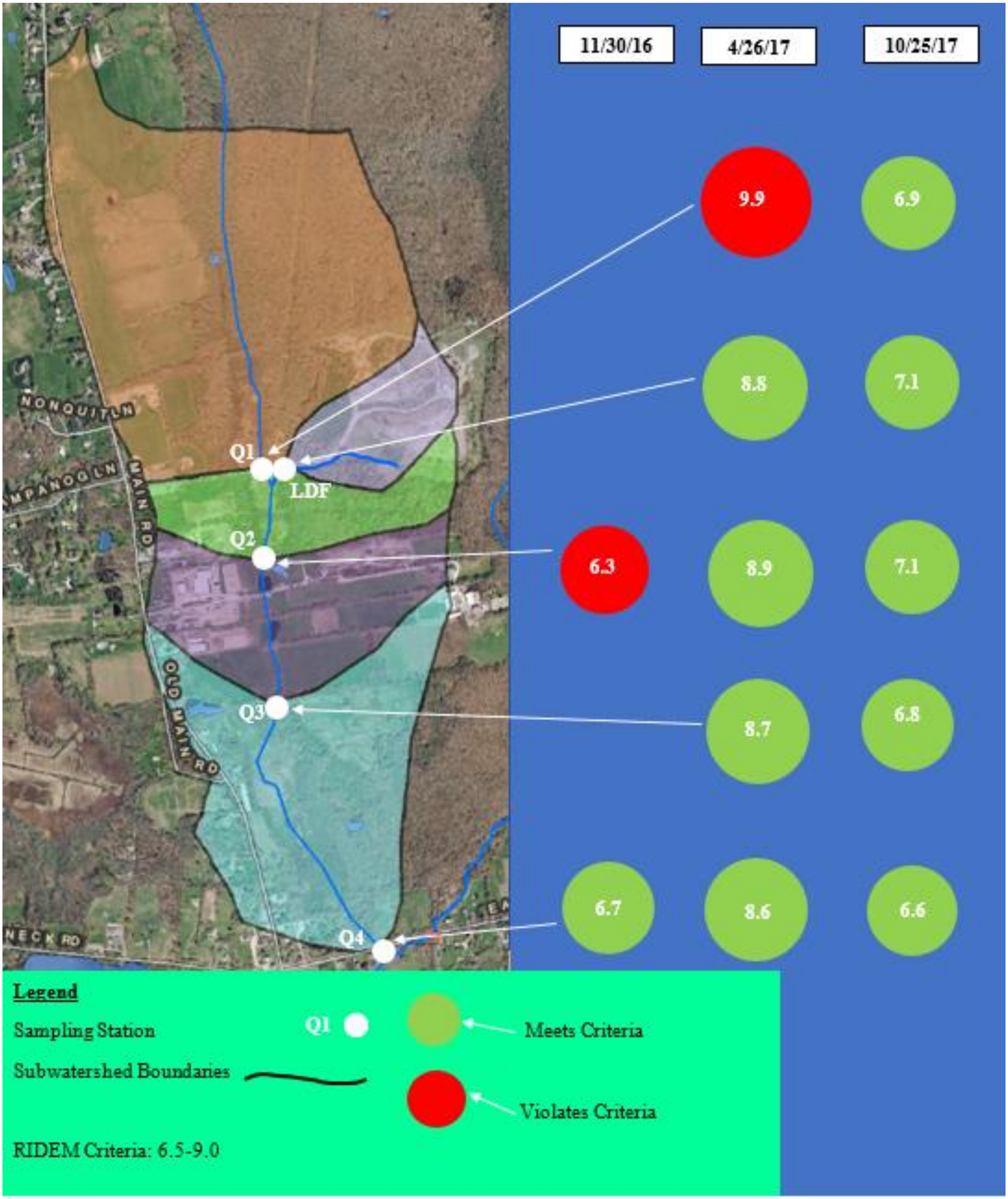


**Figure B-7. Quaker Creek Dry Weather Turbidity (ug/l) (return to: landfill swale or Quaker Creek).**

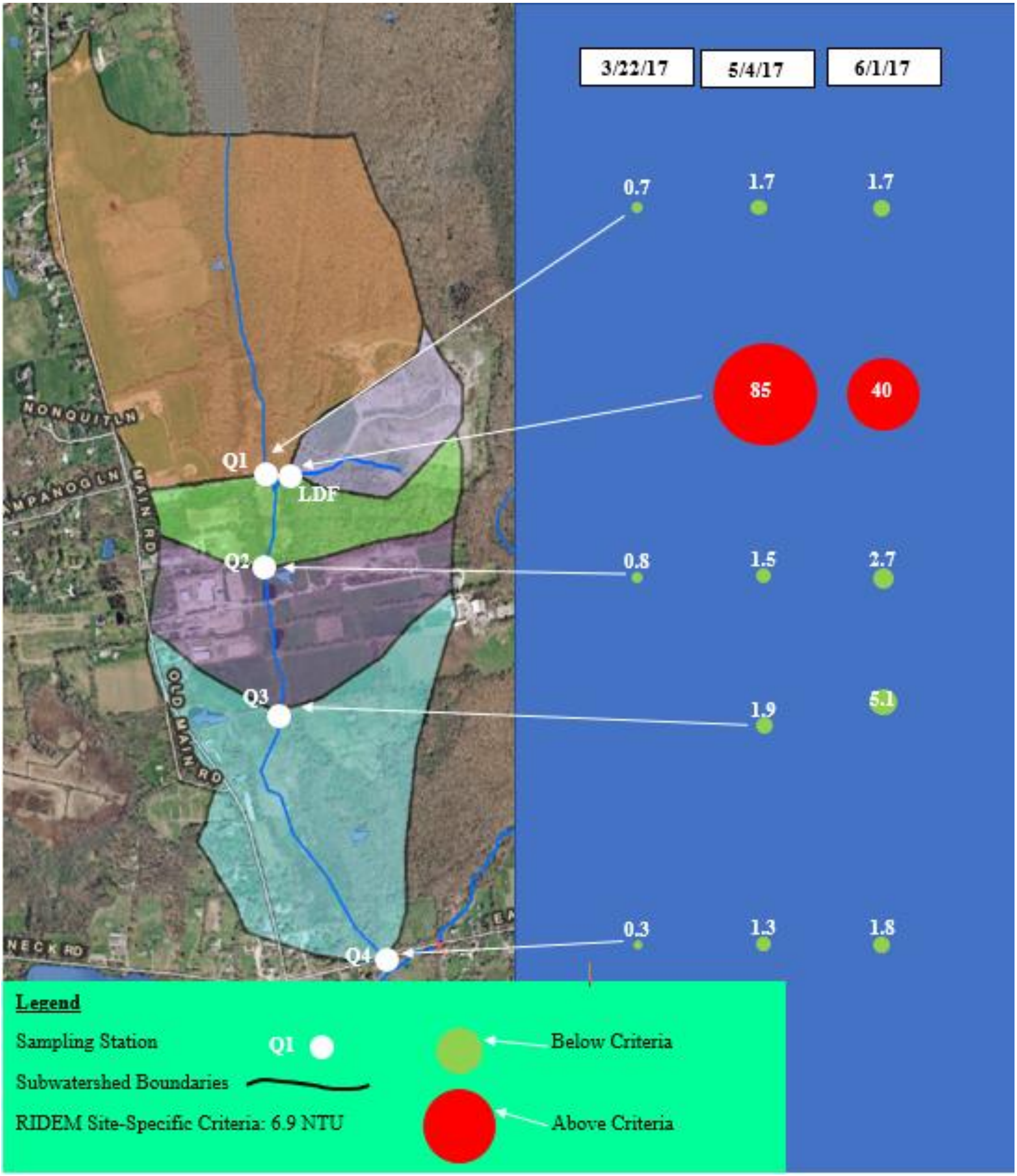


**Figure B-8. Quaker Creek Wet Weather Turbidity (NTU) (return to: landfill swale or Quaker Creek).**

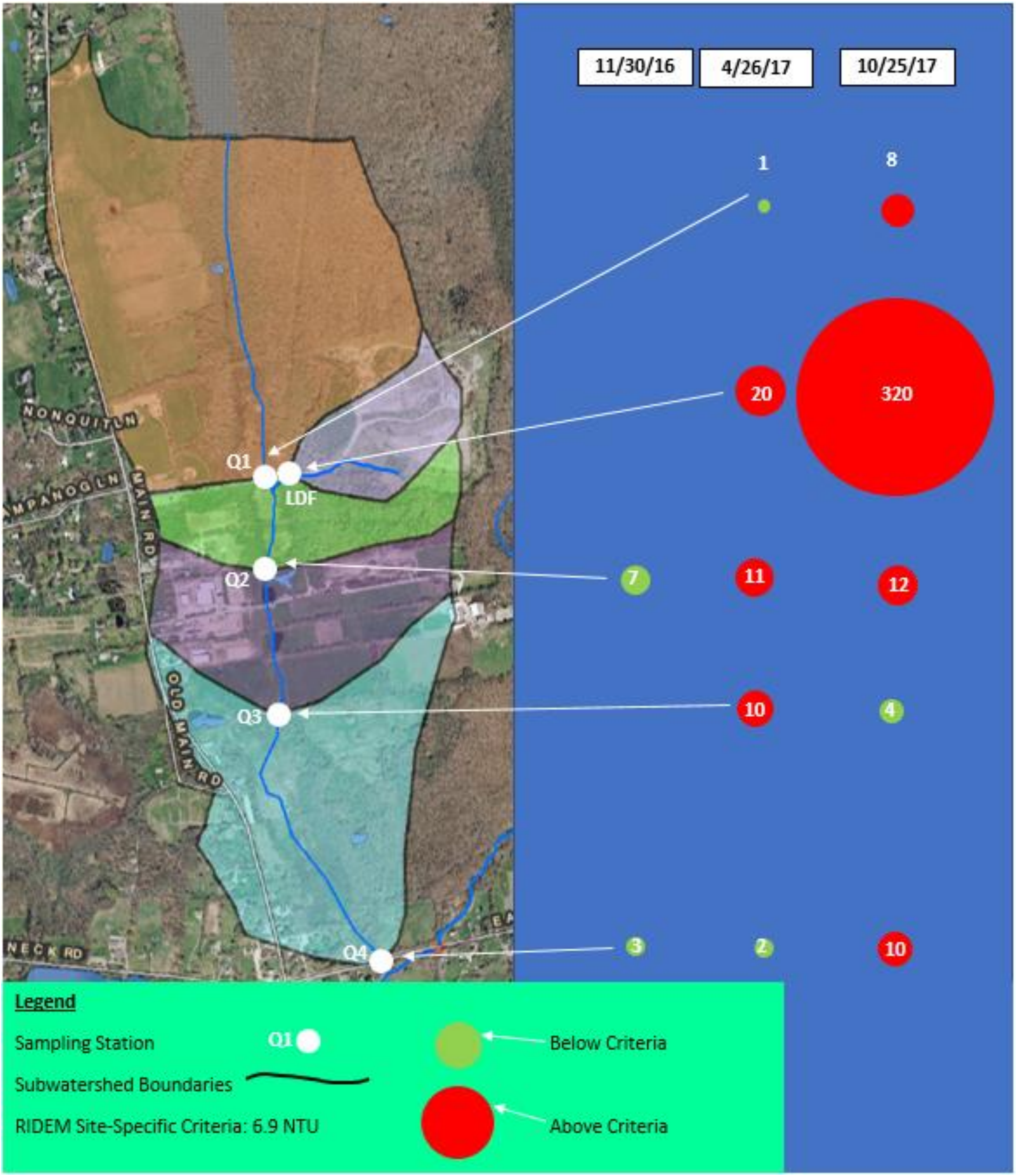


**Figure B-9. Quaker Creek Dry Weather TSS (ug/l) (return to: landfill swale or Quaker Creek).**

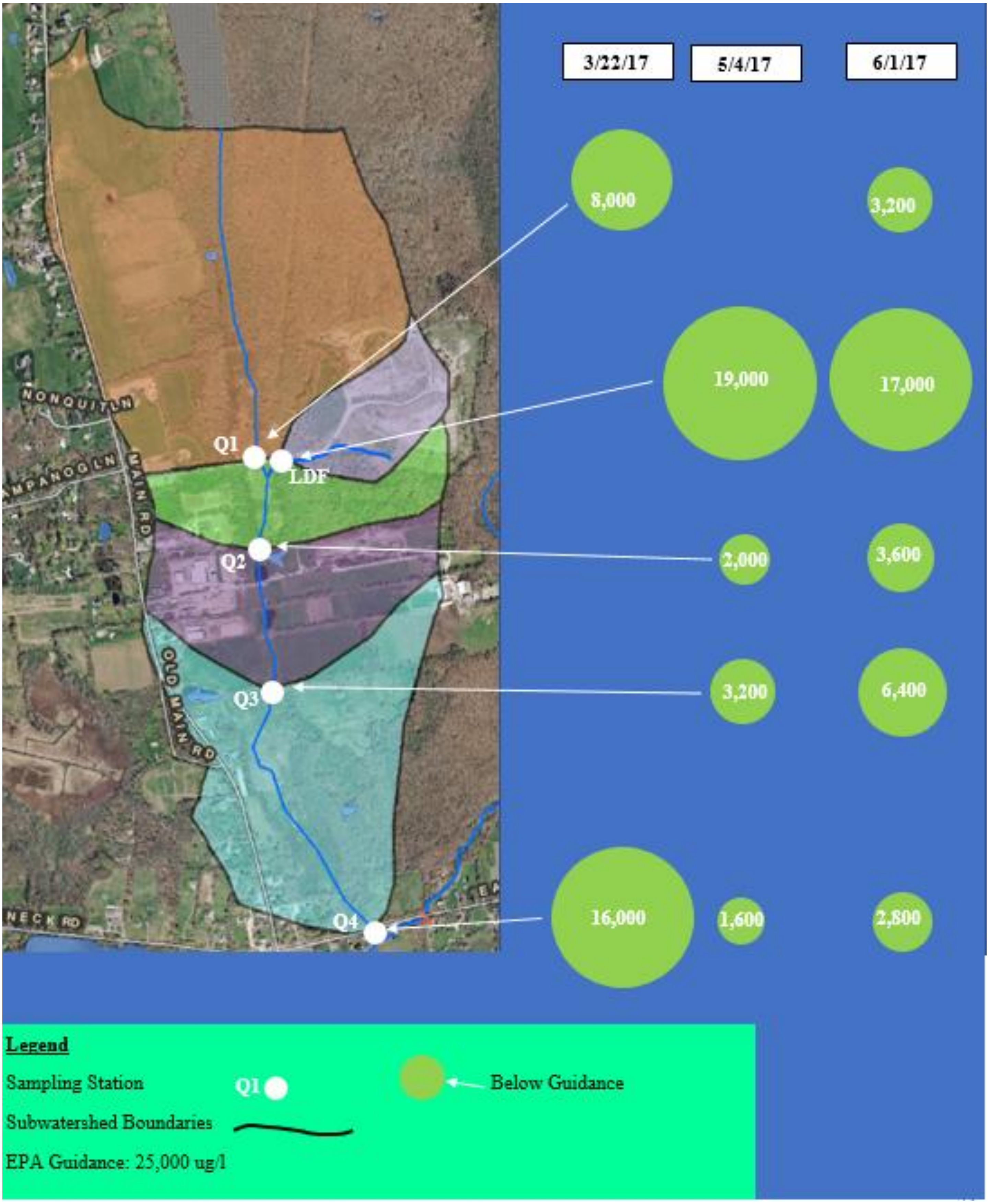


**Figure B-10. Quaker Creek Wet Weather TSS (ug/l) (return to: [landfill swale]() or [Quaker Creek]()).**

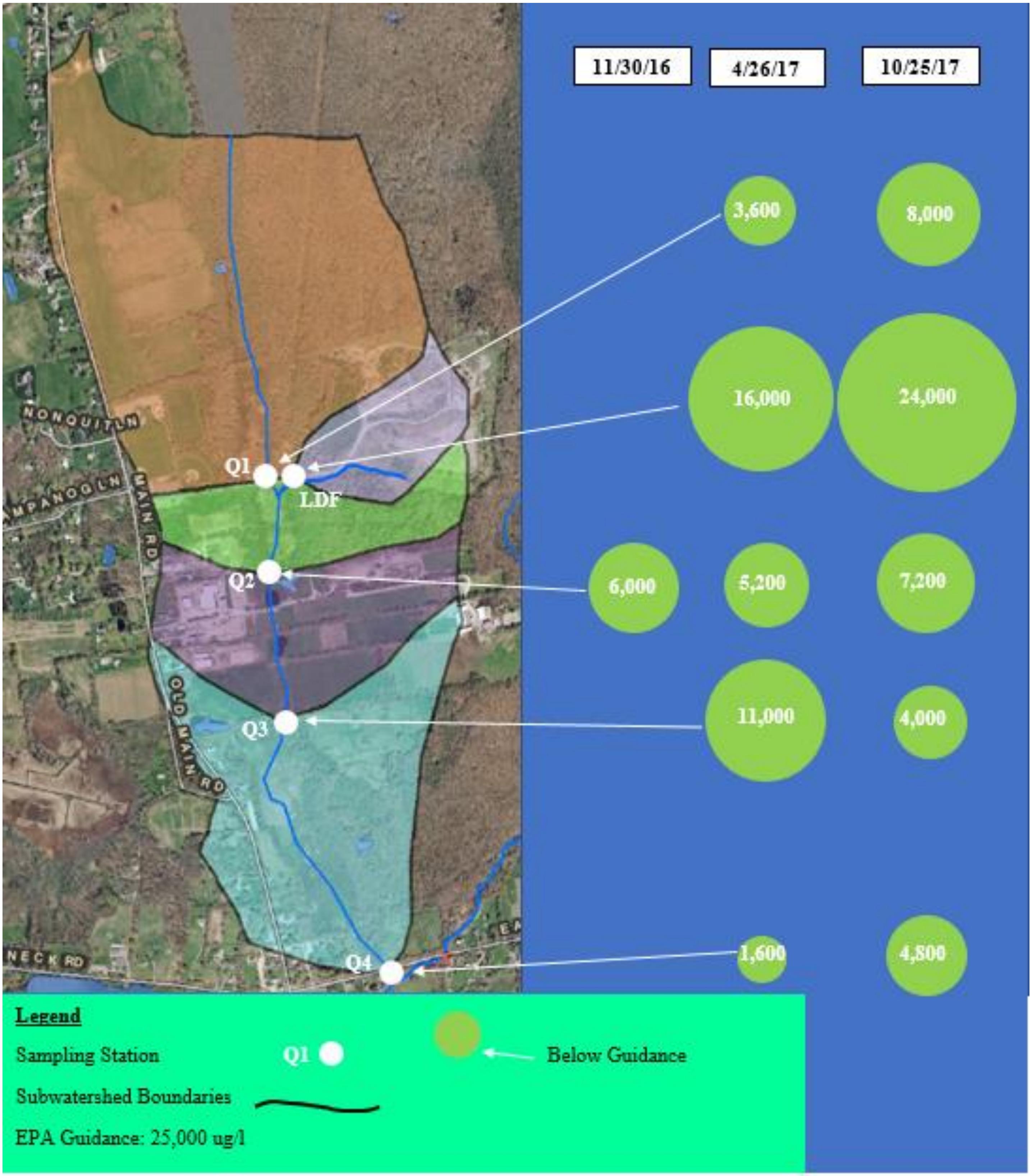


**Figure B-11. Quaker Creek Dry Weather Phosphorus (ug/l) (return to: landfill swale or Quaker Creek).**

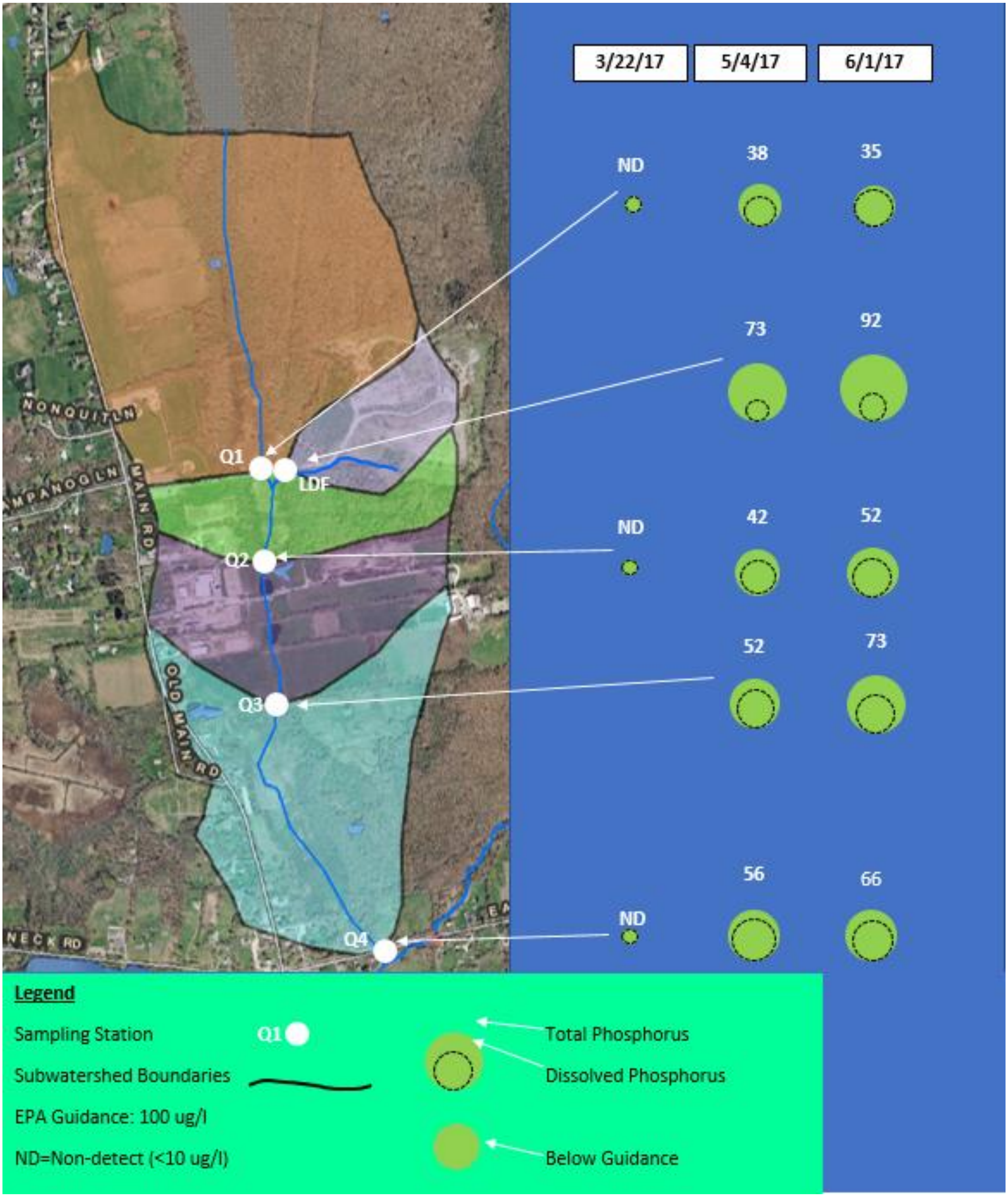


**Figure B-12. Quaker Creek Wet Weather Phosphorus (ug/l) (return to: landfill swale or Quaker Creek).**

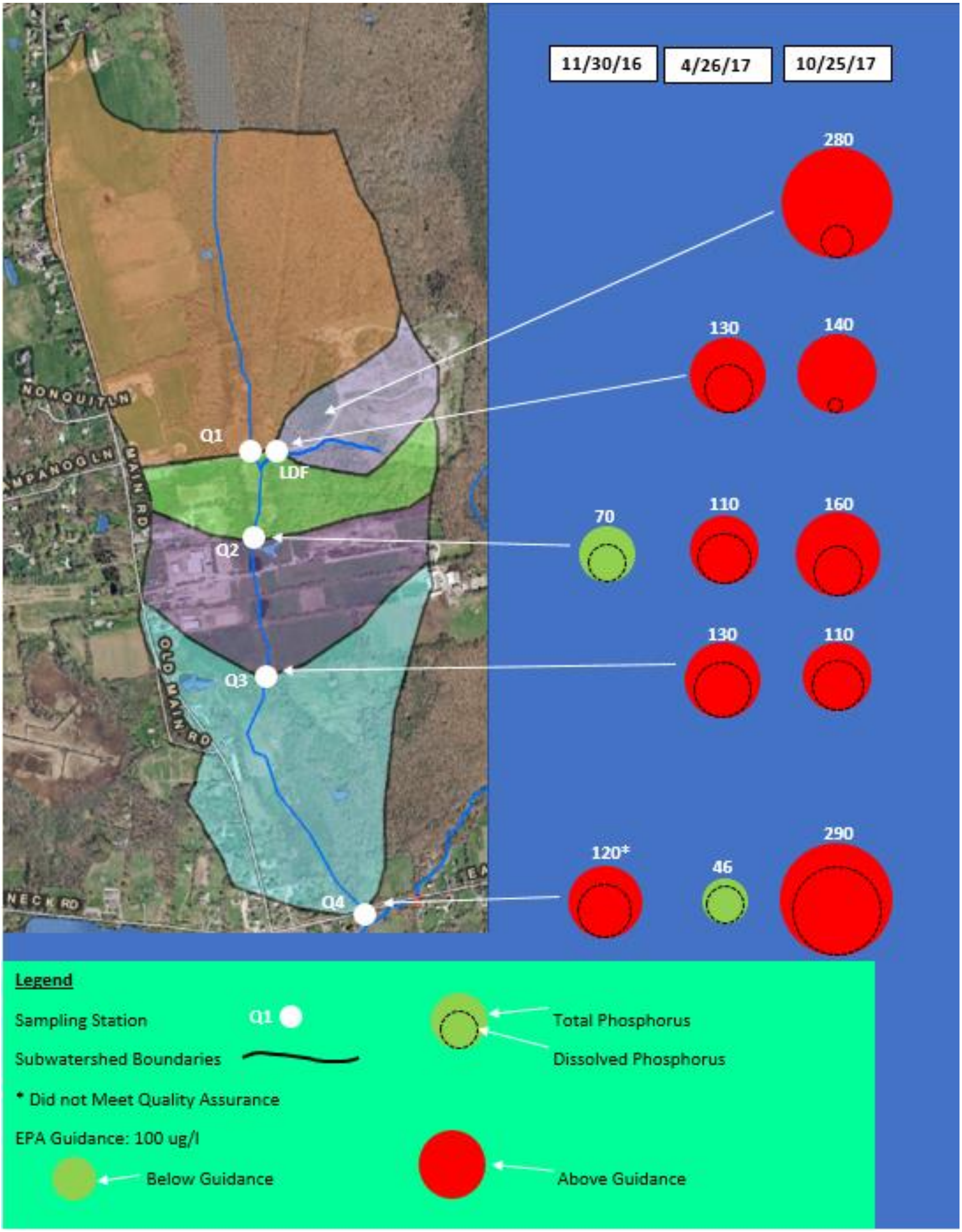


**Figure B-13. Quaker Creek Dry Weather Nitrogen (ug/l) (return to: landfill swale or Quaker Creek).**

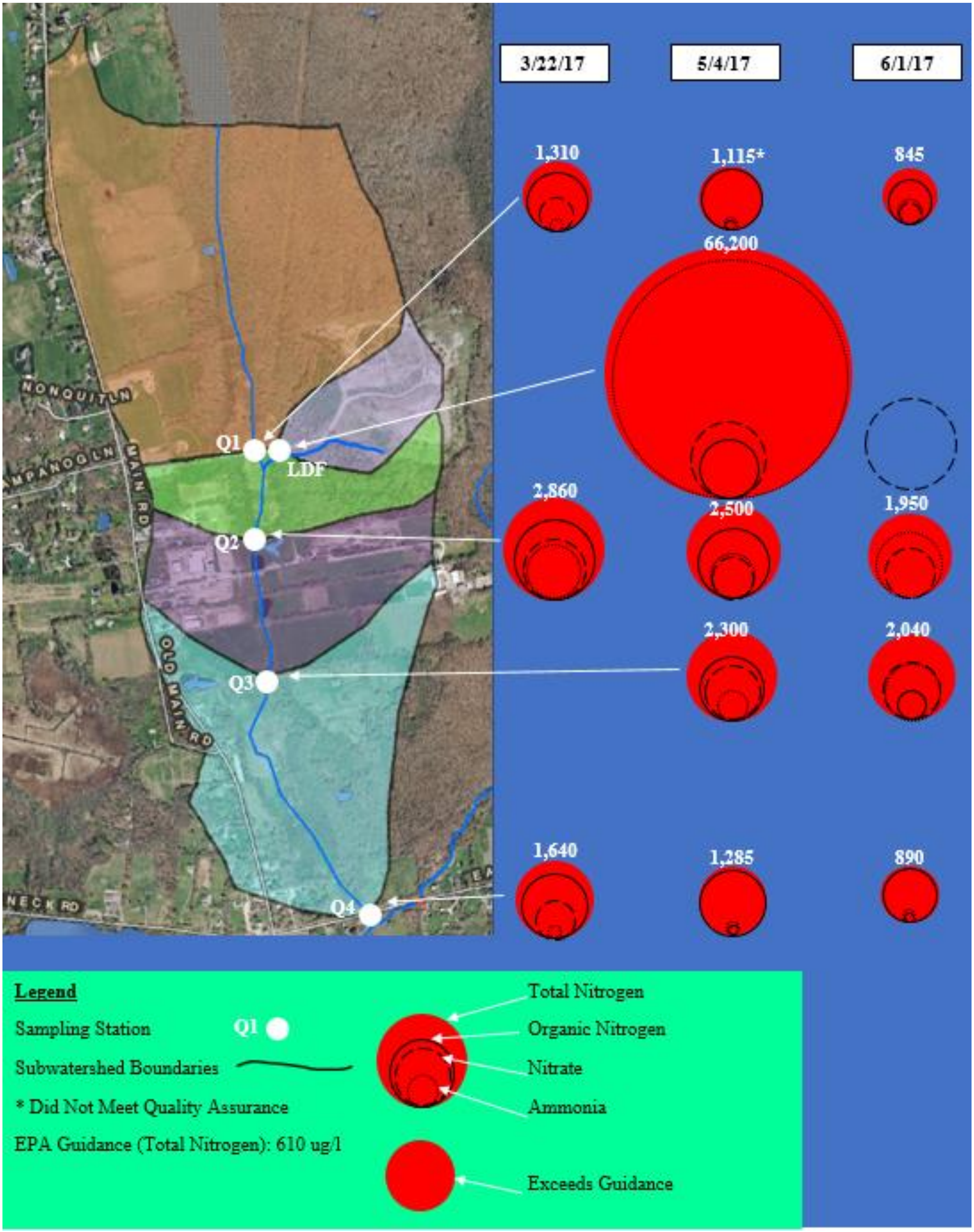


**Figure B-14. Quaker Creek Wet Weather Nitrogen (ug/l) (return to: landfill swale or Quaker Creek).**

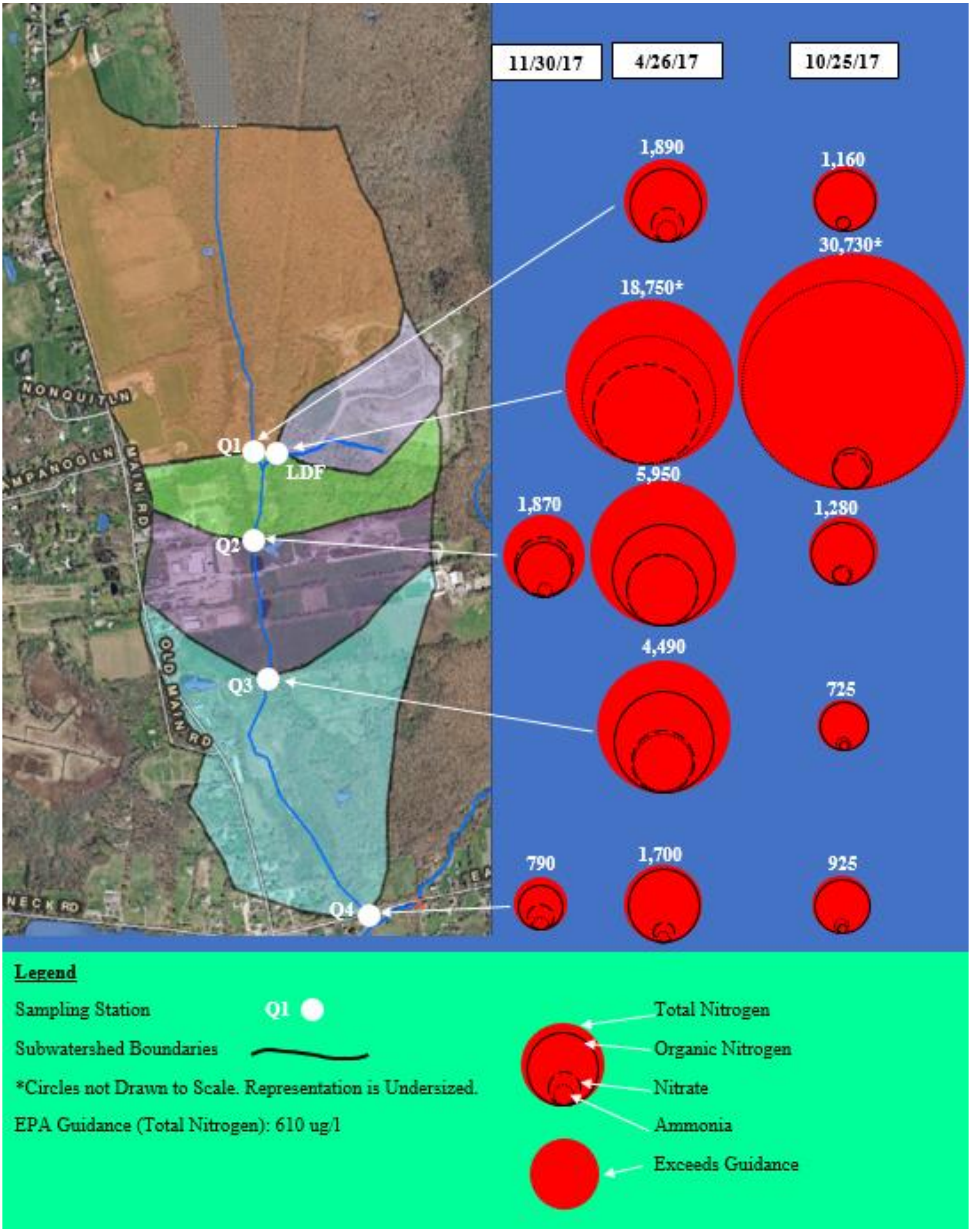


