Greens Creek 2016 Summary Report

Watershed Features

Area	19.29 square kilometres 0.46% of the Rideau Valley watershed
Land Use	12% agriculture 53% urban 19% forest 1% rural 12% meadow 1% water 2% wetland
Surficial Geology	84% clay 2% diamicton 8% Paleozoic bedrock 6% sand
Watercourse Type	Thermal Conditions (2016) **Warm** to **Cool-Warmwater**
Invasive Species	Nineteen invasive species were identified in 2016, including: *banded mystery snail, bull thistle, Chinese mystery snail, common/ glossy buckthorn, curly-leafed pondweed, dog strangling vine, European frogbit, flowering rush, garlic mustard, Himalayan balsam, honey suckle, Japanese knotweed, Manitoba maple, Norway maple, phragmites, wild parsnip, purple loosestrife* and *yellow iris*
Fish Community	44 fish species have been captured in the Greens Creek catchment

Wetland Cover

2% of the catchment is wetland