**Figure B-15. Quaker Creek Dry Weather DOC (ug/l) (return to: landfill swale or Quaker Creek).**

**Figure B-16. Quaker Creek Wet Weather DOC (ug/l) (return to: landfill swale or Quaker Creek).**

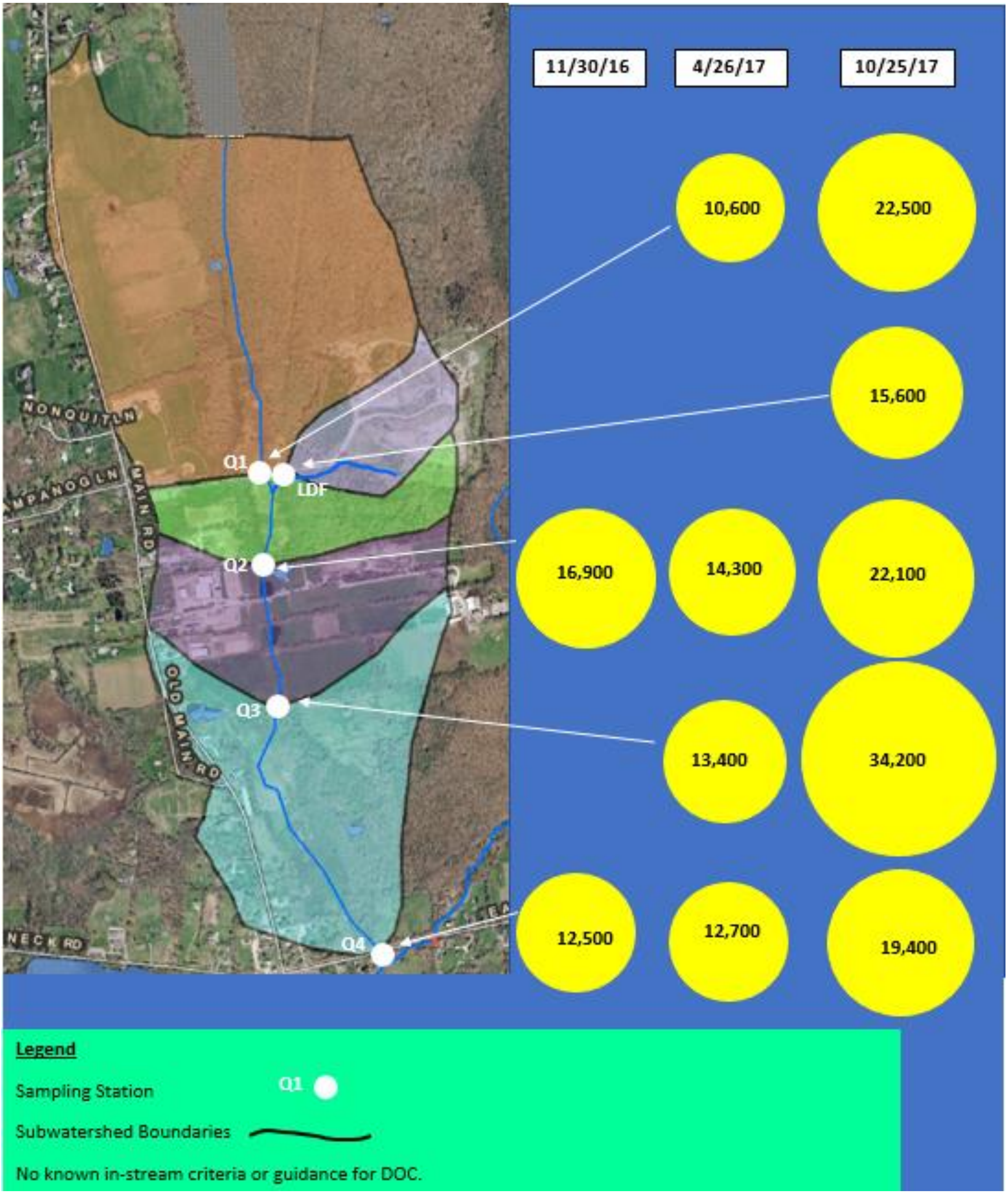


**Figure B-17. Quaker Creek Dry Weather Enterococci (MPN/100 ml) (return to: landfill swale or Quaker Creek).**

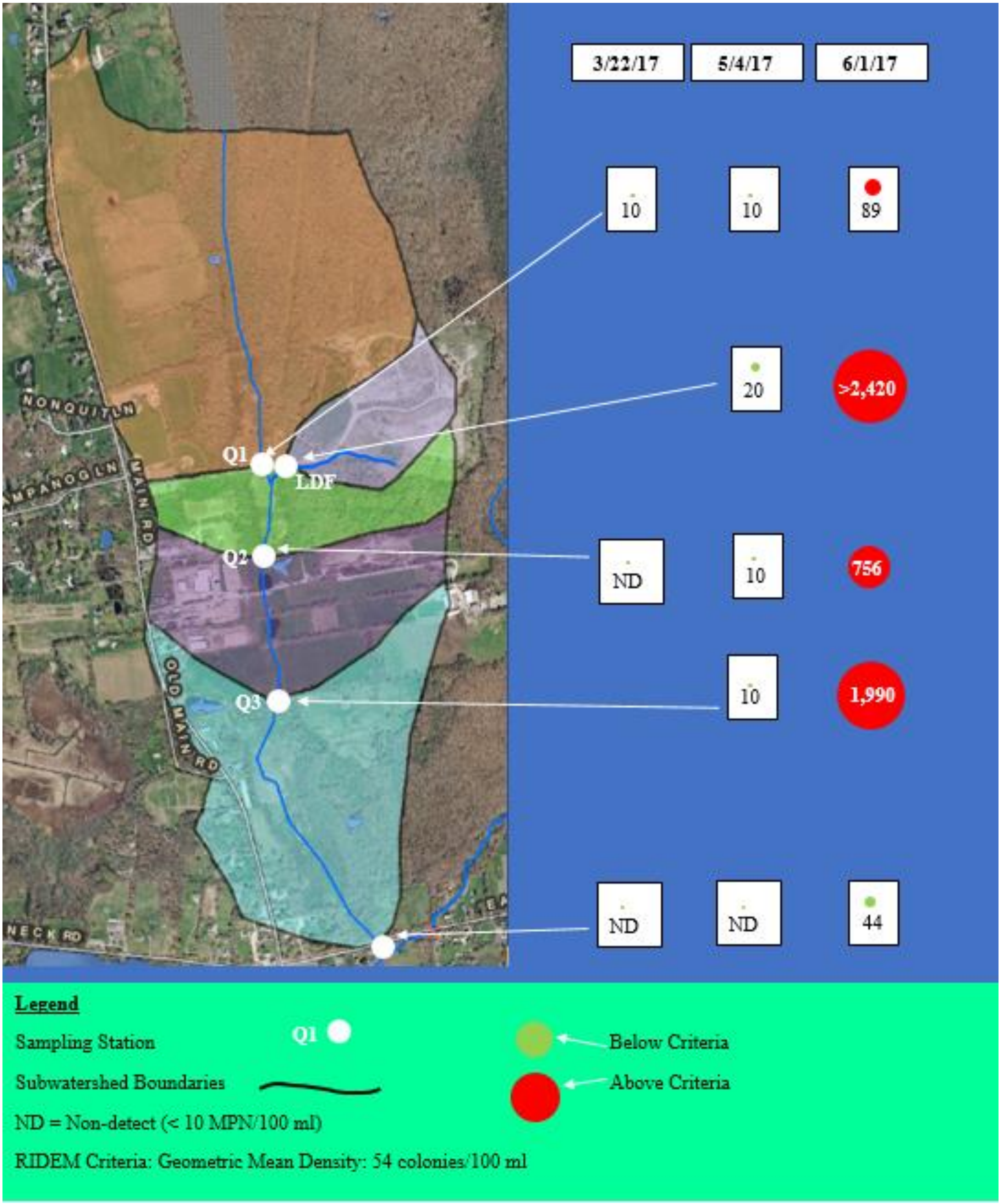


**Figure B-18. Quaker Creek Wet Weather Enterococci (MPN/100 ml) (return to: [landfill swale]() or [Quaker Creek]()).**

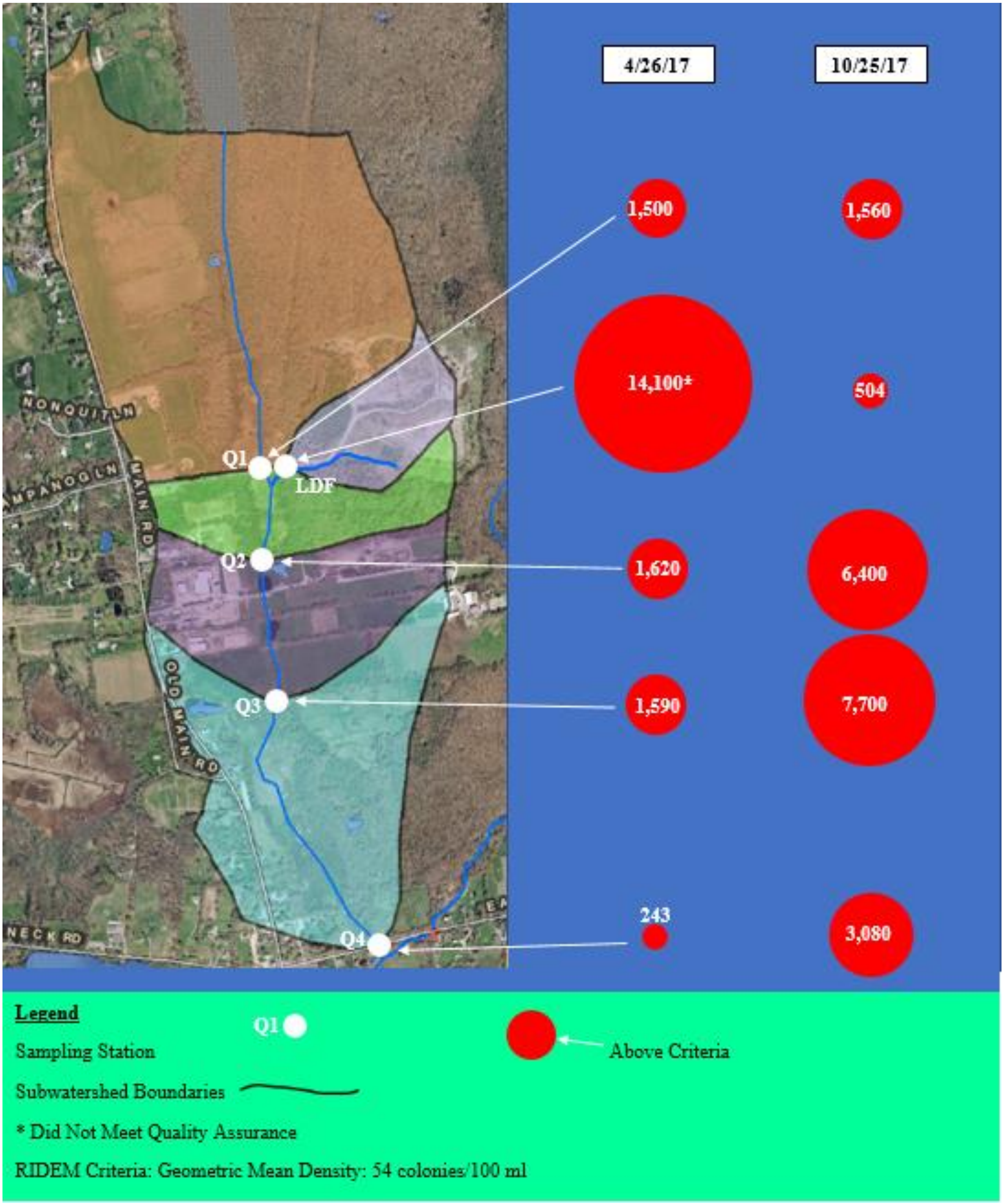


**Figure B-18. Quaker Creek Wet Weather Enterococci (MPN/100 ml) (return to: landfill swale or Quaker Creek).**

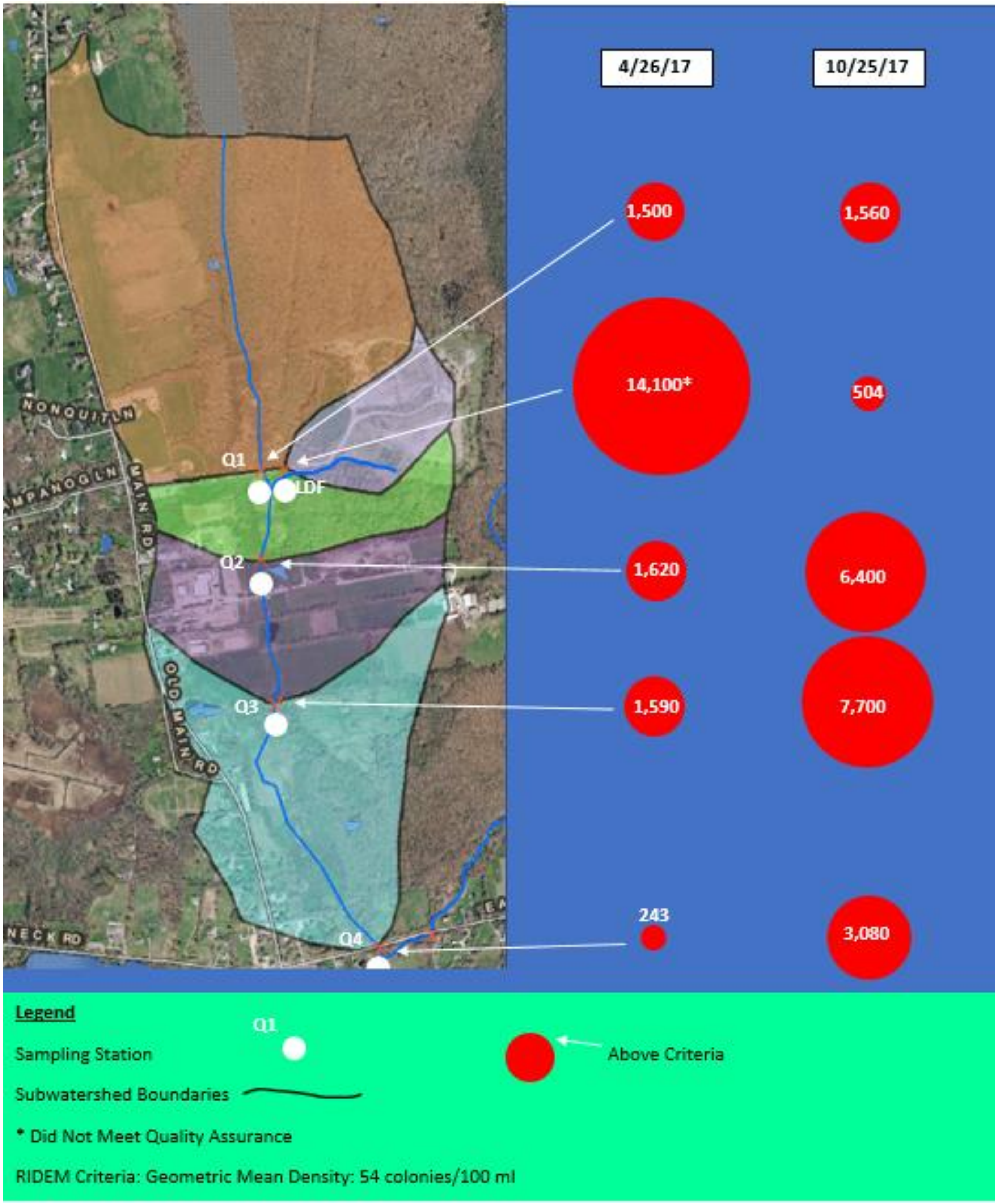


**Figure B-19. Quaker Creek Dry Weather Total Iron (ug/l) (return to: [landfill swale] or [Quaker Creek]).**

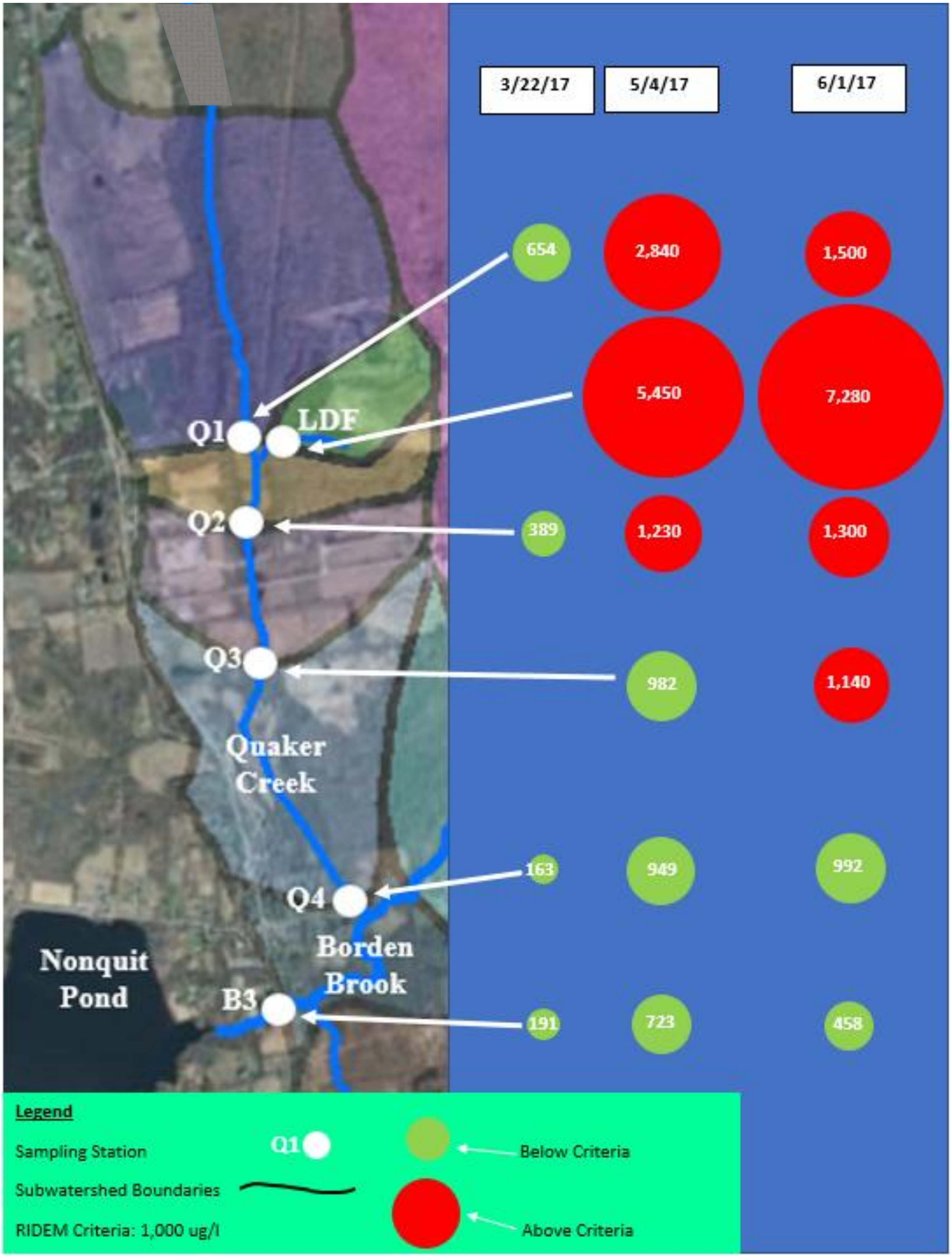


**Figure B-20. Quaker Creek Wet Weather Total Iron (ug/l) (return to: landfill swale or Quaker Creek).**

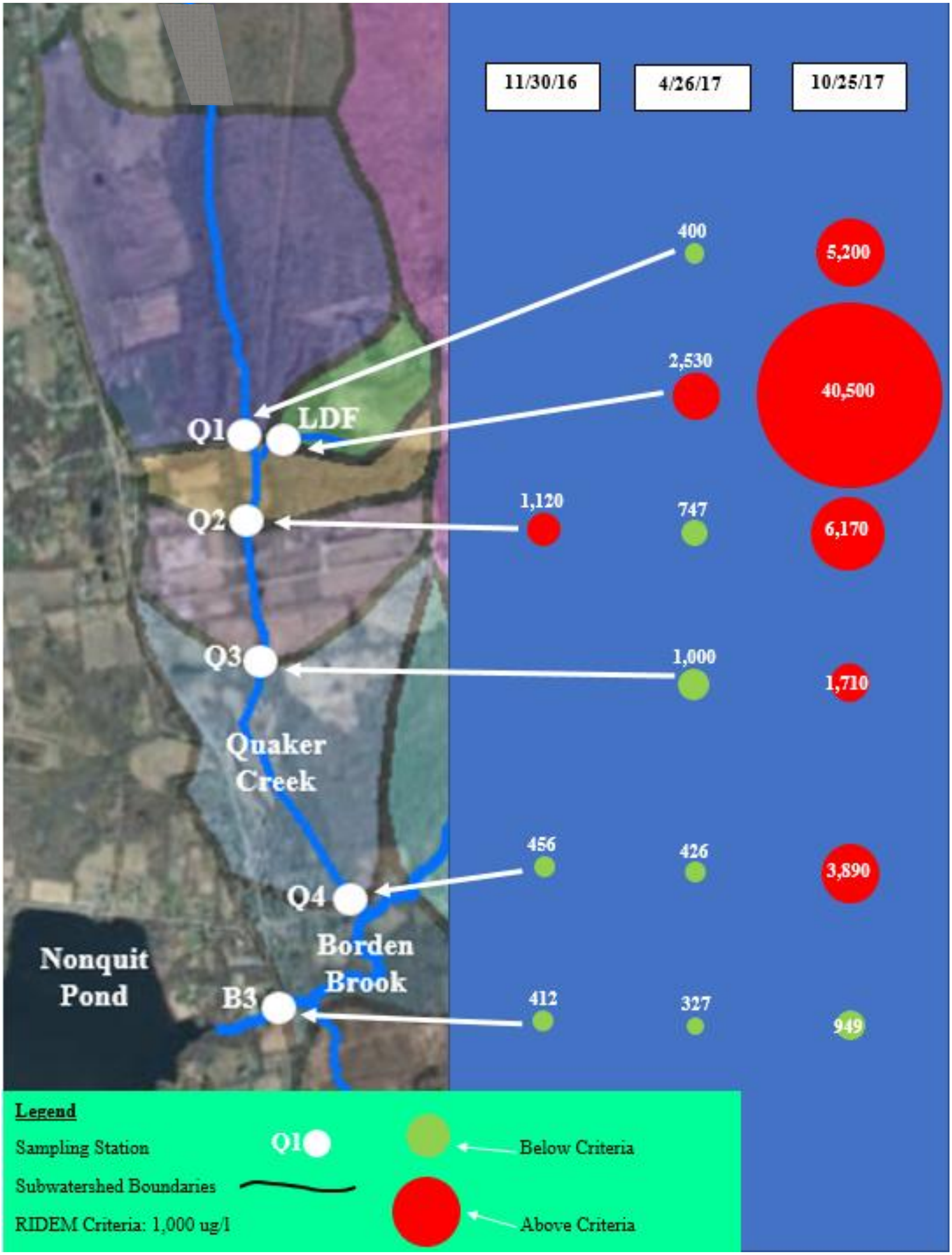


**Figure B-21. Quaker Creek Dry Weather Dissolved Cadmium (ug/l) (return to: landfill swale or Quaker Creek).**

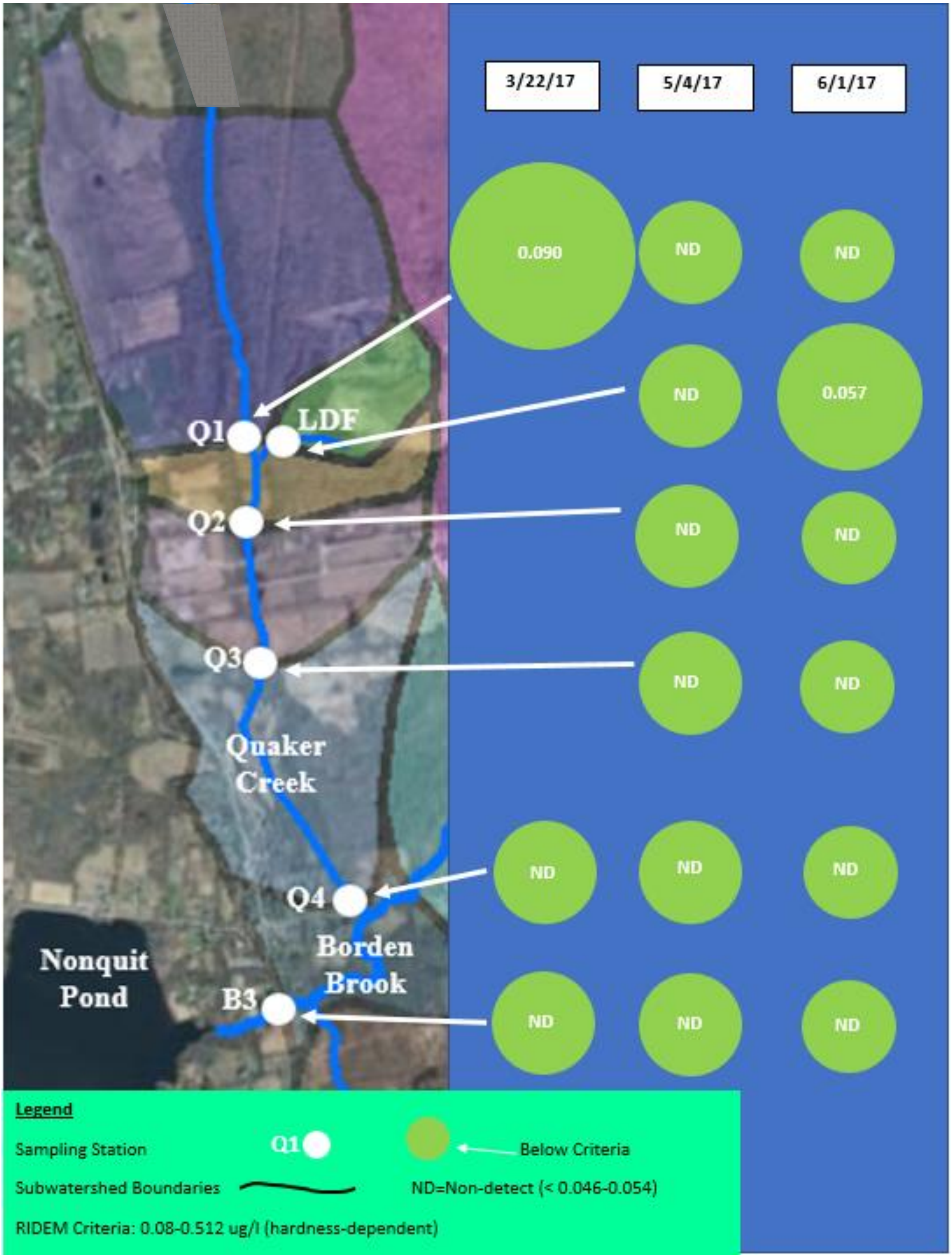


**Figure B-22. Quaker Creek Wet Weather Dissolved Cadmium (ug/l) (return to: landfill swale or Quaker Creek).**

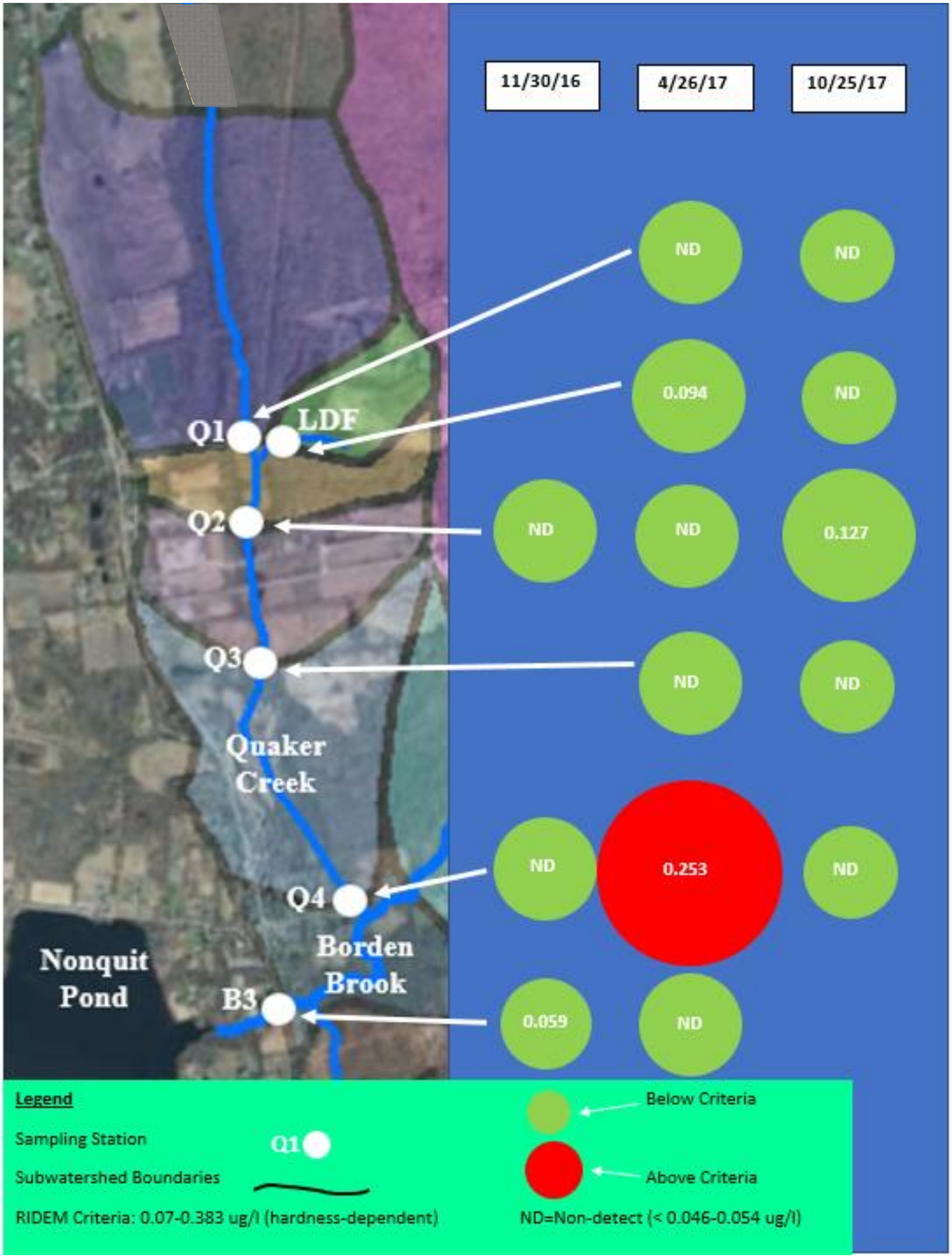


**Figure B-23. Quaker Creek Dry Weather Dissolved Chromium (ug/l) (return to: landfill swale or Quaker Creek).**

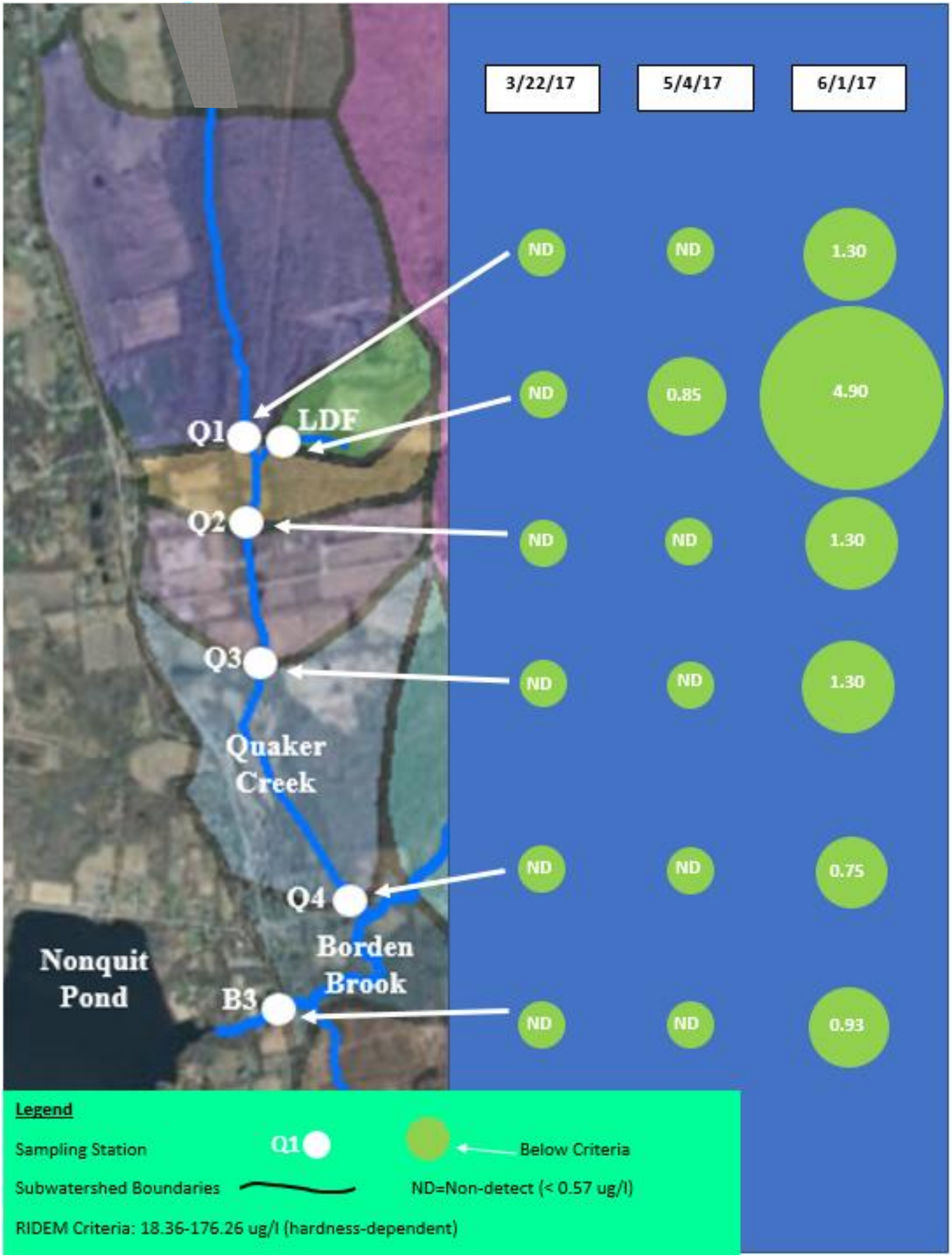


**Figure B-24. Quaker Creek Wet Weather Dissolved Chromium (ug/l) (return to: [landfill swale]() or [Quaker Creek]()).**

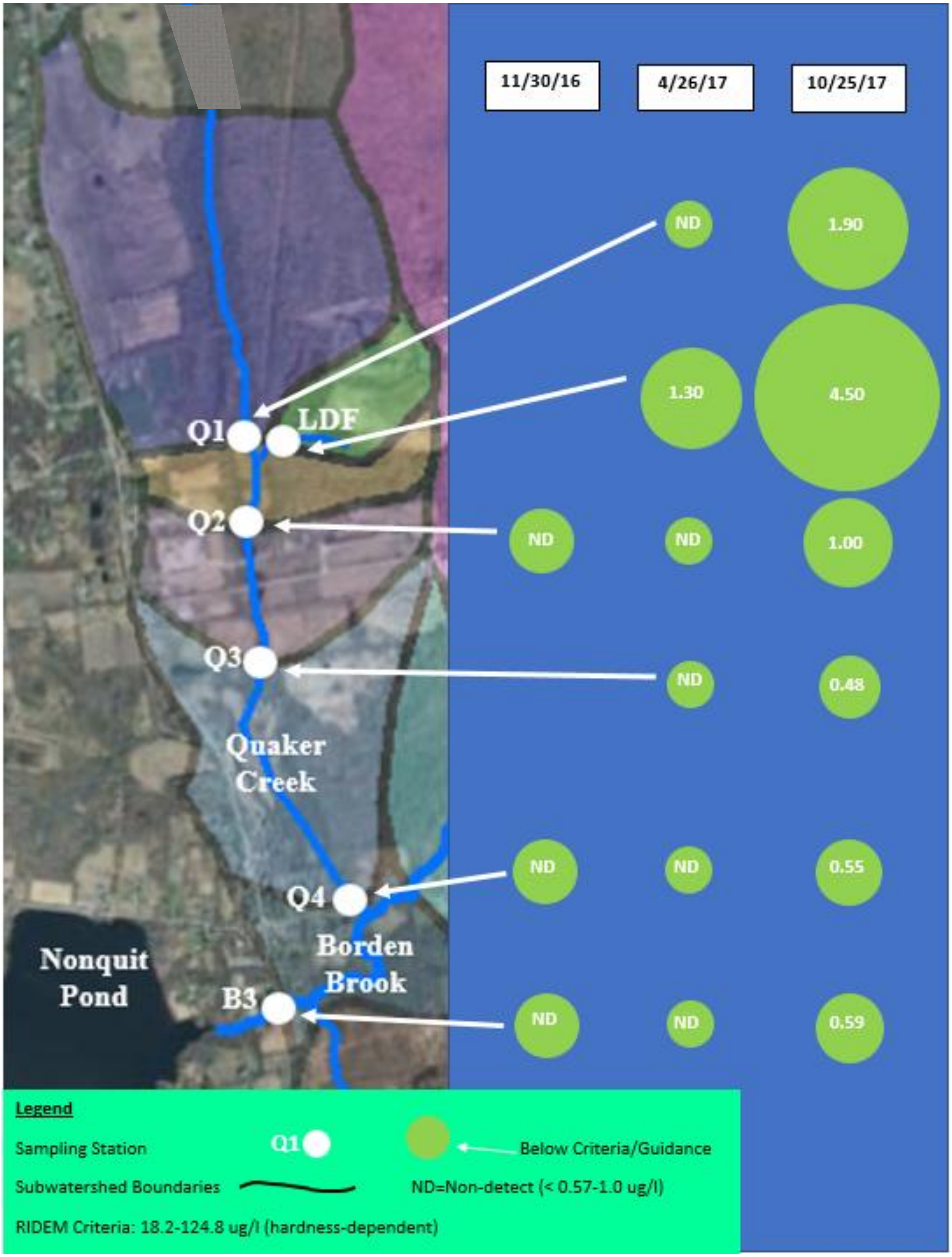


**Figure B-25. Quaker Creek Dry Weather Dissolved Copper (ug/l) (return to: landfill swale or Quaker Creek).**

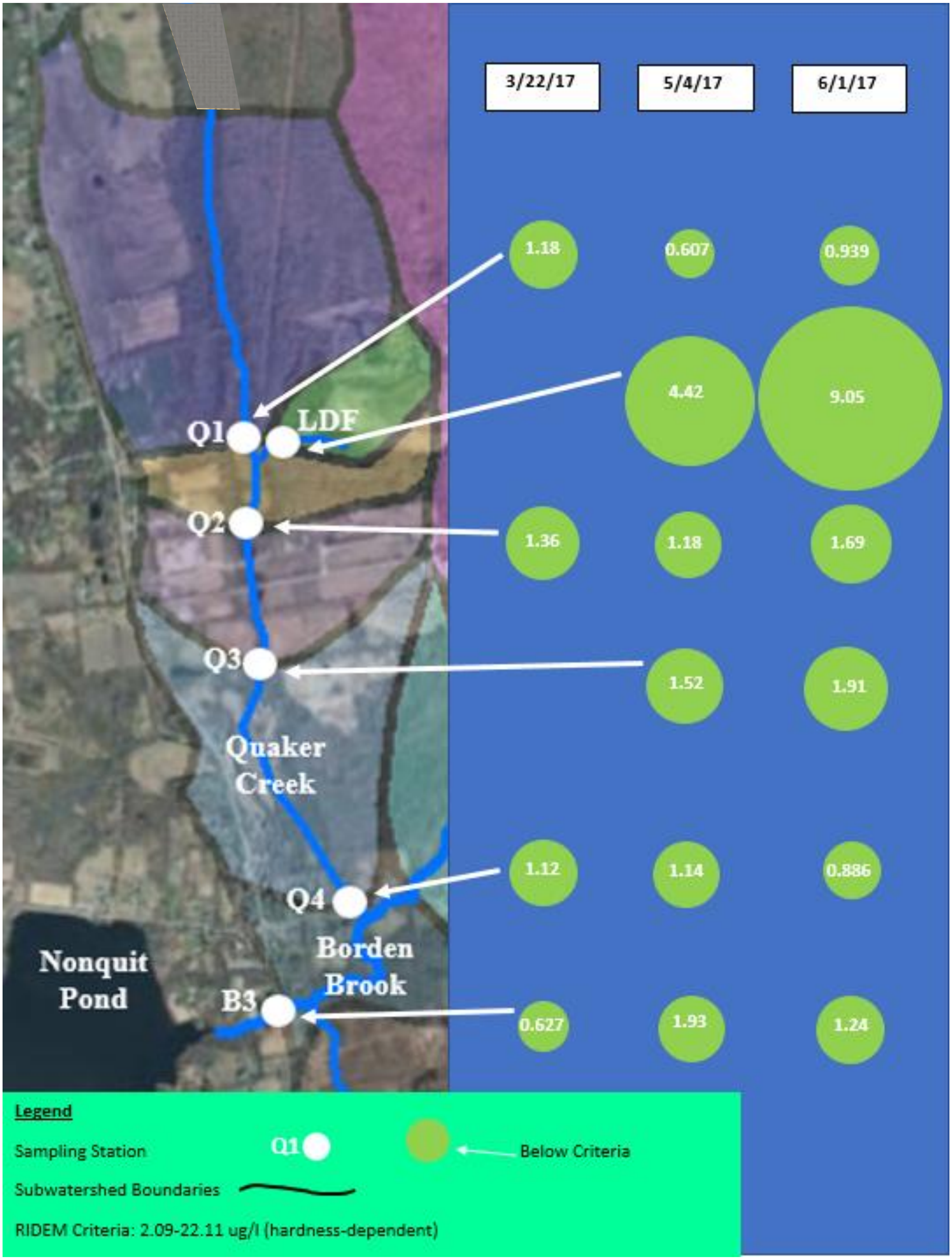


**Figure B-26. Quaker Creek Wet Weather Dissolved Copper (ug/l) (return to: landfill swale or Quaker Creek).**

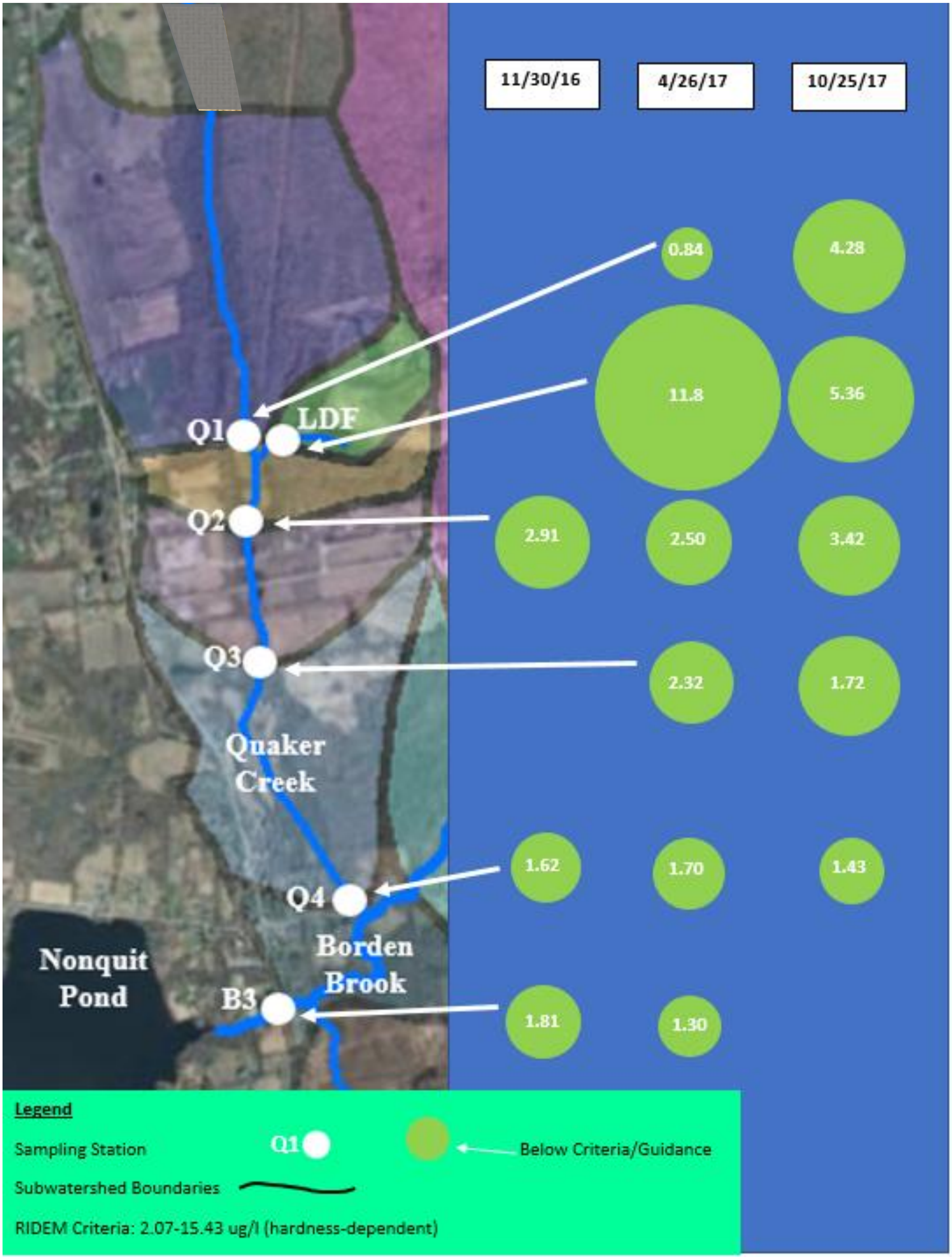


**Figure B-27. Quaker Creek Dry Weather Dissolved Lead (ug/l) (return to: landfill swale, Quaker Creek, or Borden Brook).**

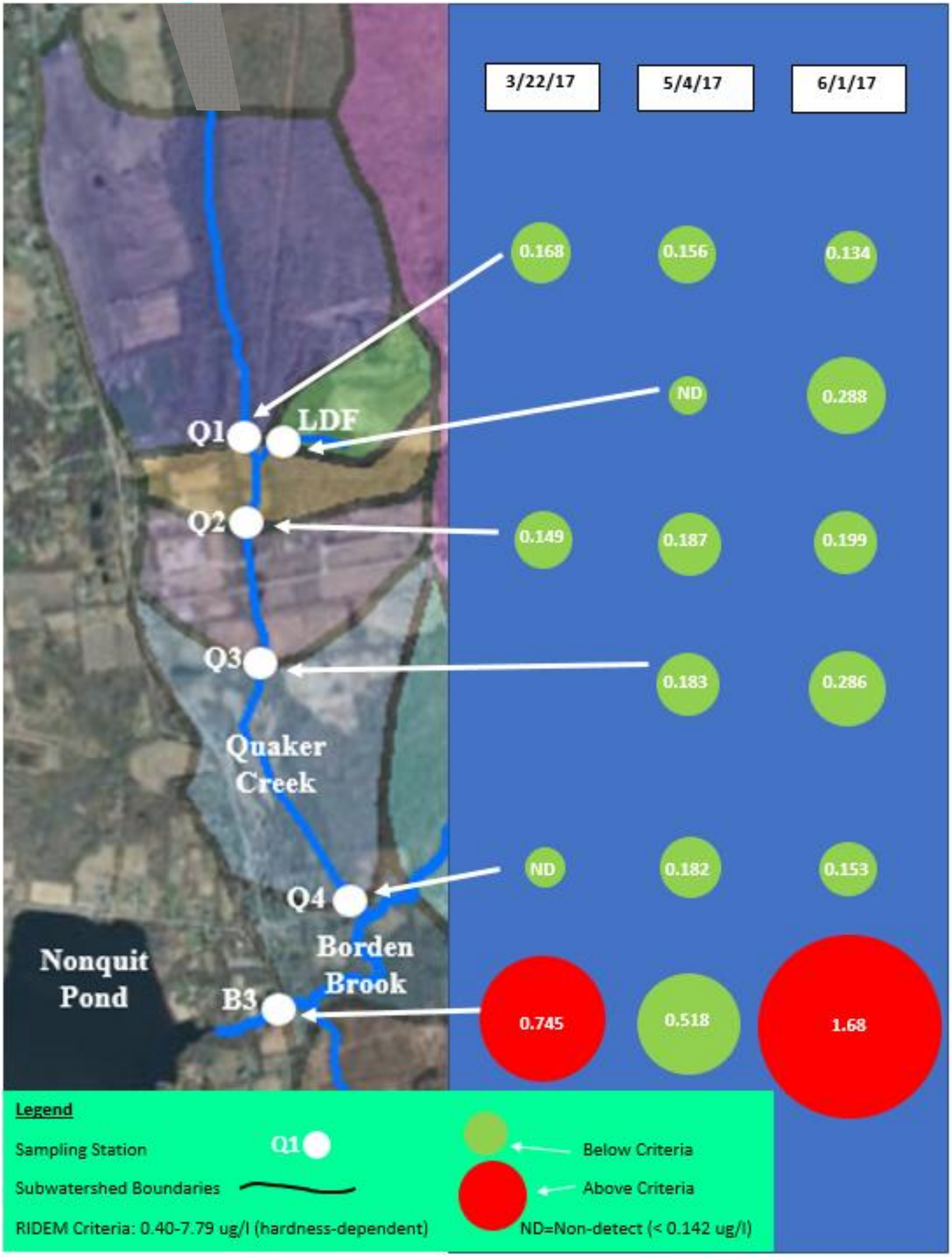


**Figure B-28. Quaker Creek Wet Weather Dissolved Lead (ug/l) (return to: landfill swale, Quaker Creek, or Borden Brook).**

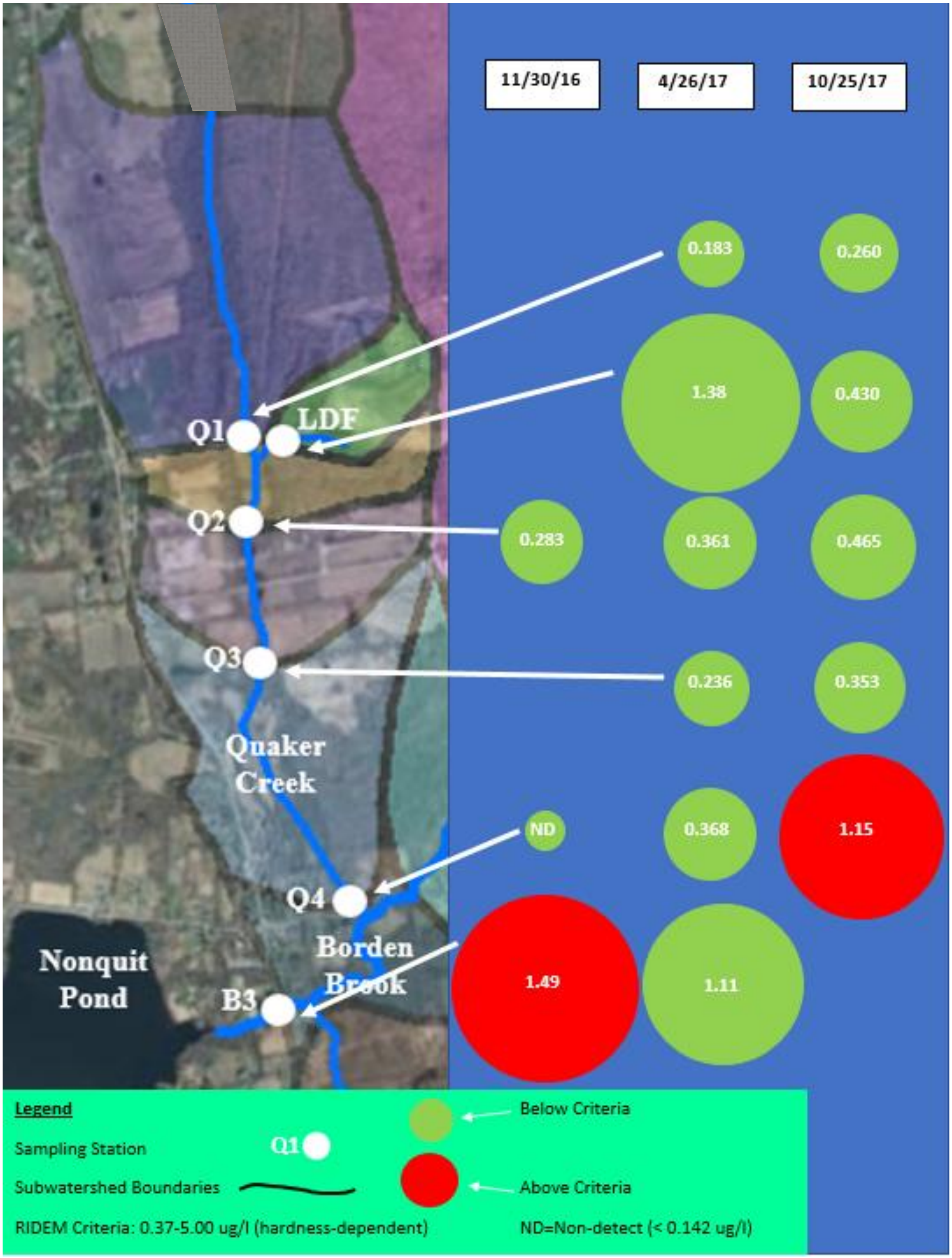


**Figure B-29. Quaker Creek Dry Weather Dissolved Selenium (ug/l) (return to: landfill swale or Quaker Creek).**

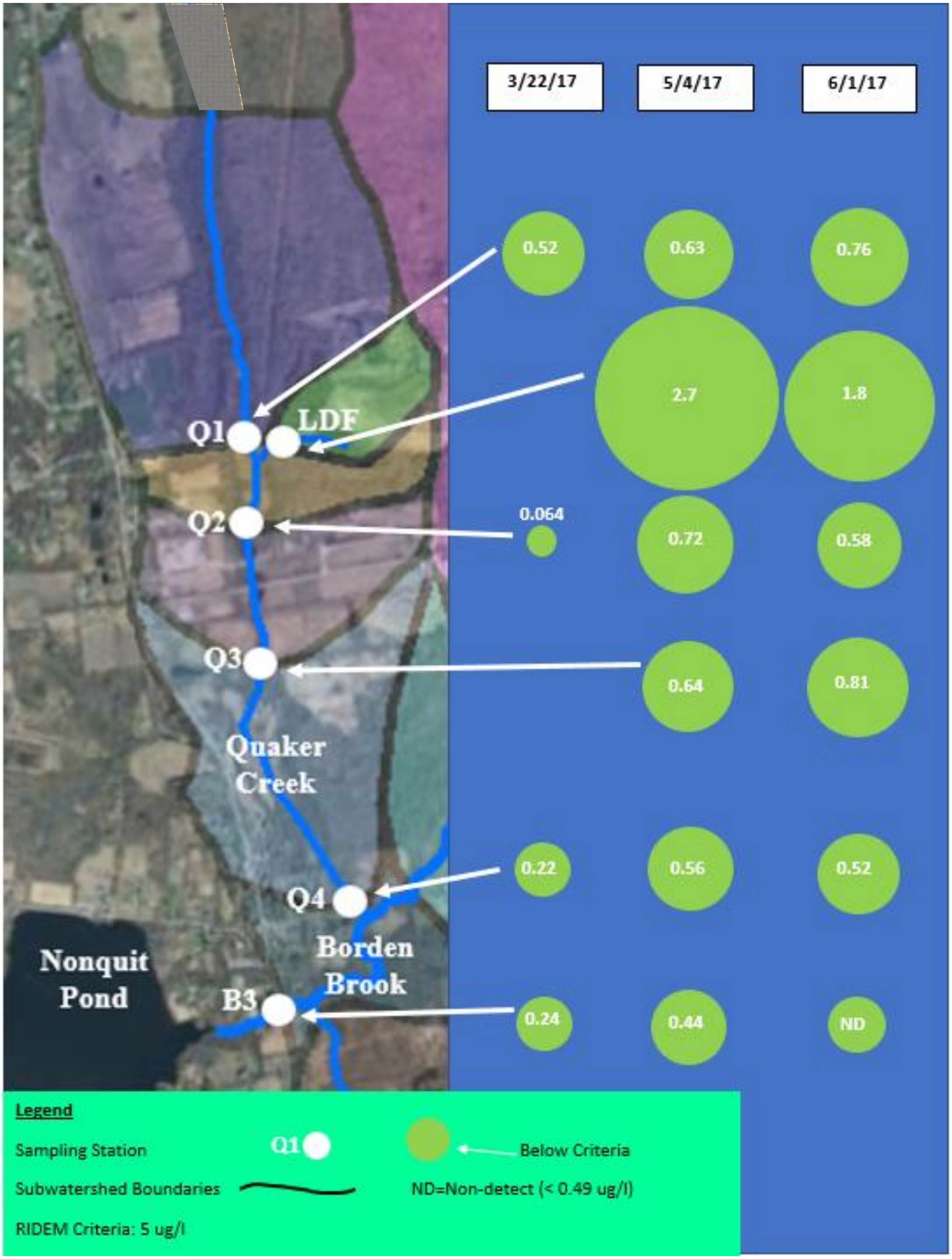


**Figure B-30. Quaker Creek Wet Weather Dissolved Selenium (ug/l) (return to: landfill swale or Quaker Creek).**

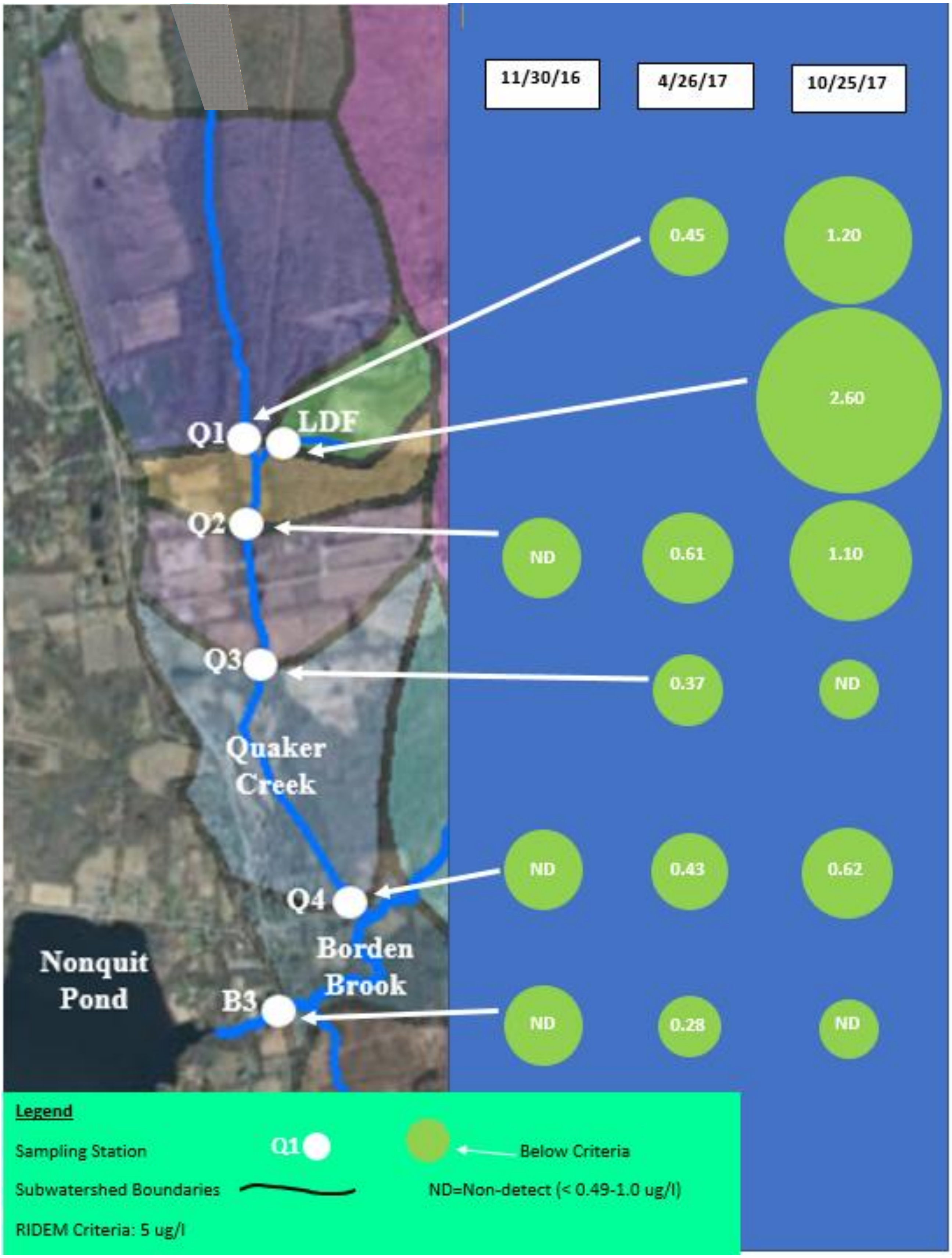


**Figure B-31. Quaker Brook Targeted Wet Weather Turbidity (NTU) (1/23/18). (return to: Quaker Creek).**

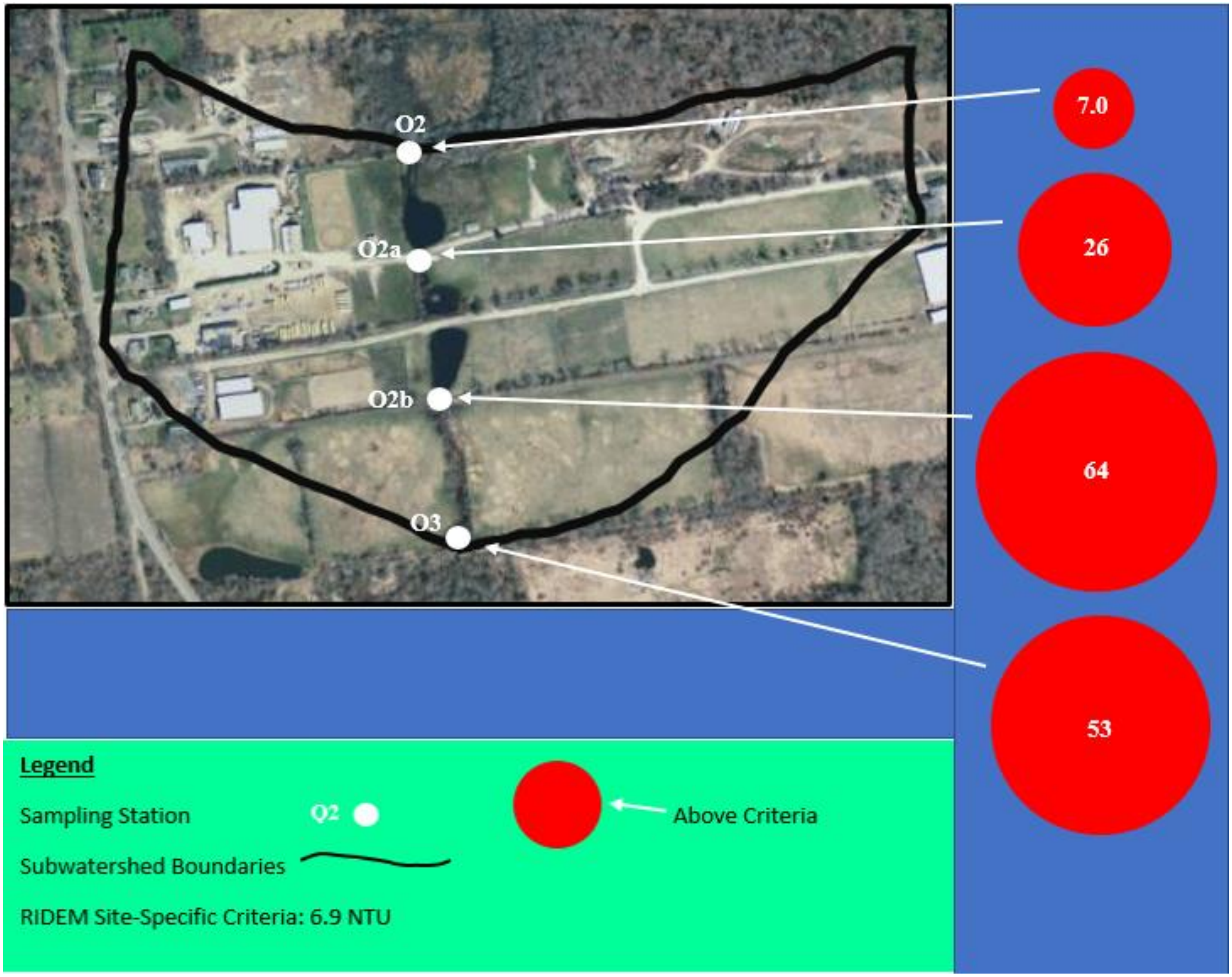


**Figure B-32. Quaker Brook Targeted Wet Weather Total Phosphorus (ug/l) (1/23/18). (return to: [Quaker Creek](#)).**

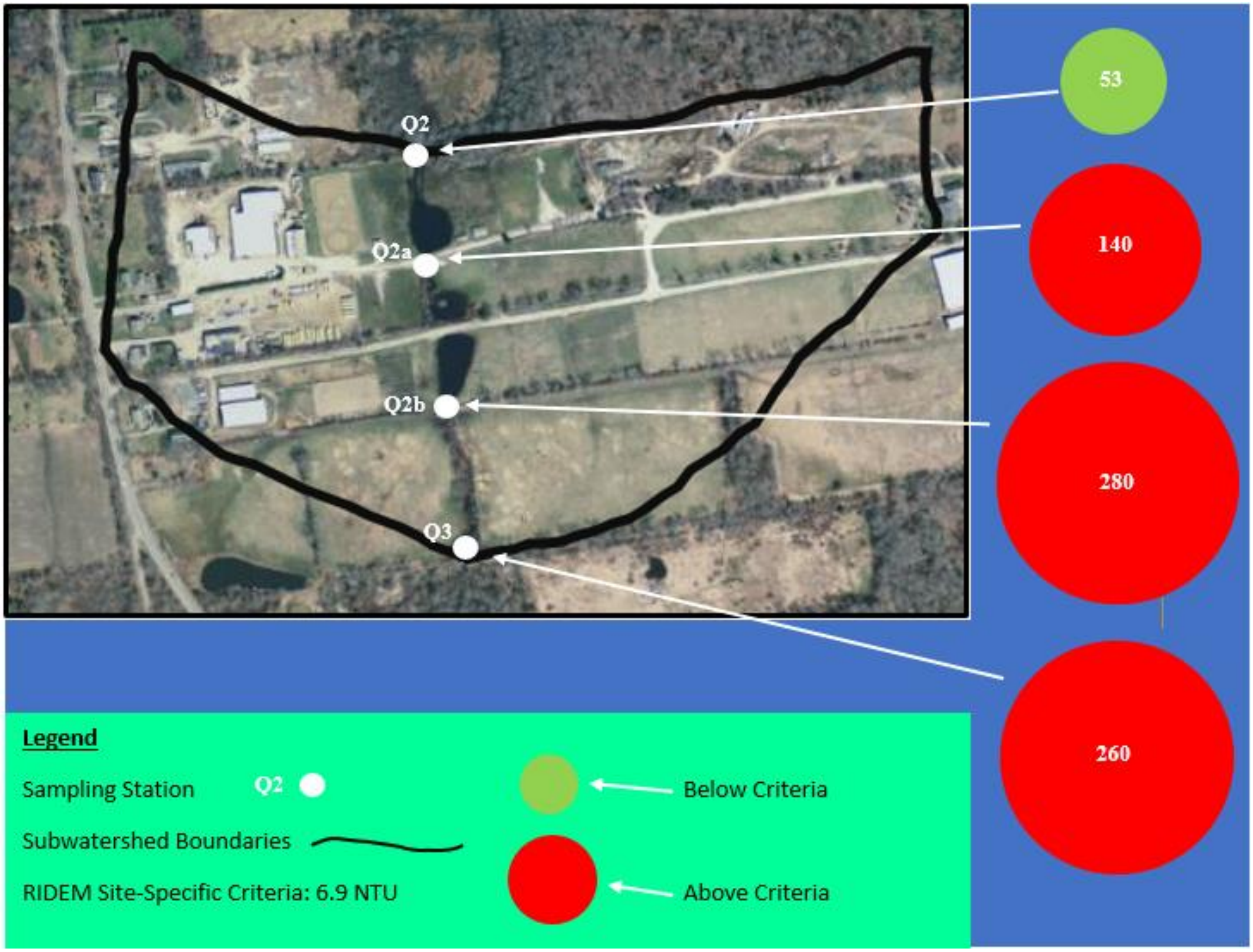


**Figure B-33. Quaker Brook Targeted Wet Weather Enterococci (MPN/100 ml) (1/23/18). (return to: Quaker Creek).**

**Figure B-34. Borden Brook Dry Weather Dissolved Oxygen (mg/l) (return to: Unnamed Tributary or Borden Brook).**

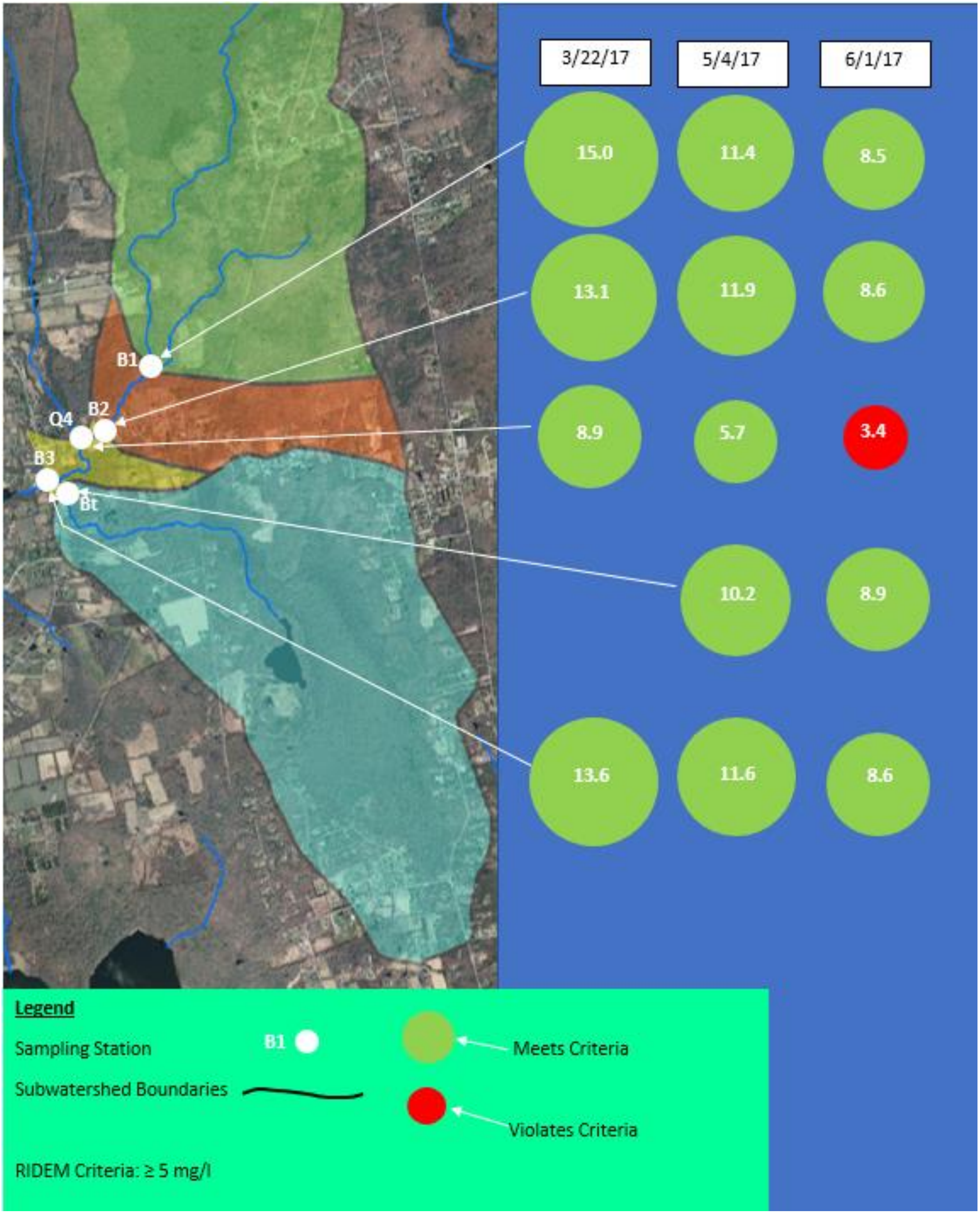


**Figure B-35. Borden Brook Wet Weather Dissolved Oxygen (mg/l) (return to: Unnamed Tributary or Borden Brook).**

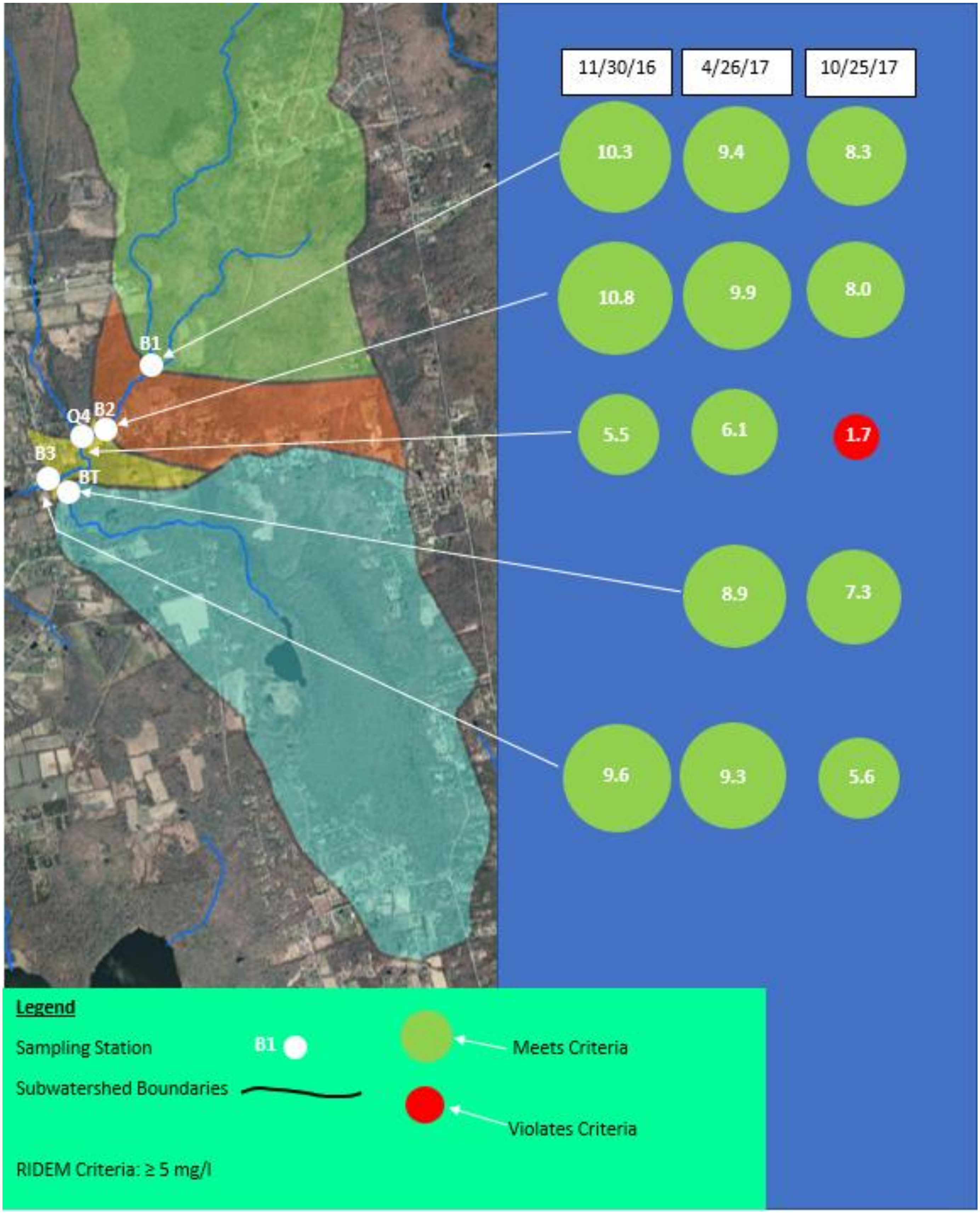


**Figure B-36. Borden Brook Dry Weather Specific Conductance (µs/cm) (return to: Unnamed Tributary or Borden Brook).**

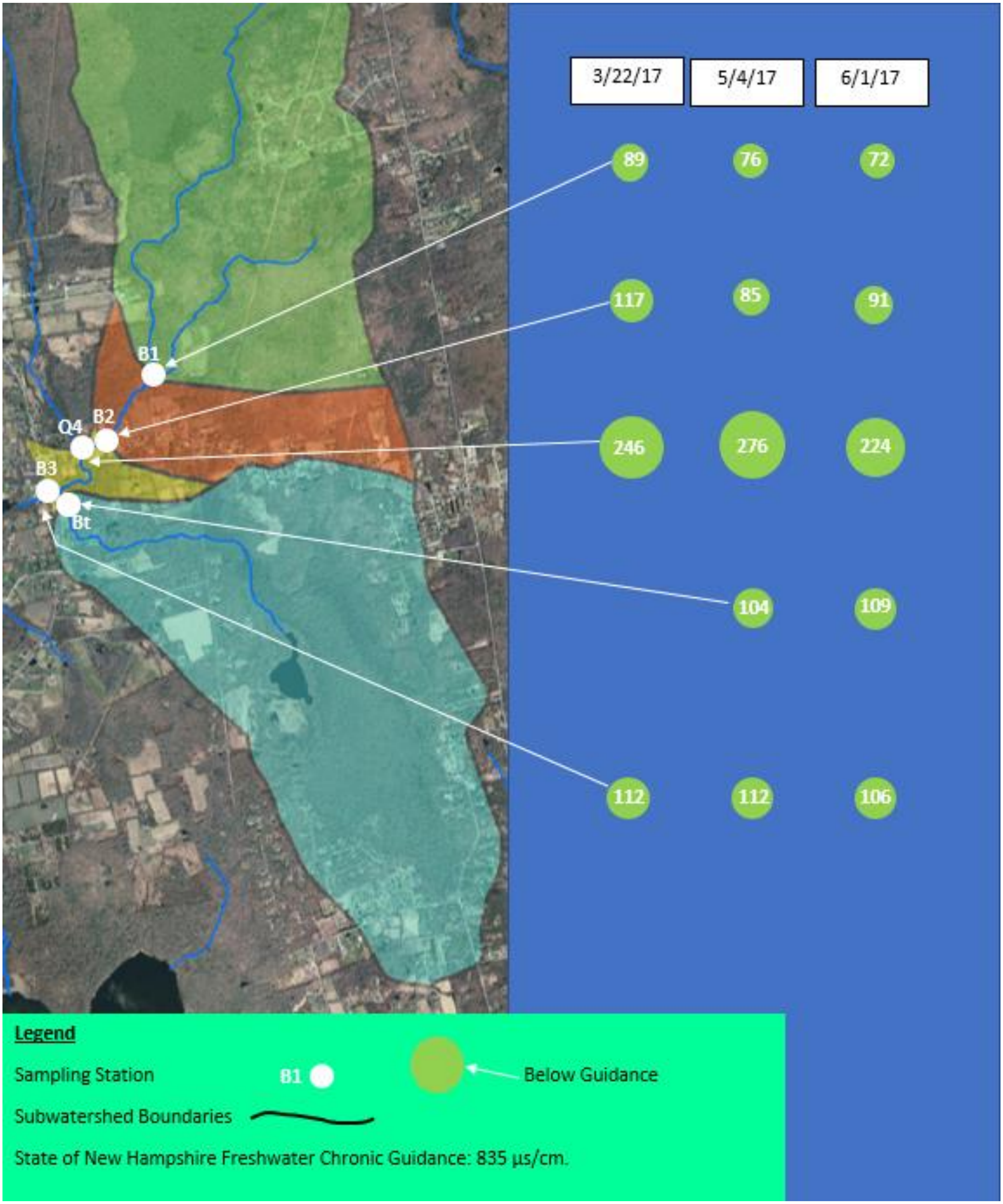


**Figure B-37. Borden Brook Wet Weather Specific Conductance (µs/cm) (return to: Unnamed Tributary or Borden Brook).**

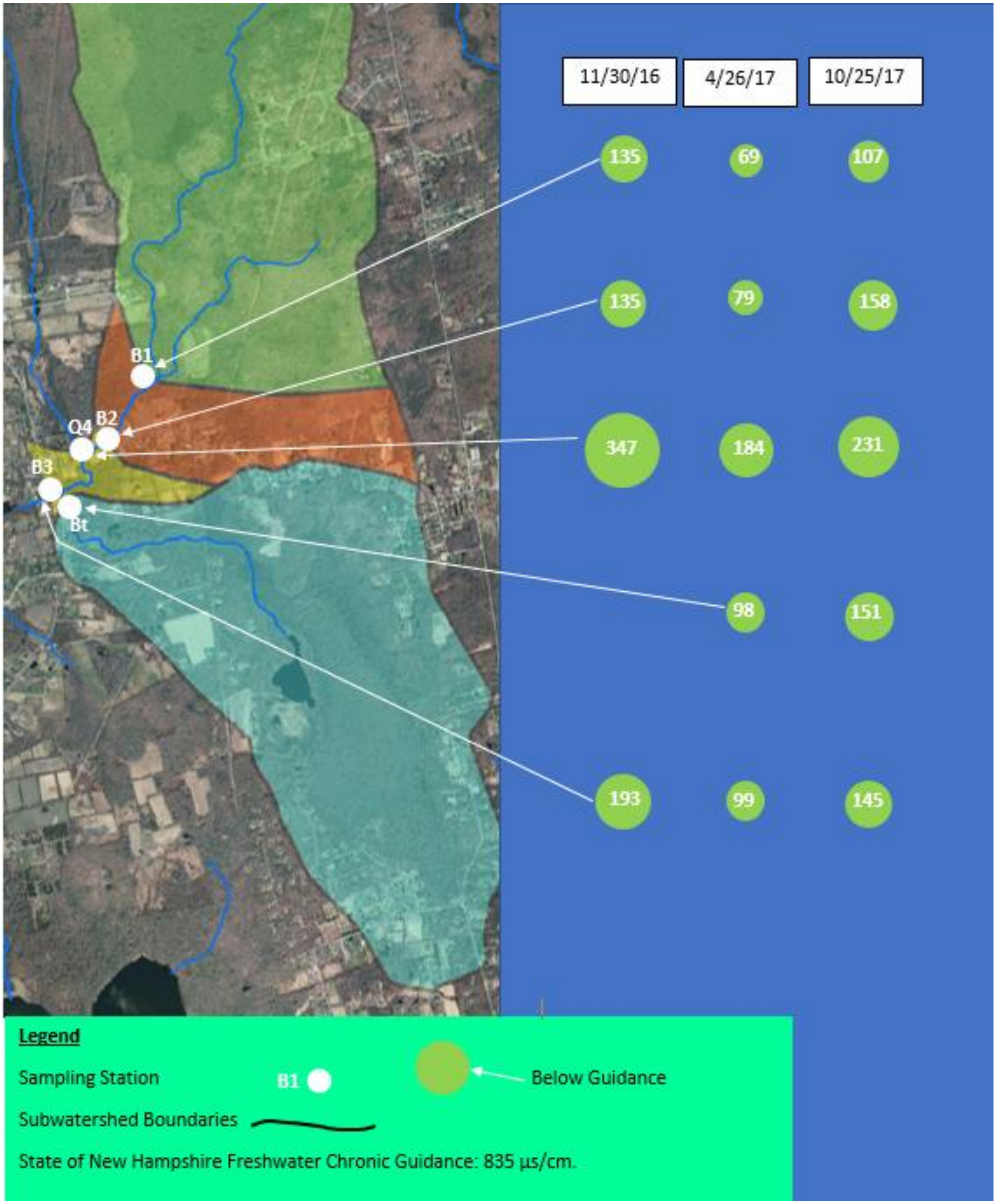


**Figure B-38. Borden Brook Dry Weather pH (return to: Unnamed Tributary or Borden Brook).**

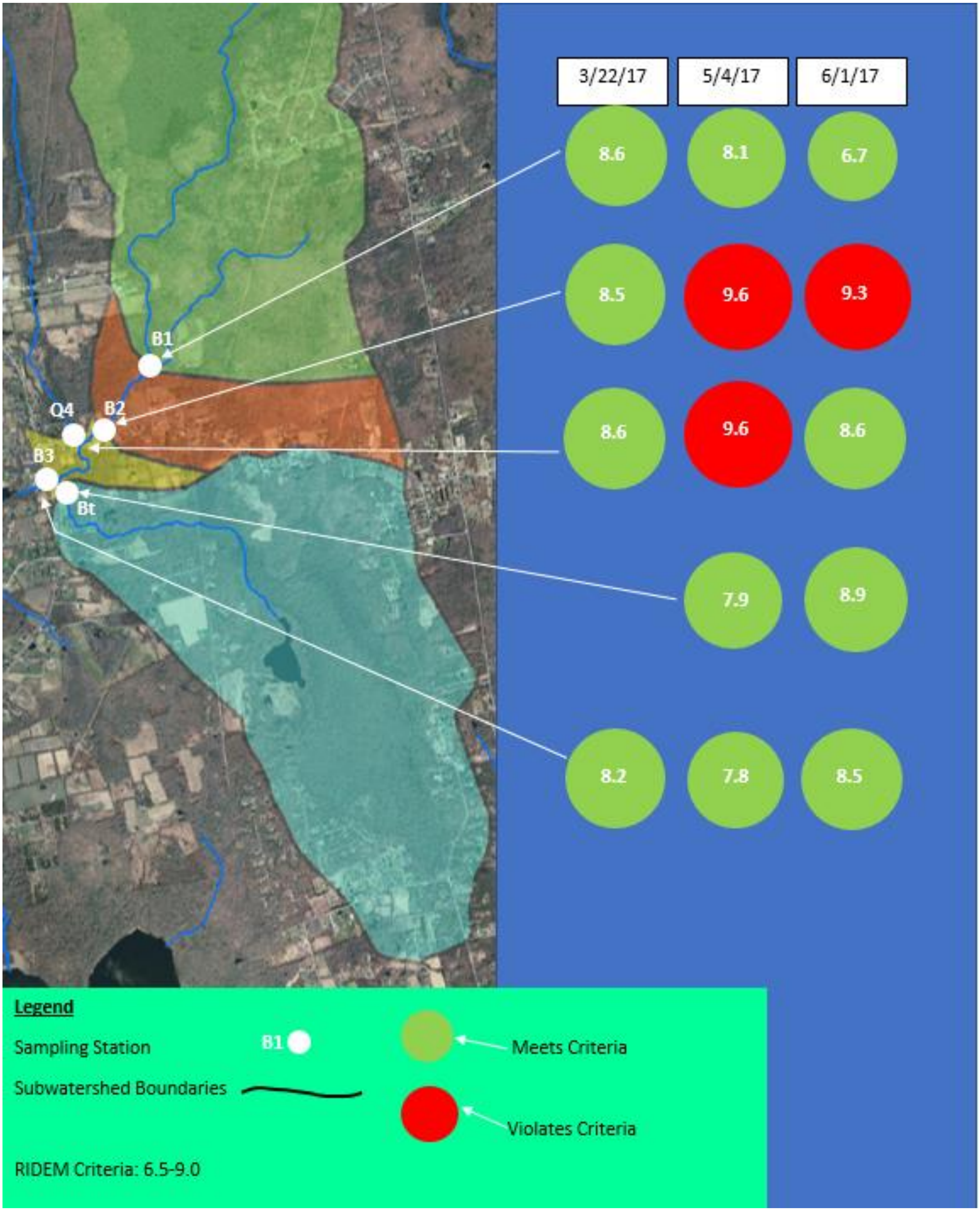


**Figure B-39. Borden Brook Wet Weather pH (return to: Unnamed Tributary or Borden Brook).**

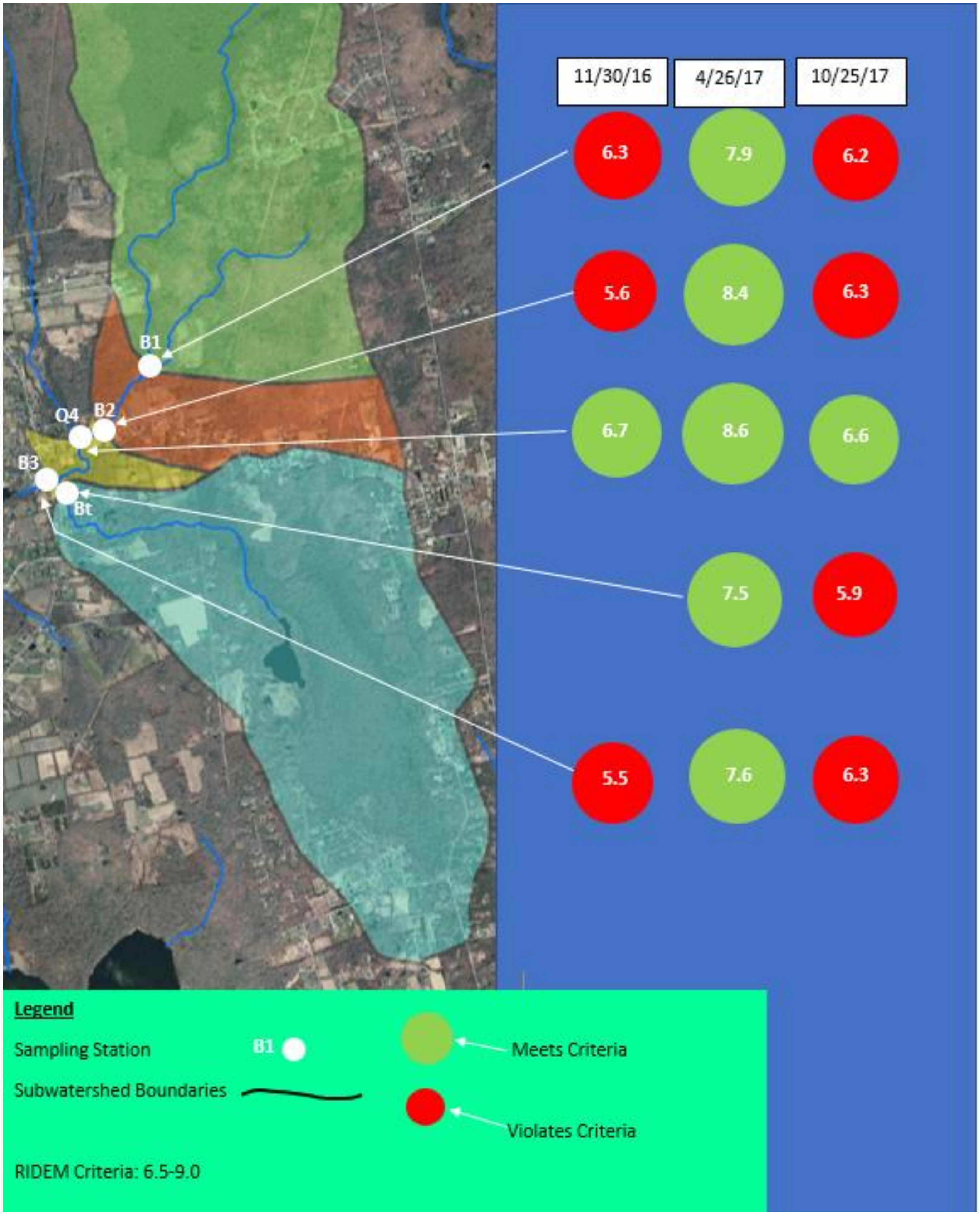


**Figure B-40. Borden Brook Dry Weather Turbidity (NTU) (return to: Unnamed Tributary or Borden Brook).**

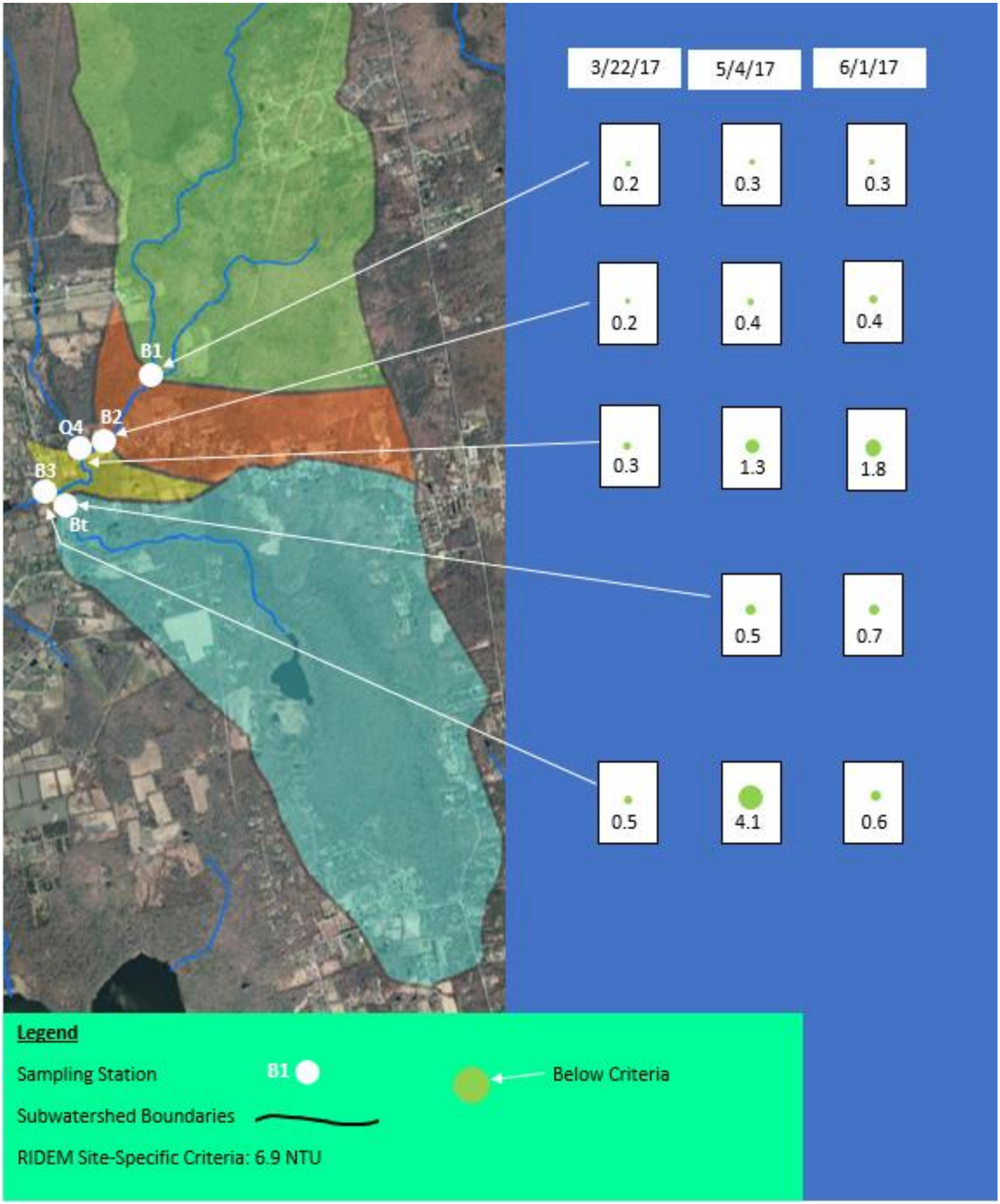


**Figure B-41. Borden Brook Wet Weather Turbidity (NTU) (return to: Unnamed Tributary or Borden Brook).**

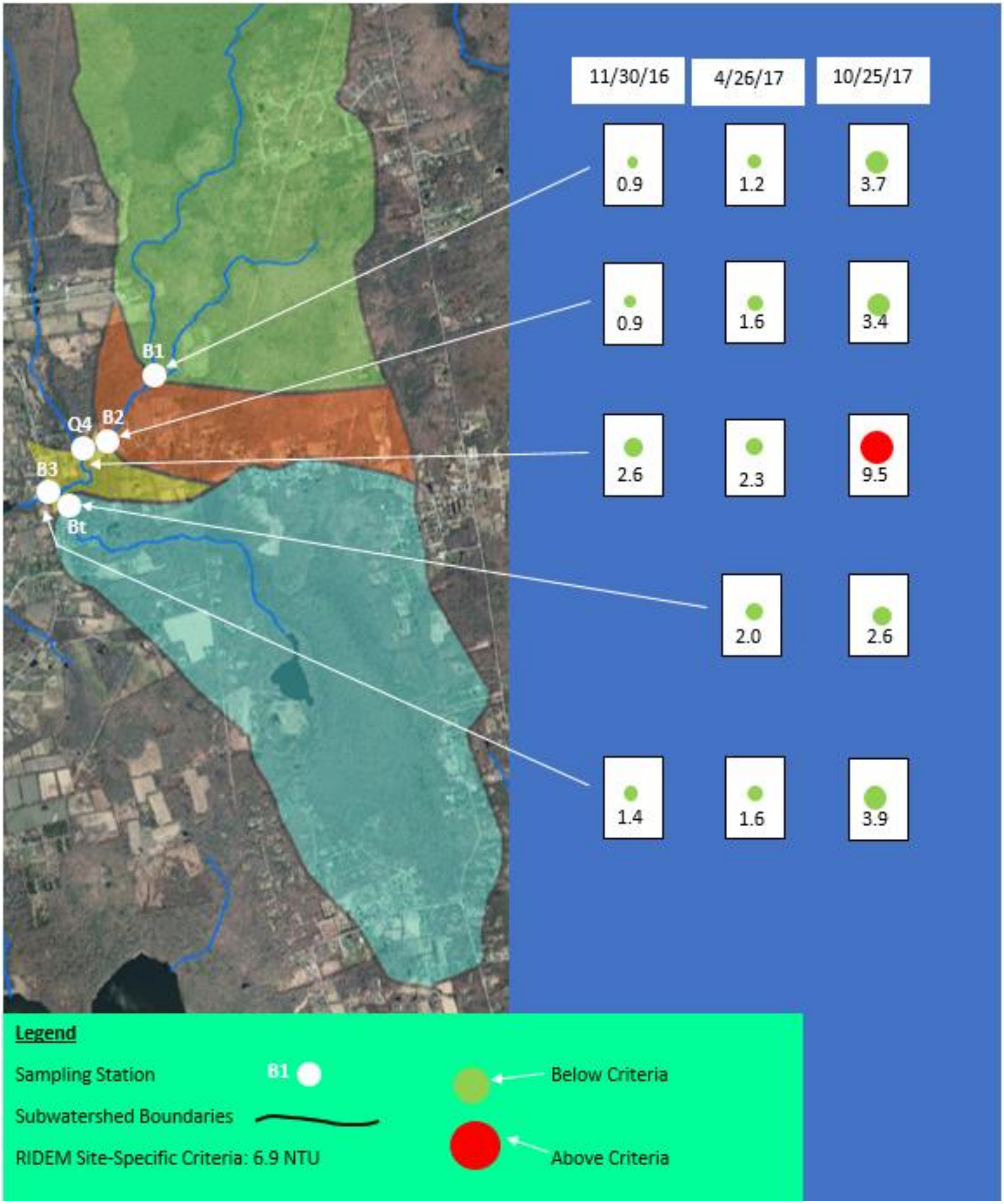


**Figure B-42. Borden Brook Dry Weather Total Suspended Solids (ug/l) (return to: Unnamed Tributary or Borden Brook).**

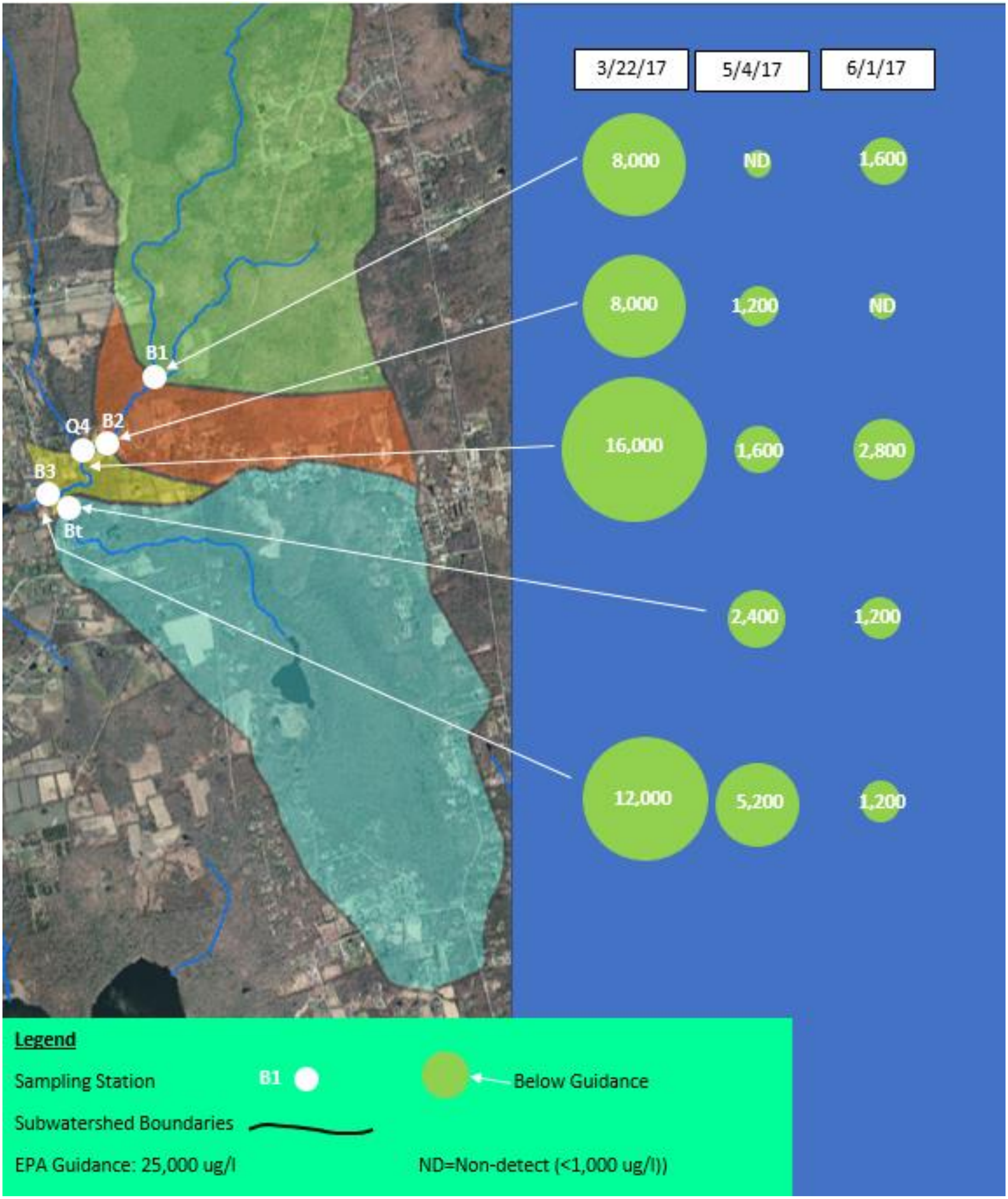


**Figure B-43. Borden Brook Wet Weather Total Suspended Solids (ug/l) (return to: Unnamed Tributary or Borden Brook).**

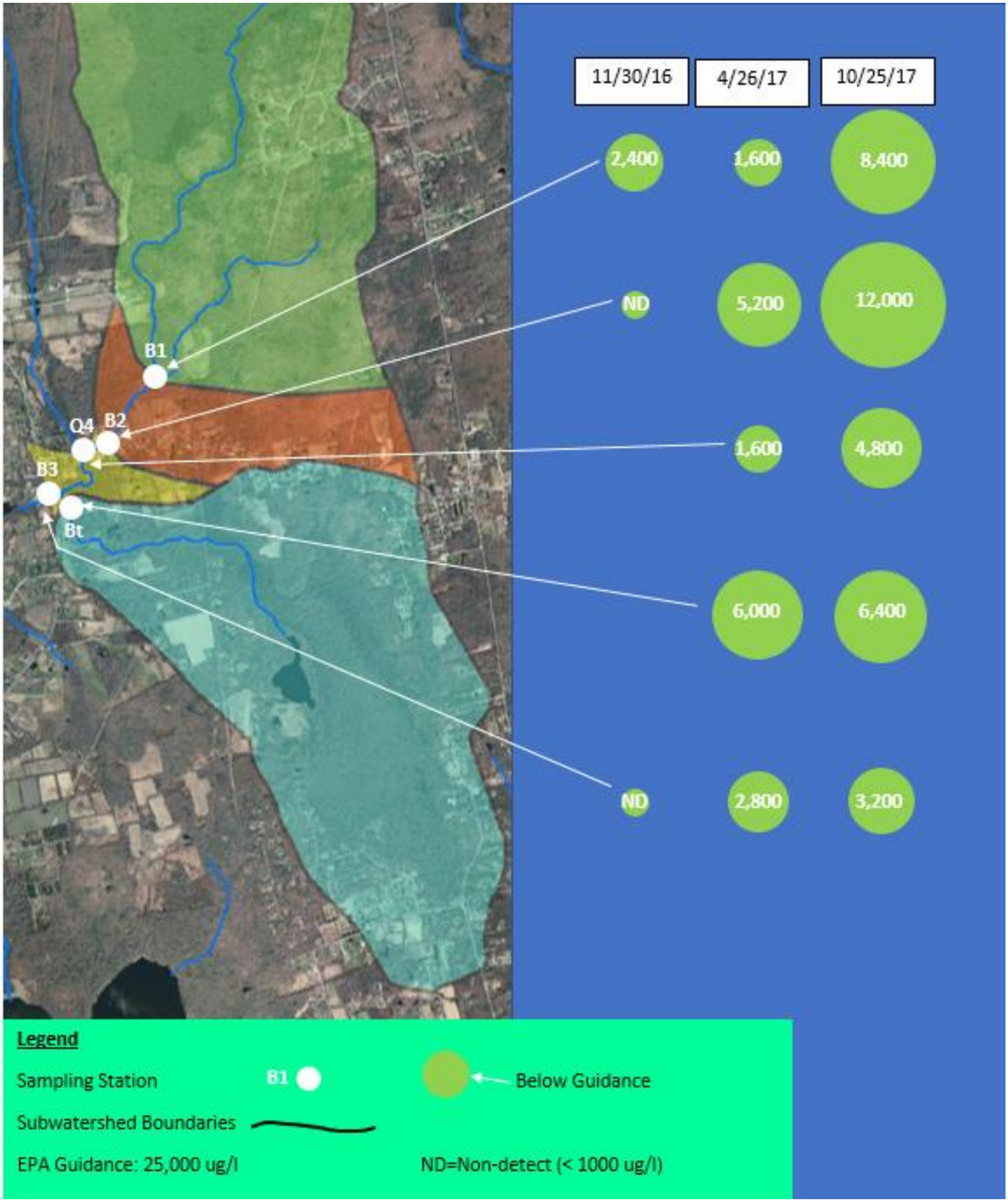


**Figure B-44. Borden Brook Dry Weather Phosphorus (ug/l) (return to: Unnamed Tributary or Borden Brook).**

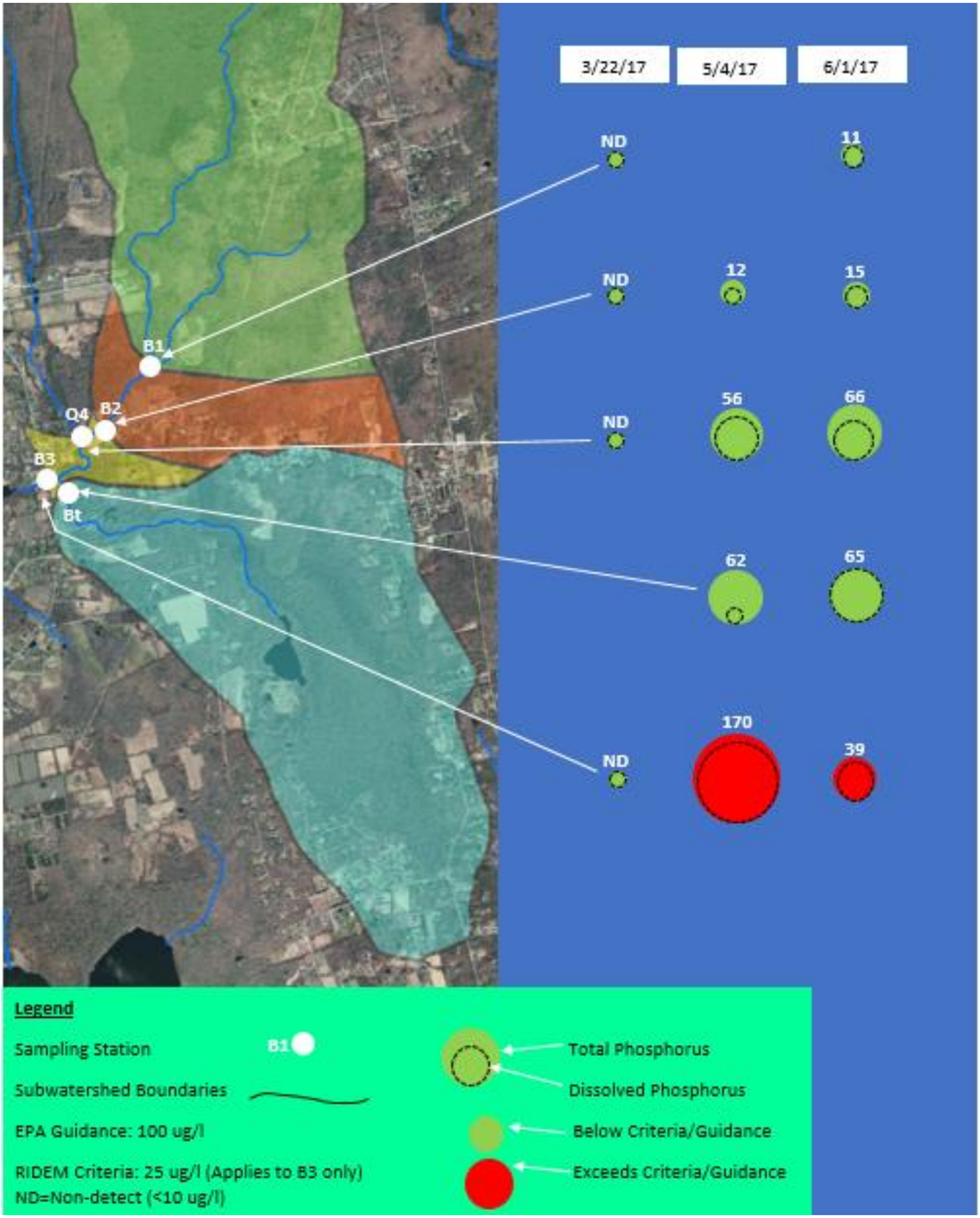


**Figure B-45. Borden Brook Wet Weather Phosphorus (ug/l) (return to: [Unnamed Tributary] or [Borden Brook]).**

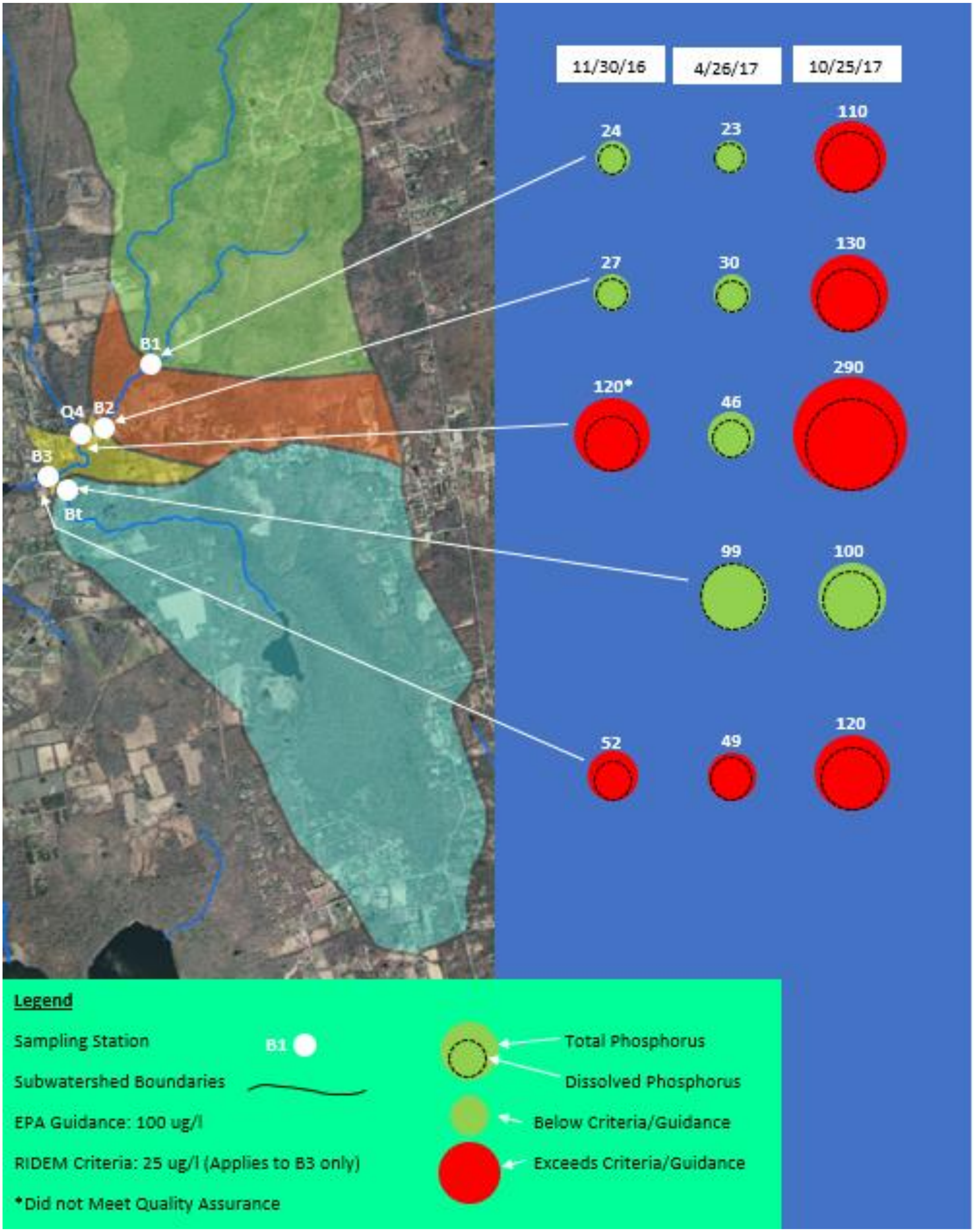


**Figure B-46. Borden Brook Dry Weather Nitrogen (ug/l) (return to: Unnamed Tributary or Borden Brook).**

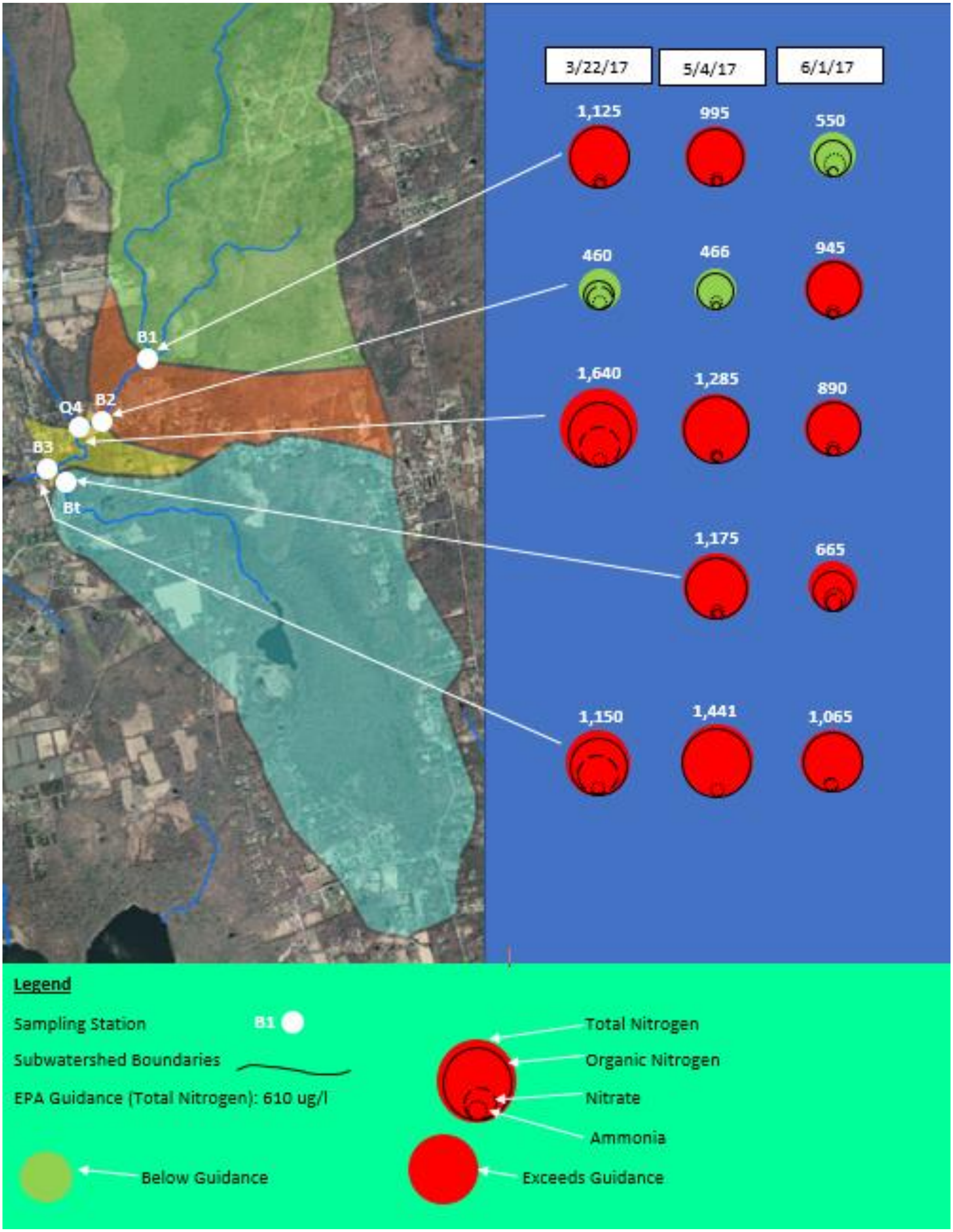


**Figure B-47. Borden Brook Wet Weather Nitrogen (ug/l) (return to: Unnamed Tributary or Borden Brook).**

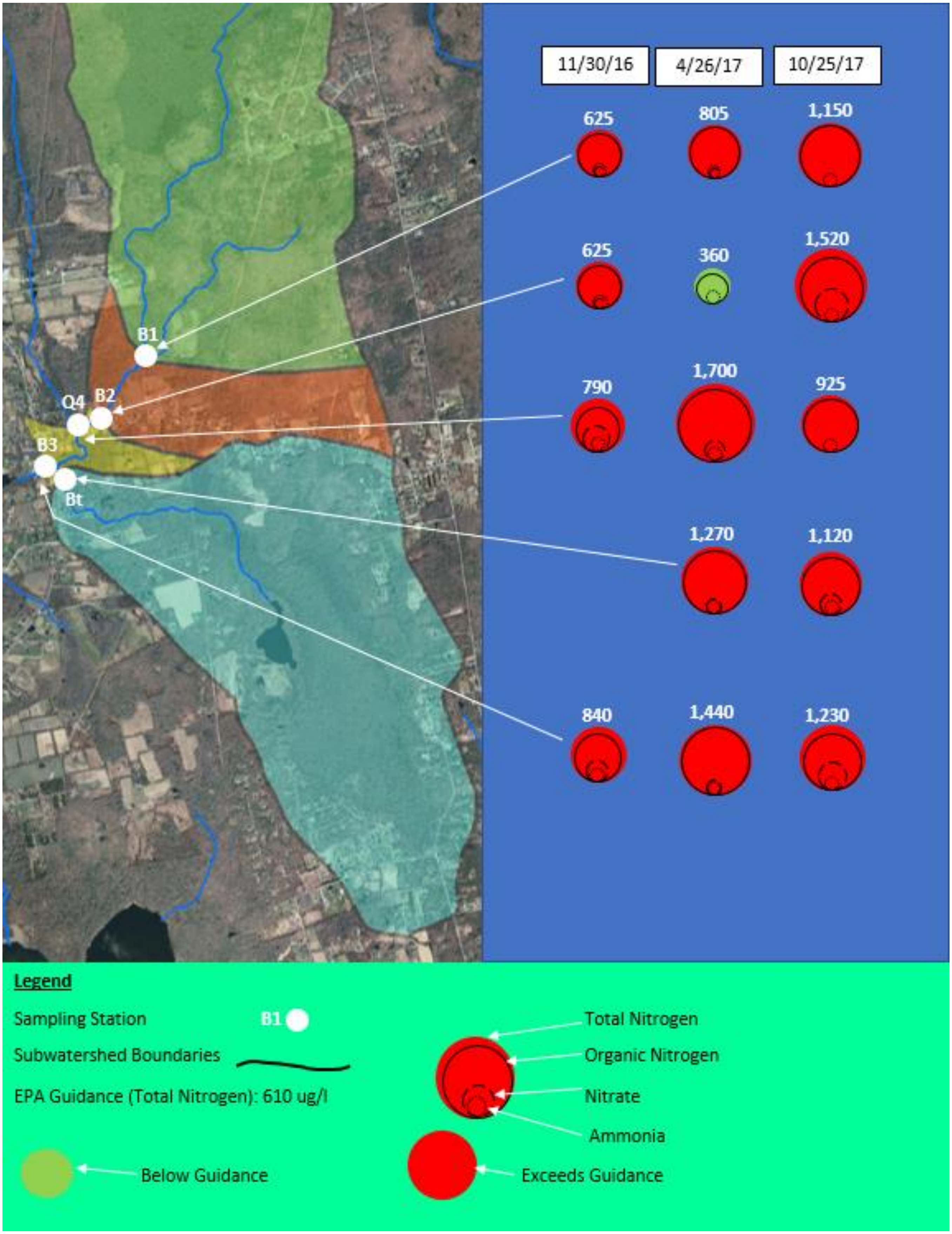


**Figure B-48. Borden Brook Dry Weather Total Dissolved Carbon (ug/l) (return to: Unnamed Tributary or Borden Brook).**

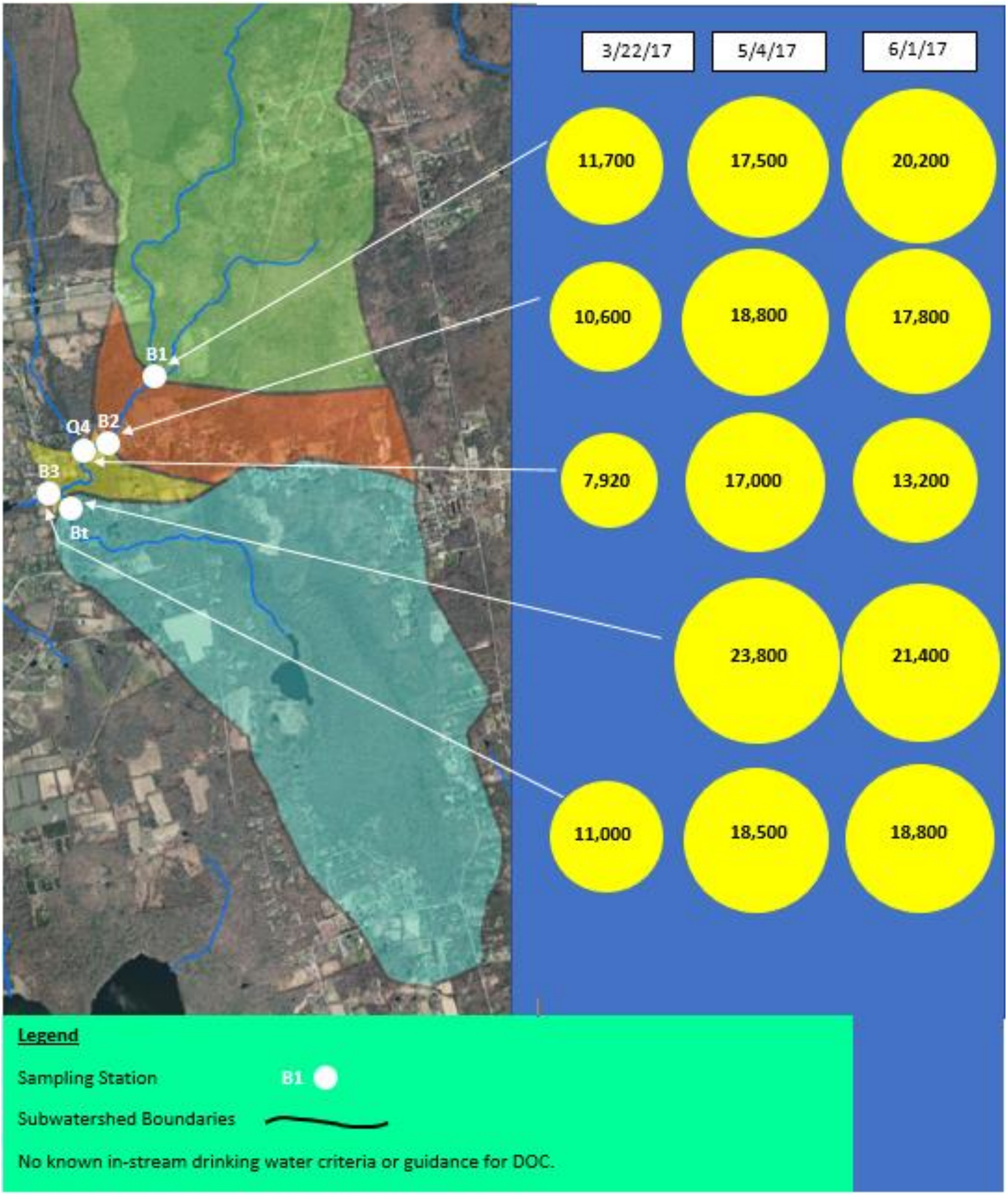


**Figure B-49. Borden Brook Wet Weather Total Dissolved Carbon (ug/l) (return to: Unnamed Tributary or Borden Brook).**

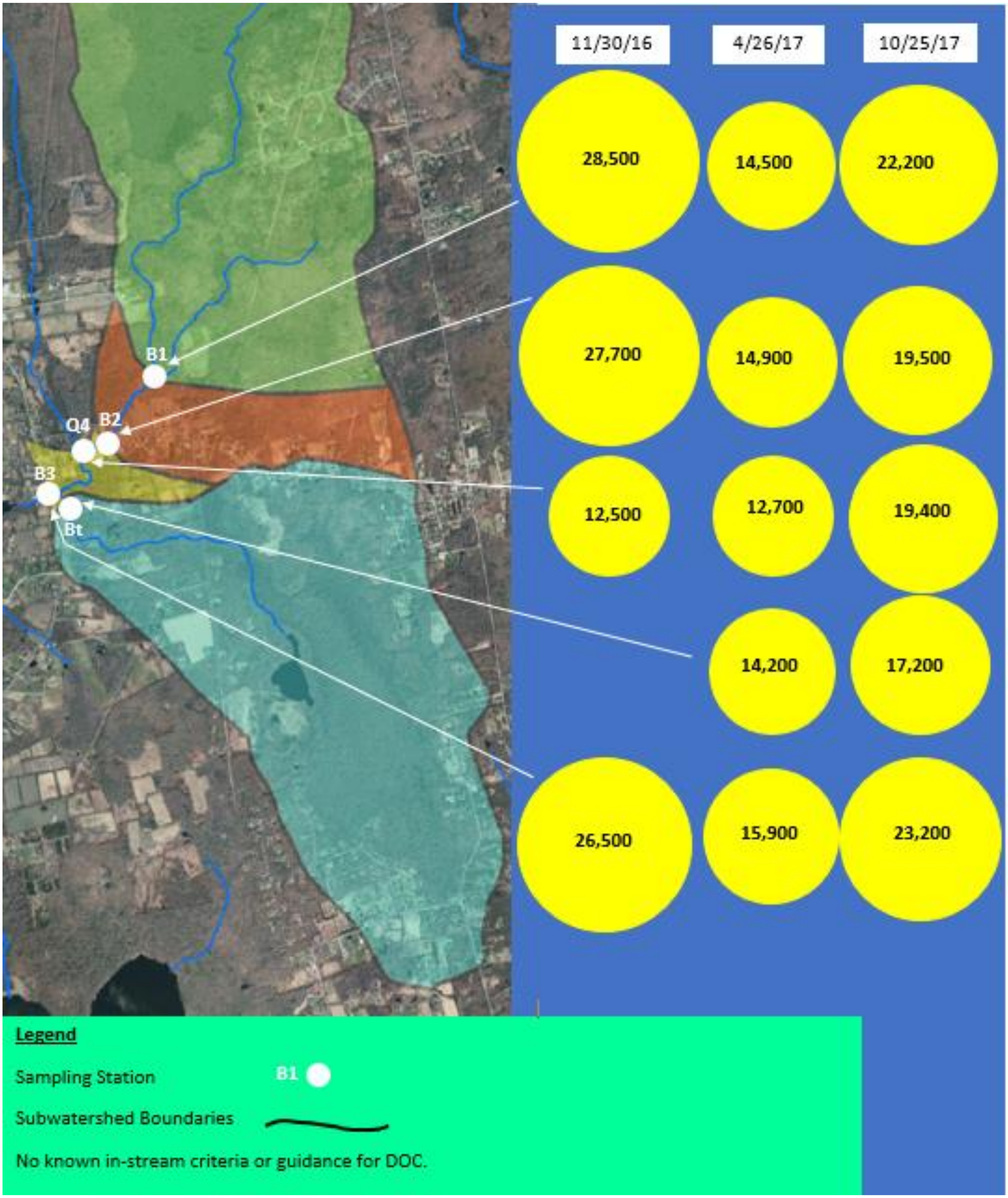


**Figure B-50. Borden Brook Dry Weather Enterococci (MPN/100 ml) (return to: Unnamed Tributary or Borden Brook).**

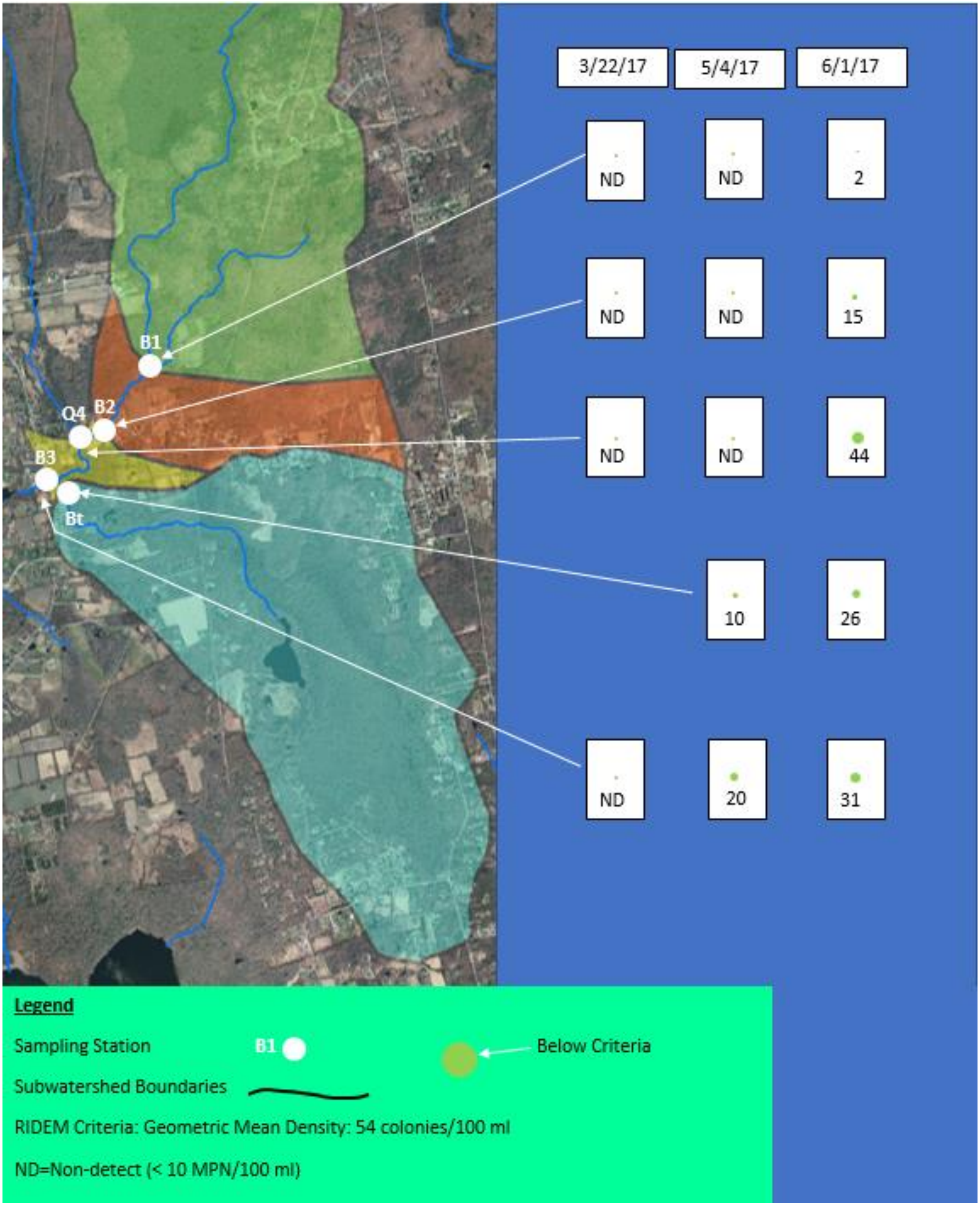


**Figure B-51. Borden Brook Wet Weather Enterococci (MPN/100 ml) (return to: Unnamed Tributary or Borden Brook).**

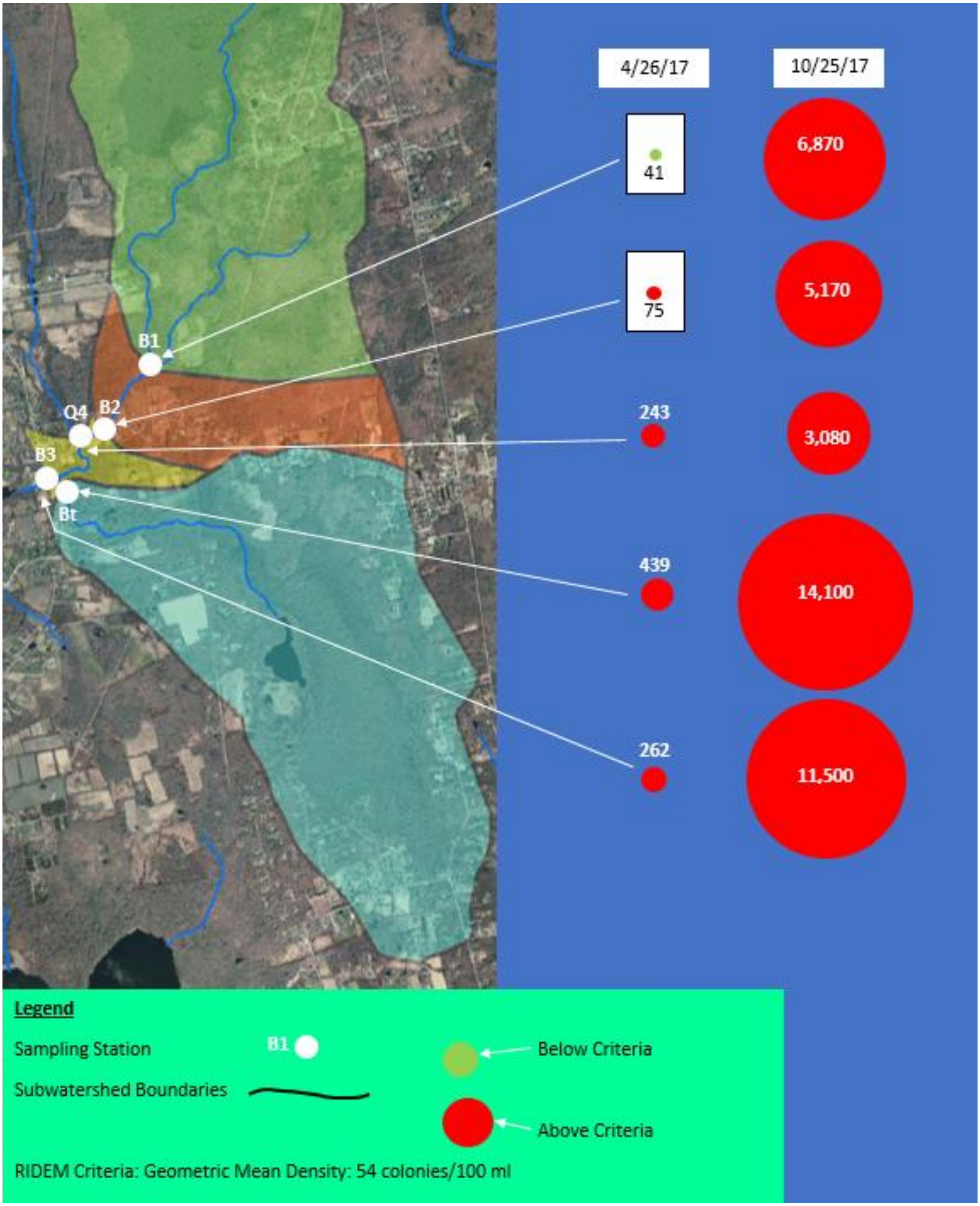


**Figure B-52. Nonquit Brook Dry Weather Dissolved Oxygen (mg/l) (return to: Nonquit Pond Tributary).**

**Figure B-53. Nonquit Brook Wet Weather Dissolved Oxygen (mg/l) (return to: Nonquit Pond Tributary).**

**Figure B-54. Nonquit Brook Dry Weather Specific Conductance (µs/cm) (return to: Nonquit Pond Tributary).**

**Figure B-55. Nonquit Brook Wet Weather Specific Conductance (µs/cm) (return to: Nonquit Pond Tributary).**

**Figure B-56. Nonquit Brook Dry Weather pH (return to: Nonquit Pond Tributary).**

**Figure B-57. Nonquit Brook Wet Weather pH (return to: Nonquit Pond Tributary).**

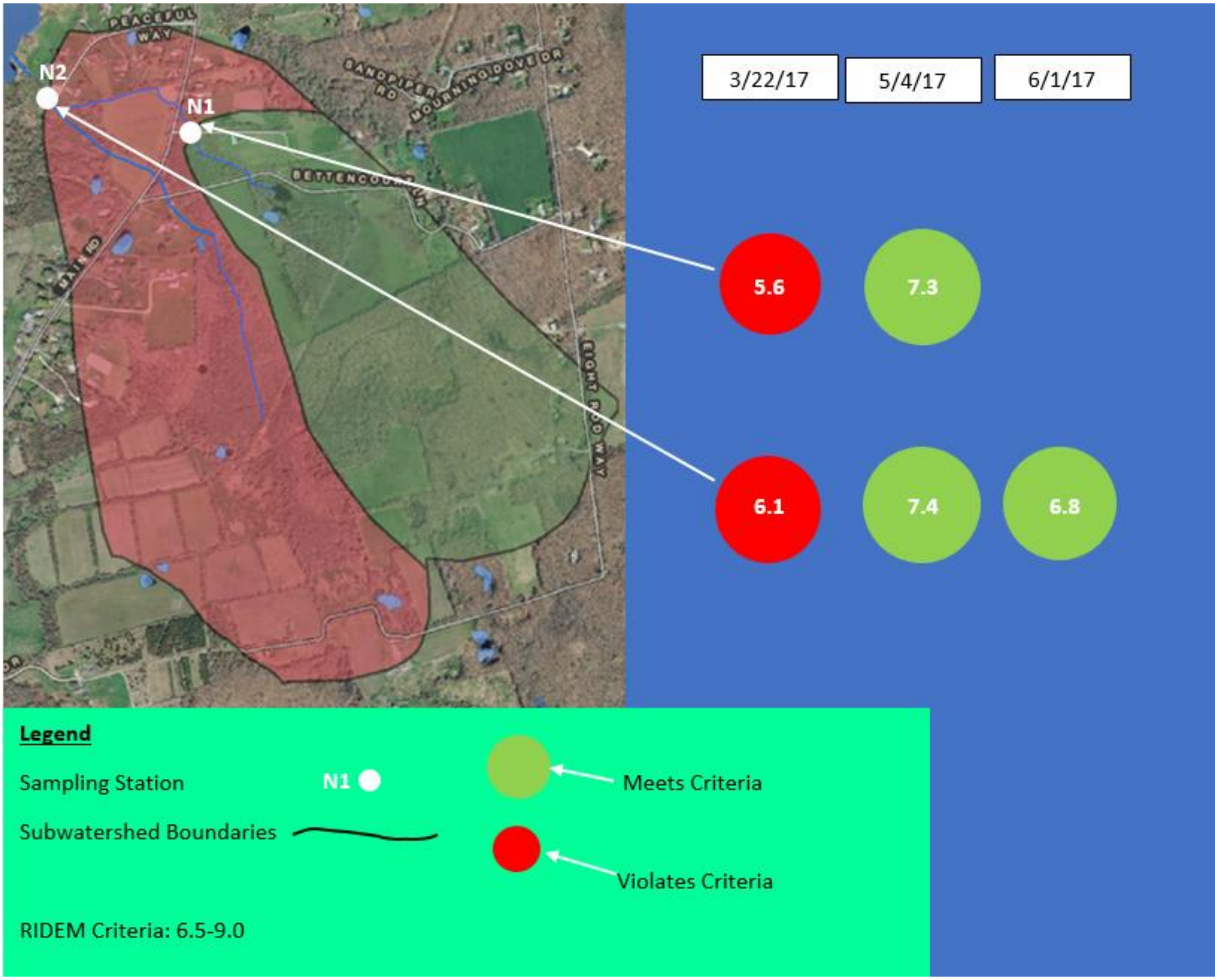


**Figure B-58. Nonquit Brook Dry Weather Turbidity (NTU) (return to: Nonquit Pond Tributary).**

**Figure B-59. Nonquit Brook Wet Weather Turbidity (NTU) (return to: Nonquit Pond Tributary).**

**Figure B-60. Nonquit Brook Dry Weather Total Suspended Sediment (ug/l) (return to: Nonquit Pond Tributary).**

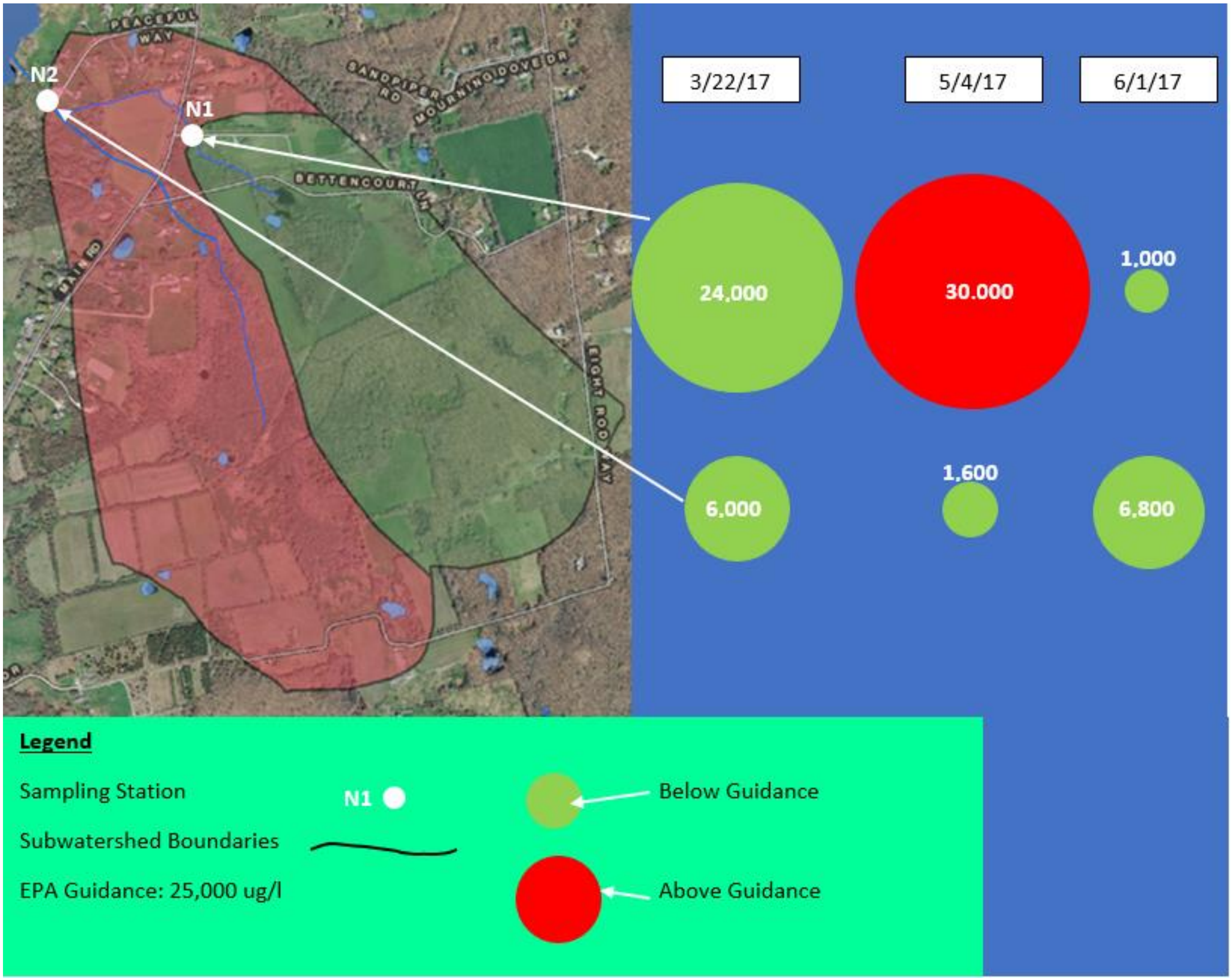


**Figure B-61. Wet Weather Total Suspended Sediment (ug/l) (return to: Nonquit Pond Tributary).**

**Figure B-62. Nonquit Brook Dry Weather Phosphorus (ug/l) (return to: Nonquit Pond Tributary).**

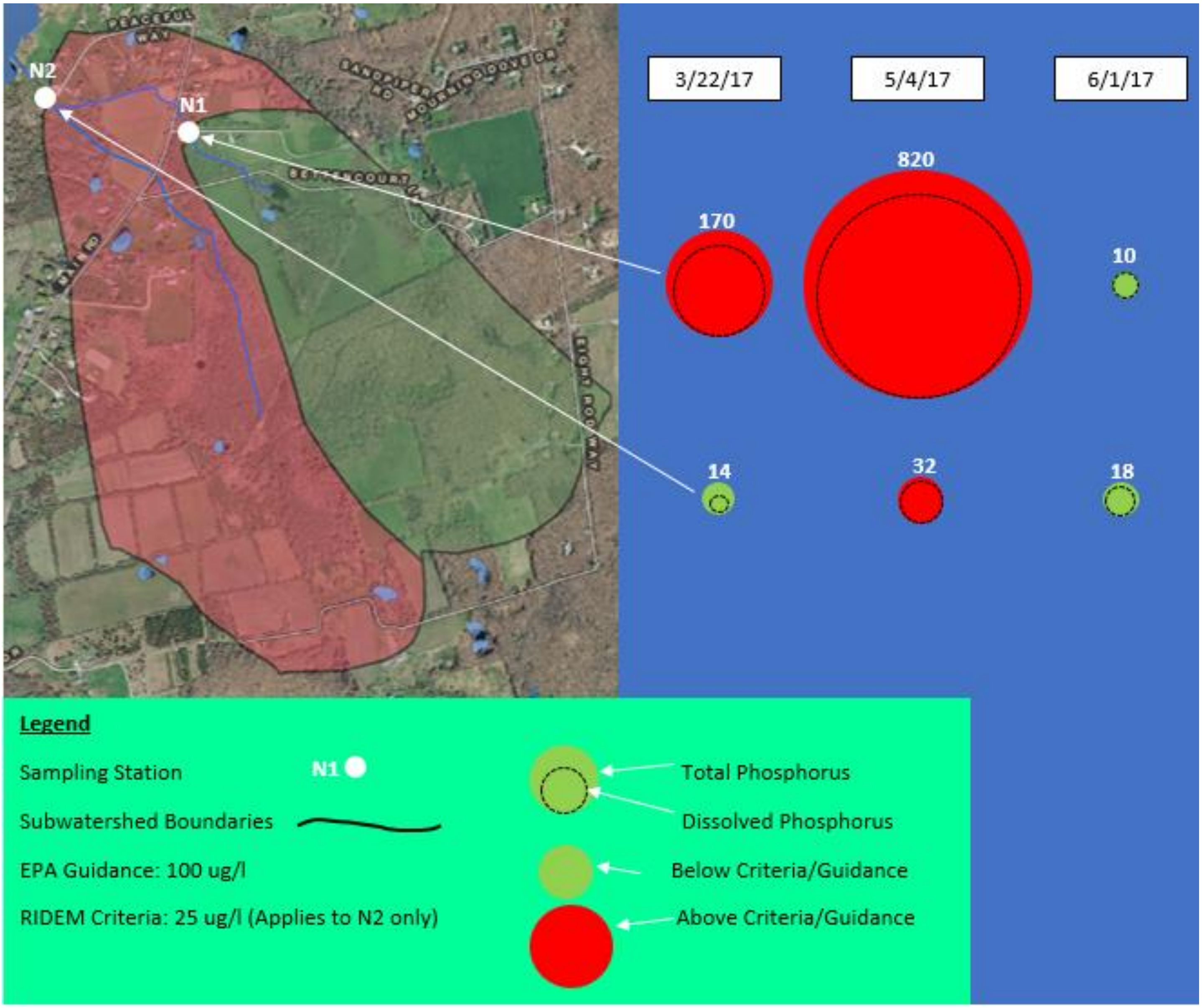


**Figure B-63. Nonquit Brook Wet Weather Phosphorus (ug/l) (return to: [Nonquit Pond Tributary]).**

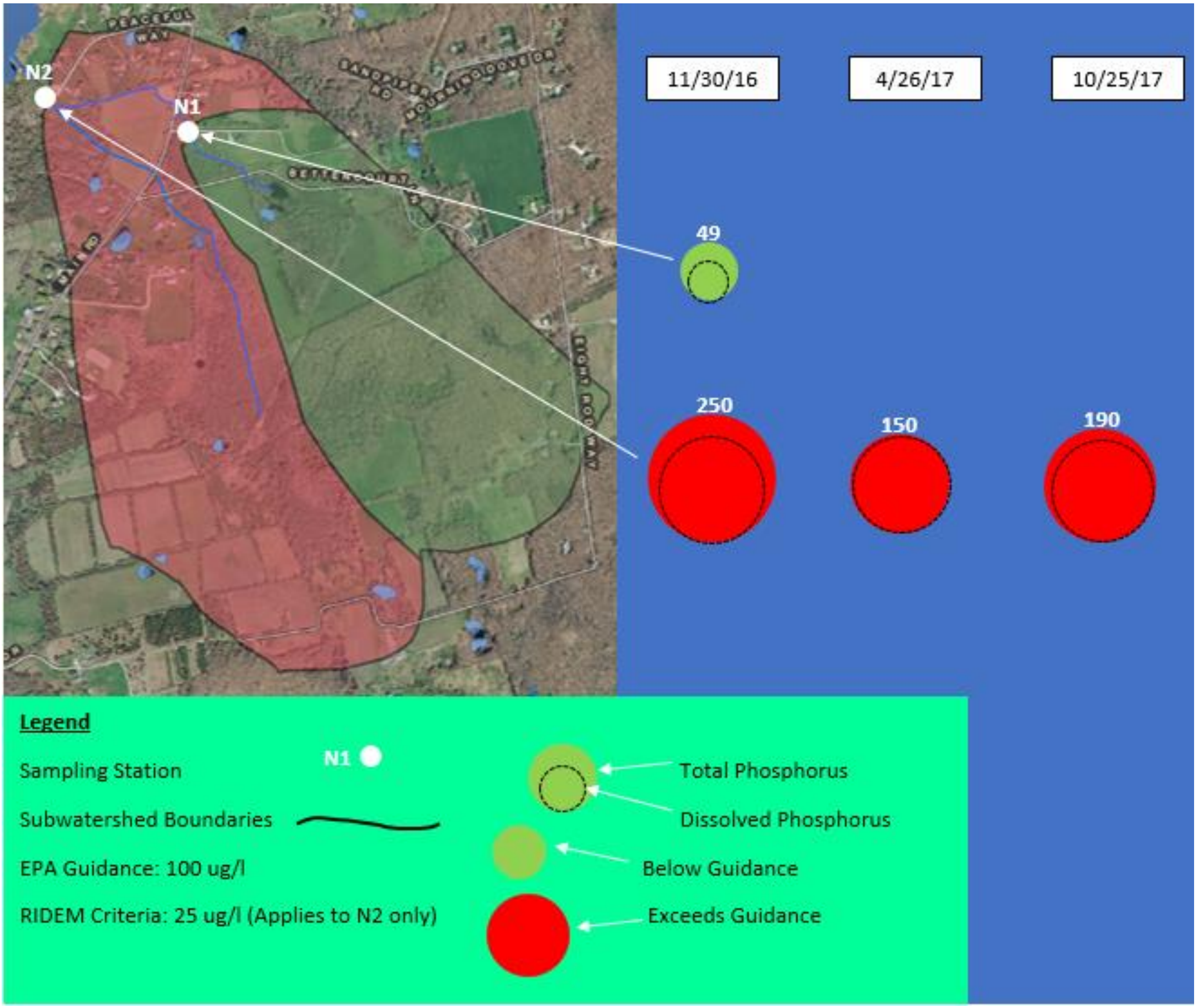


**Figure B-64. Nonquit Brook Dry Weather Nitrogen (ug/l) (return to: Nonquit Pond Tributary).**

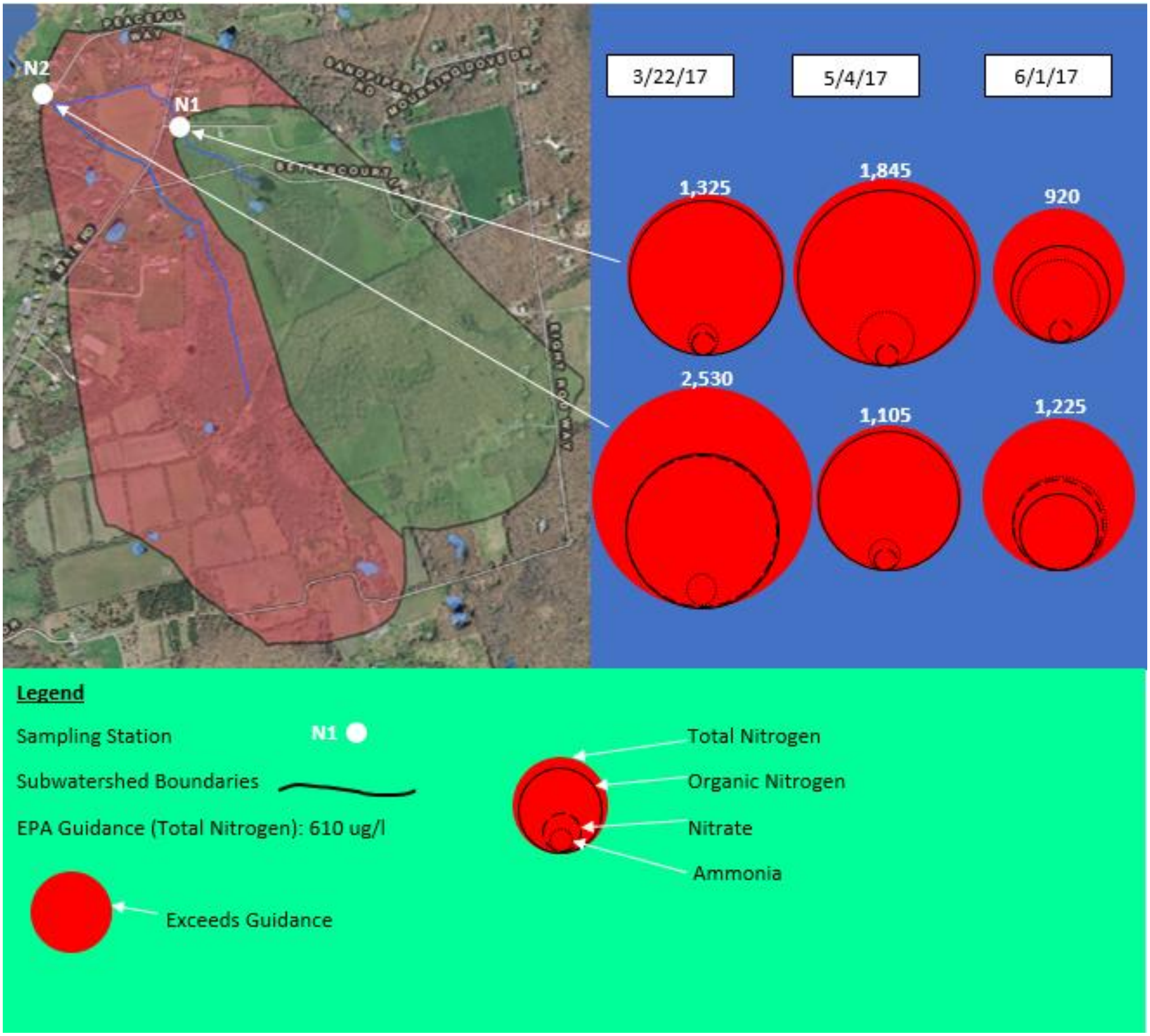


**Figure B-65. Nonquit Brook Wet Weather Nitrogen (ug/l) (return to: Nonquit Pond Tributary).**

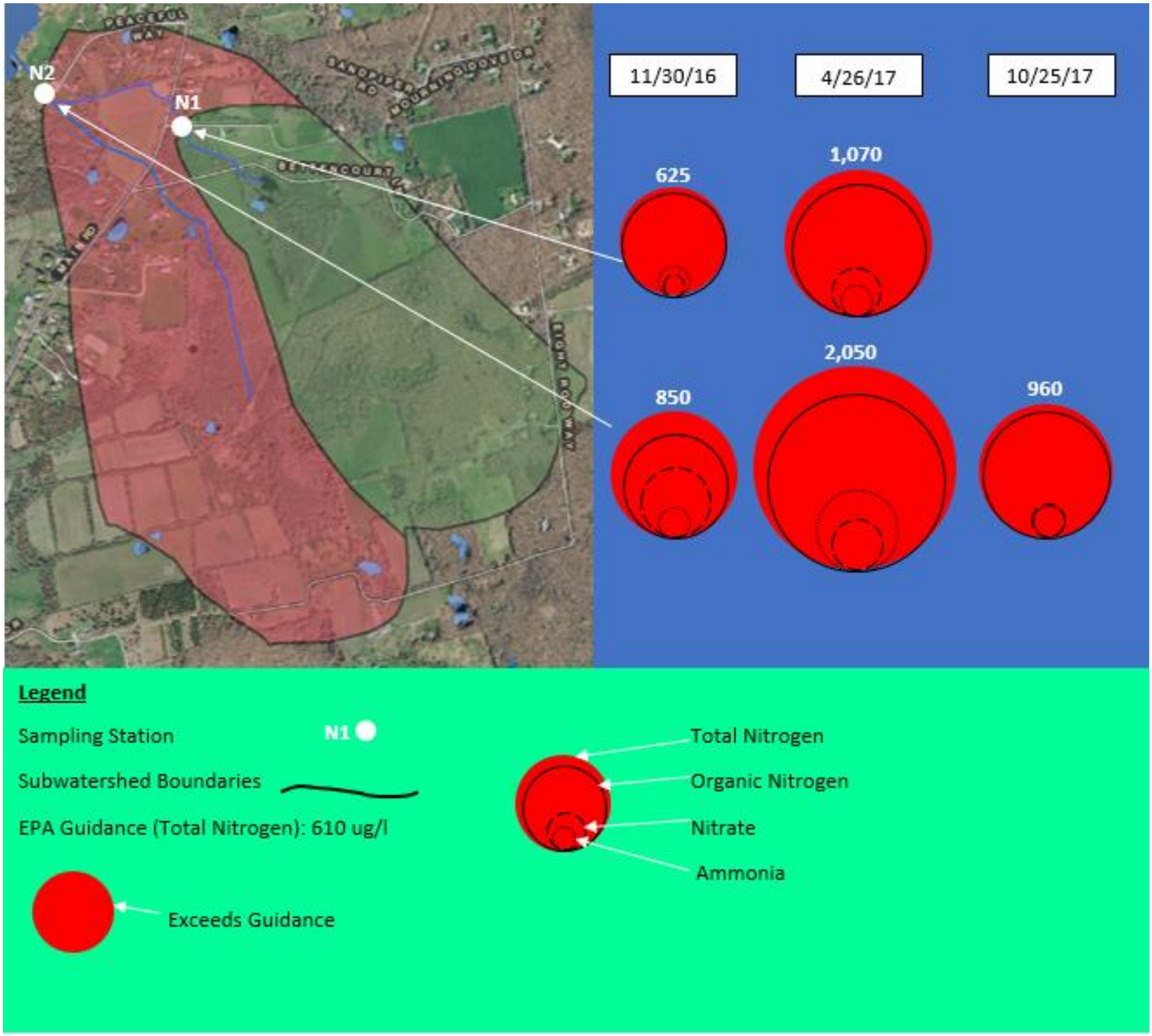


**Figure B-66. Nonquit Brook Dry Weather Total Dissolved Carbon (ug/l) (return to: Nonquit Pond Tributary).**

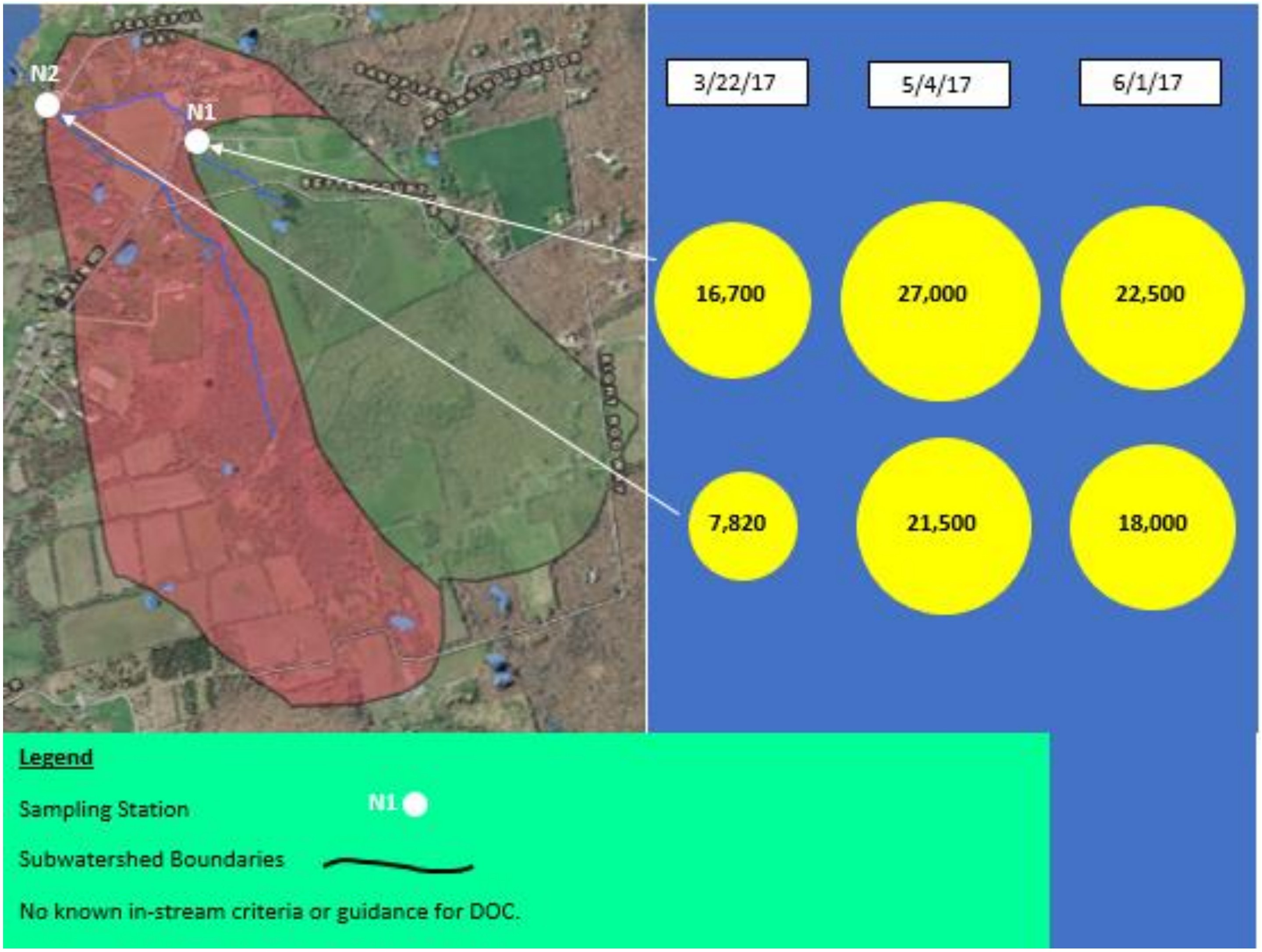


**Figure B-67. Nonquit Brook Wet Weather Total Dissolved Carbon (ug/l) (return to: Nonquit Pond Tributary).**

**Figure B-68 Nonquit Brook Dry Weather Enterococci (MPN/100ml) (return to: Nonquit Pond Tributary).**

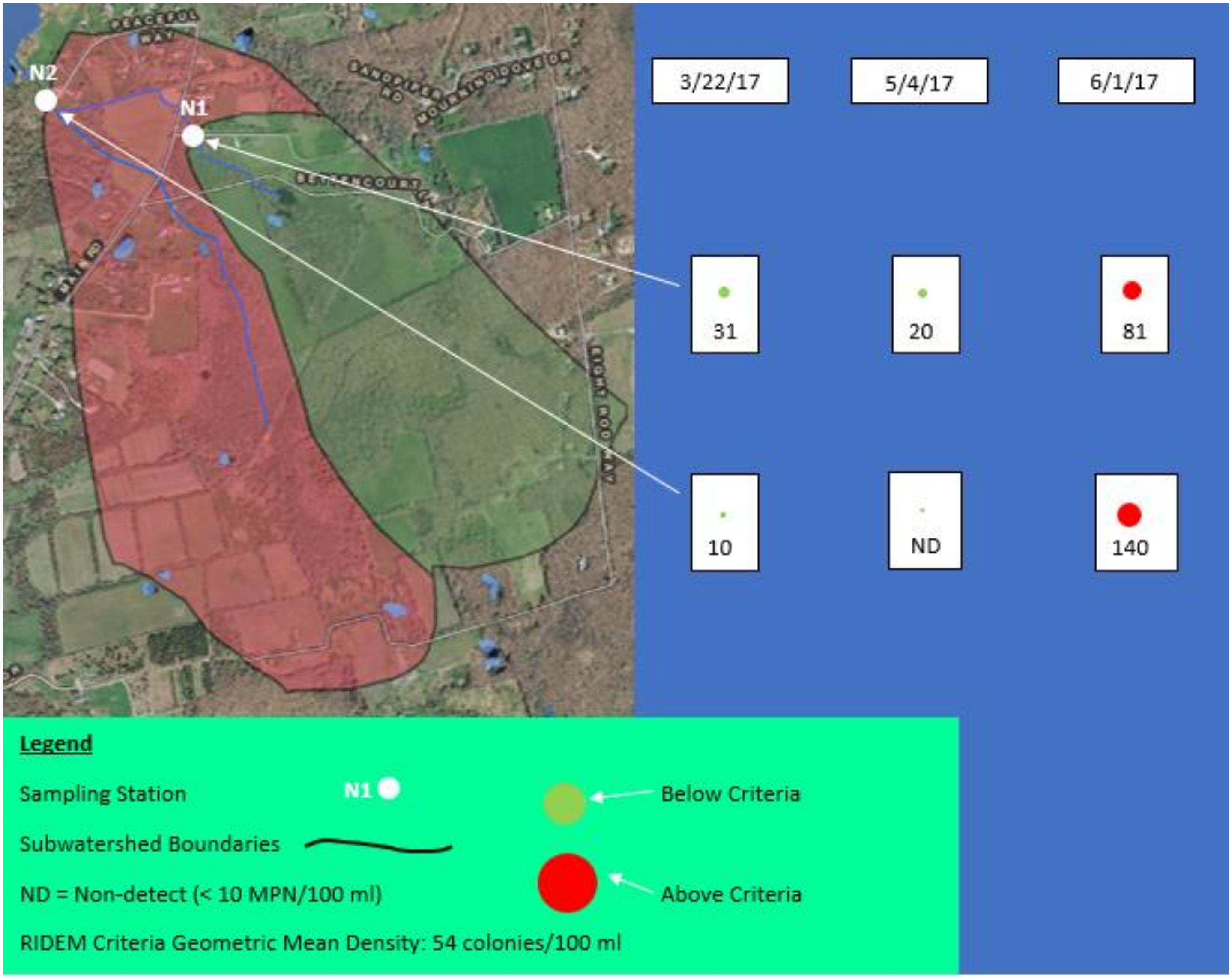
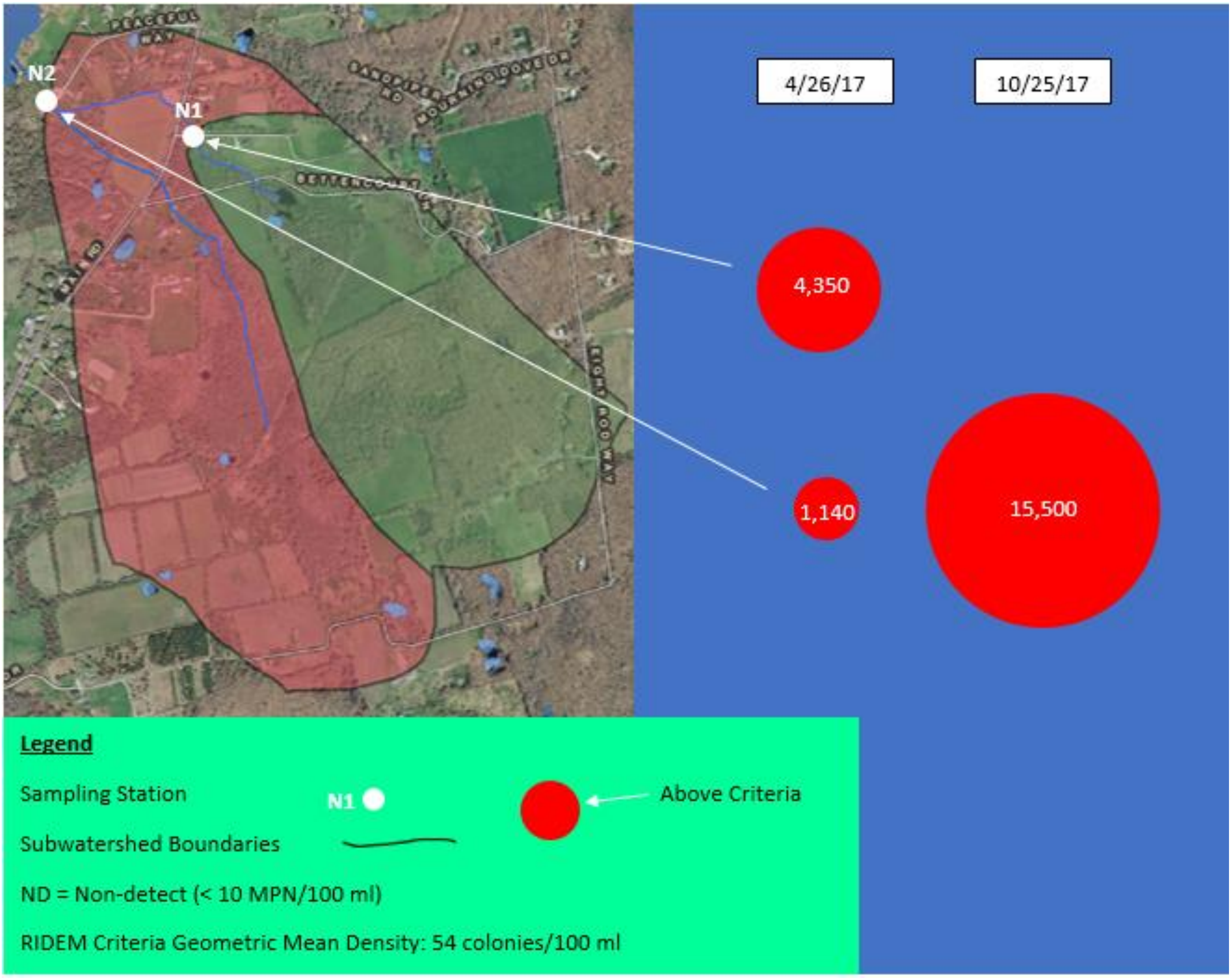


**Figure B-69. Nonquit Brook Wet Weather Enterococci (MPN/100ml) (return to: Nonquit Pond Tributary).**



## APPENDIX C. PHOTOGRAPHIC DOCUMENTATION

(return to document)

**Photograph Location and Orientation Key: Quaker Creek: Headwaters Upstream of Station Q1 (return to: source section).**

Photo 1. Iron Flocculent in wetland north (upstream) of Tiverton landfill access road (return to: Quaker Creek or Photo Key**).**

Photo 2. Seagulls at Town baseball field (return to: Quaker Creek or Photo Key).

Photo 3. Tilled area in Pardon Gray Preserve bordering wetland corridor (return to: Quaker Creek or Photo Key).

Photo 4. Town soccer field bordering wetland corridor (return to: Quaker Creek or Photo Key).

Photo 5. Wetland at bottom-of-slope of soccer field **(**return to: Quaker Creek or Photo Key).

**Photograph Location and Orientation Key: Quaker Creek: Tiverton landfill subwatershed upstream of Station LDF (return to: source section).**

Photo 6. Iron flocculent in leachate as it flows out of small impoundment to landfill swale (return to: pollution sources or Photo Key).

Photo 7. Turbid stormwater runoff from upper landfill (return to: pollution sources or Photo Key).

Photo 8. Closeup of previous photograph showing petroleum sheen (return to: pollution sources or Photo Key).

Photo 9. Stormwater runoff from upper landfill on left mixing with iron-rich landfill leachate on right (return to: pollution sources or Photo Key).

Photo 10. Landfill swale adjacent to access road
(return to: pollution sources or Photo Key).

Photo 11. Flow from swale entering wetland (return to: pollution sources or Photo Key).

**Photograph Location and Orientation Key: Quaker Creek: Livestock Area between Stations Q2 & Q3 (return to: source section).**

Photo 12. Flooded lower paddock on western side of upstream farm pond (return to: pollution sources or Photo Key).

Photo 13. Saturated muddy corral adjacent to western side of stream between farm ponds (return to: pollution sources or Photo Key).

Photo 14. From bus depot looking east showing saturated paddock area west of stream between farm ponds (return to: pollution sources or Photo Key).

Photo 15. Inlet of downstream farm pond looking northwest. Saturated pasture adjacent to western streambank between farm ponds (return to: pollution sources or Photo Key).

Photo 16. Inlet of downstream farm pond looking north, showing turbid runoff on left from corrals shown in above photo (return to: pollution sources or Photo Key).

Photo 17. Manure pile near barn of lower equestrian center up-gradient of corrals to west of stream between farm ponds (return to: pollution sources or Photo Key).

Photo 18. Manure in wet area adjacent to eastern streambank, between farms ponds. Note manure in foreground (return to: pollution sources or Photo Key).

Photo 19. Downstream farm pond and pasture looking east. Livestock have access to pond in foreground (return to: pollution sources or Photo Key).

Photo 20. Northern end of cattle pasture looking southwest. Note cattle have access to stream (return to: pollution sources or Photo Key).

Photo 21. Northern end of cattle pasture looking southeast. Note cattle have access to stream (return to: pollution sources or Photo Key).

Photo 22. Southern end of cow pasture where cows have access to the stream (return to: pollution sources or Photo Key).

Photo 23. Excavated area to the east of stream and Station Q2 (return to: pollution sources or Photo Key).

Photo 24. Turbid runoff from seashell-surface parking and driveway associated with artist's cooperative, landscaping business and upper equestrian center entering main drive accessing equestrian center (return to: pollution sources or Photo Key).

Photo 25. Turbid runoff from commercial areas and equestrian center parking lot entering driveway swale (return to: pollution sources or Photo Key).

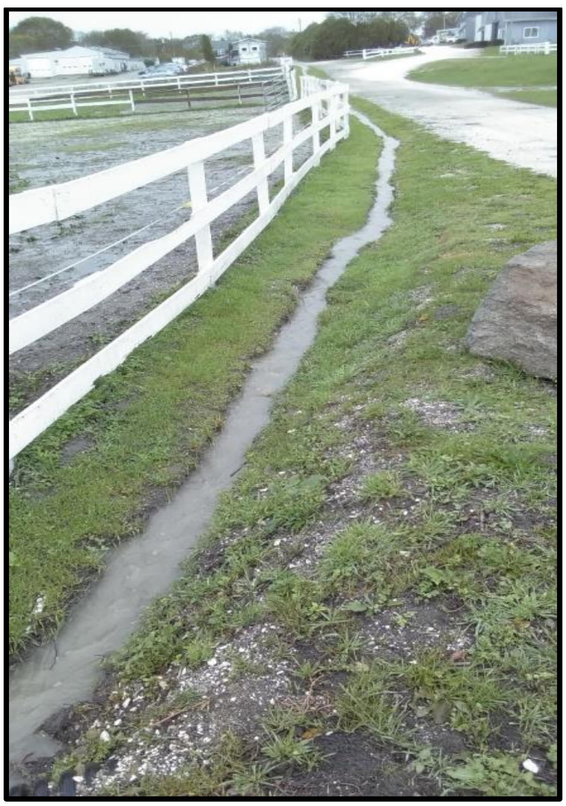


Photo 26. Flow from driveway ditch, shown in photo above, discharging to stream, downstream of upper farm pond (return to: pollution sources or Photo Key).

Photo 27. Flow from driveway ditch discoloring flow in the stream. Note that there was no flow from upper pond outlet as shown in photo (return to: pollution sources or Photo Key).

Photo 28. Lower end of bus depot looking west (return to: pollution sources or Photo Key).


Photo 29. Inlet of downstream farm pond looking south, showing turbid water. Note cattle have access to pond (return to: pollution sources or Photo Key).

**Photograph Location and Orientation Key: Quaker Creek: Terminal Reach between Stations Q3 & Q4 (return to: source section).**

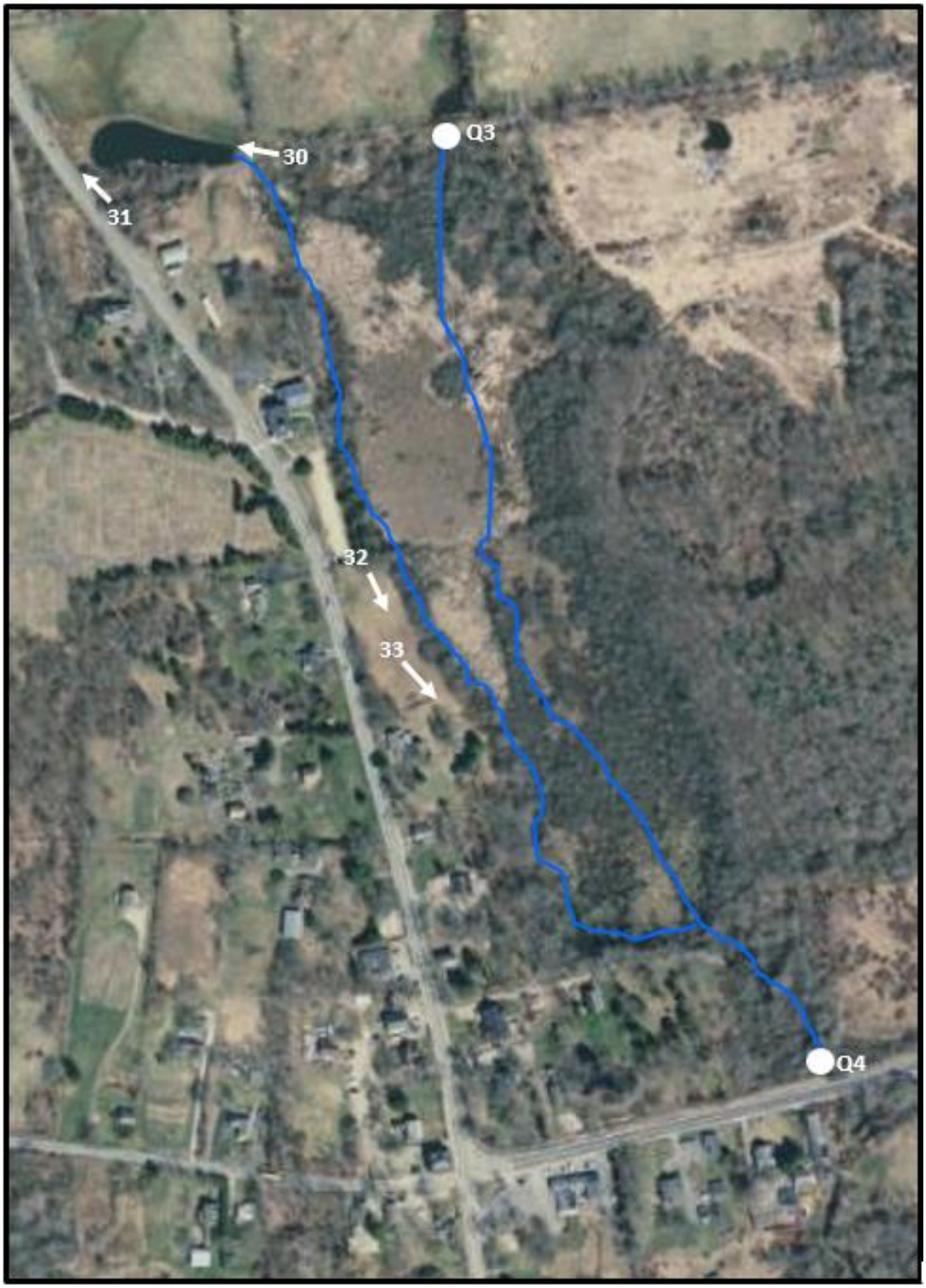


Photo 30. Farm pond in cattle pasture. Note muddy area where cows have access to the pond (return to: pollution sources or Photo Key).

Photo 31. Stormwater runoff from a roadside ditch along Main Road discharges to farm pond shown in photo above (return to: pollution sources or Photo Key).

Photo 32. Hay field with approximately 40 ft. of vegetated buffer from stream (return to: pollution sources or Photo Key).

Photo 33. Residential lawn with approximately 40 ft. of vegetated buffer from stream (return to: pollution sources or Photo Key).

**Photograph Location and Orientation Key: Unnamed Southern Tributary to Borden Brook, Upstream of Station Bt (return to: source section).**

Photo 34. Lawns extending to streambank at northeastern fork of unnamed tributary to Borden Brook (return to: pollution sources or Photo Key).

Photo 35. Confluence of southwest and northeast forks of the tributary showing grazed pasture straddling stream. Goat barn at rear of photo and aviary in upper right (return to: pollution sources or Photo Key).

Photo 36. Hog pen in right-center of photograph approximately 70 ft. from stream (return to: pollution sources or Photo Key).

Photo 37. Grazed pasture adjacent to stream (return to: pollution sources or Photo Key).

Photo 38. Closeup of above photo. Manure adjacent to stream (return to: pollution sources or Photo Key).

Photo 39. Hay field with approximately 25 ft. vegetated buffer from stream (return to: pollution sources or Photo Key).

Photo 40. Residential lawn with no vegetated buffer adjacent to the stream at left (return to: pollution sources or Photo Key).

Photo 41. Lawn in commercial area extending to streambank at Station Bt (return to: pollution sources or Photo Key).

Photo 42. Small farm pond at edge of wetland. Cattle have access to the farm pond (return to: pollution sources or Photo Key).

Photo 43. Pasture in wetland at headwaters of southwestern fork of Borden Brook tributary (return to: pollution sources or Photo Key).

Photo 44. Pasture adjacent to wetland headwaters. Note close-cropped grass (return to: pollution sources or Photo Key).

Photo 45. Silage pile at headwaters of southwestern fork of Borden Brook tributary (approx. 130 x 40 x 10 ft.) (return to: pollution sources or Photo Key).

Photo 46. Closeup of silage adjacent to paved drive (return to: pollution sources or Photo Key).

Photo 47. Flooded wetland at headwaters of stream adjacent to silage pile (return to: pollution sources or Photo Key).

Photo 48. Filamentous algae with white scum (potentially dead algae) immediately downstream of silage pile (return to: pollution sources or Photo Key).

Photo 49. Filamentous algae further downstream (return to: pollution sources or Photo Key).

Photo 50. Old farm pond downslope of extensive lawn associated with large-lot residence (return to: pollution sources or Photo Key).

Photo 51. Hay field with 40-50 ft. vegetated buffer from stream (return to: pollution sources or Photo Key).

Photo 52. Residential lawns with 20-30 ft. buffer from stream (return to: pollution sources or Photo Key).

**Photograph Location and Orientation Key: Borden Brook: Middle reach between Stations B1 an B2, including unnamed northern tributary (return to: source section).**

Photo 53. Edge of hay field approximately 20 ft. from Borden Brook (return to: pollution sources or Photo Key).

Photo 54. Residential lawn approximately 30 ft. from Borden Brook (return to: pollution sources or Photo Key).

Photo 55. Manure pile on paved drive on the northern side of East Road. (return to: pollution sources or Photo Key).


Photo 56. Chicken pen adjacent to roadside ditch on southern side of East Road (return to: pollution sources or Photo Key).

Photo 57. Residential lawn to top of stream bank (return to: pollution sources or Photo Key).

Photo 58. Small crop field and green houses as seen from stream. Tilled area greater than 100 ft. from stream (return to: pollution sources or Photo Key).

Photo 59. Lawn adjacent to stream associated with crop field in above photo (return to: pollution sources or Photo Key).

Photo 60. Residential lot with land recently cleared to streambanks (return to: pollution sources or Photo Key).

Photo 61. Eastern edge of grazed pasture with no vegetated buffer along stream (return to: pollution sources or Photo Key).

Photo 62. Grazed pasture from same location as above photo. Cattle have access to stream (return to: pollution sources or Photo Key).

Photo 63. Western end of grazed pasture (return to: pollution sources or Photo Key).

Photo 64. Stream flowing along western end of grazed pasture (return to: pollution sources or Photo Key).

Photo 65. Residential lawn extending to top-of-bank of Borden Brook (return to: pollution sources or Photo Key).

**Photograph Location and Orientation Key: Borden Brook: Terminal Reach between Stations B2 an B3 (return to: source section).**

Photo 66. Manure in pasture on eastern bank of Borden Brook (return to: pollution sources or Photo Key).

Photo 67. Pasture on western bank of Borden Brook (return to: pollution sources or Photo Key).

Photo 68. Bridge over Borden Brook connecting pastures on east and west sides of the river (return to: pollution sources or Photo Key).

Photo 69. Pasture on east side of river. Note manure pile (return to: pollution sources or Photo Key).

Photo 70. Rear of small ponded area in Borden Brook with commercial buildings on Main Road (return to: pollution sources or Photo Key).

Photo 71. Ponded area in Borden Brook. Photo taken from footbridge at Station B3 (return to: pollution sources or Photo Key).

Photo 72. Mill dam between buildings on Main Road at footbridge at Station B3. Note orange color (return to: pollution sources or Photo Key).

Photo 73. Commercial buildings on bank of Borden Brook with footbridge (return to: pollution sources or Photo Key).

**Photograph Location and Orientation Key: Northeast fork of unnamed tributary to Nonquit Pond upstream of Station N1 (return to: source section).**

Photo 75. Fenced cattle pasture from eastern corner of wetland (return to: pollution sources or Photo Key).

Photo 76. Fence separating winter pasture from seasonal pasture area (in foreground) with gate in upper right (return to: pollution sources or Photo Key).

Photo 77. Low earthen berm around eastern corner of wetland with pasture in the background (return to: pollution sources or Photo Key).

Photo 78. Grazed pasture within flooded marsh (return to: pollution sources or Photo Key).

Photo 79. Grazed pasture in wetland (return to: pollution sources or Photo Key).

Photo 80. Cattle have access to small farm pond on northern side of wetland (return to: pollution sources or Photo Key).

Photo 81. Saturated grazed area on southeastern side of wetland (return to: pollution sources or Photo Key).

Photo 82. Pasture on western side of wetland (return to: pollution sources or Photo Key).

Photo 83. Grazed pasture adjacent to flooded wetland and stream (return to: pollution sources or Photo Key).

**Photograph Location and Orientation Key: Unnamed tributary to Nonquit Pond between Stations N1 and N2 (return to: source section).**

Photo 84. Stream flowing along edge of large-lot residential property (return to: pollution sources or Photo Key).

Photo 85. Old farm pond on edge of large-lot residential property. Stream flows along stone wall to left (return to: pollution sources or Photo Key).

Photo 86. Stream with 10-15 ft. vegetated buffer adjacent to crop field (return to: pollution sources or Photo Key).

Photo 87. Residential lawn to edge of streambank (return to: pollution sources or Photo Key).

Photo 88. Erosional swale on edge of corn field flowing towards stream and Station N2
(return to: pollution sources or Photo Key).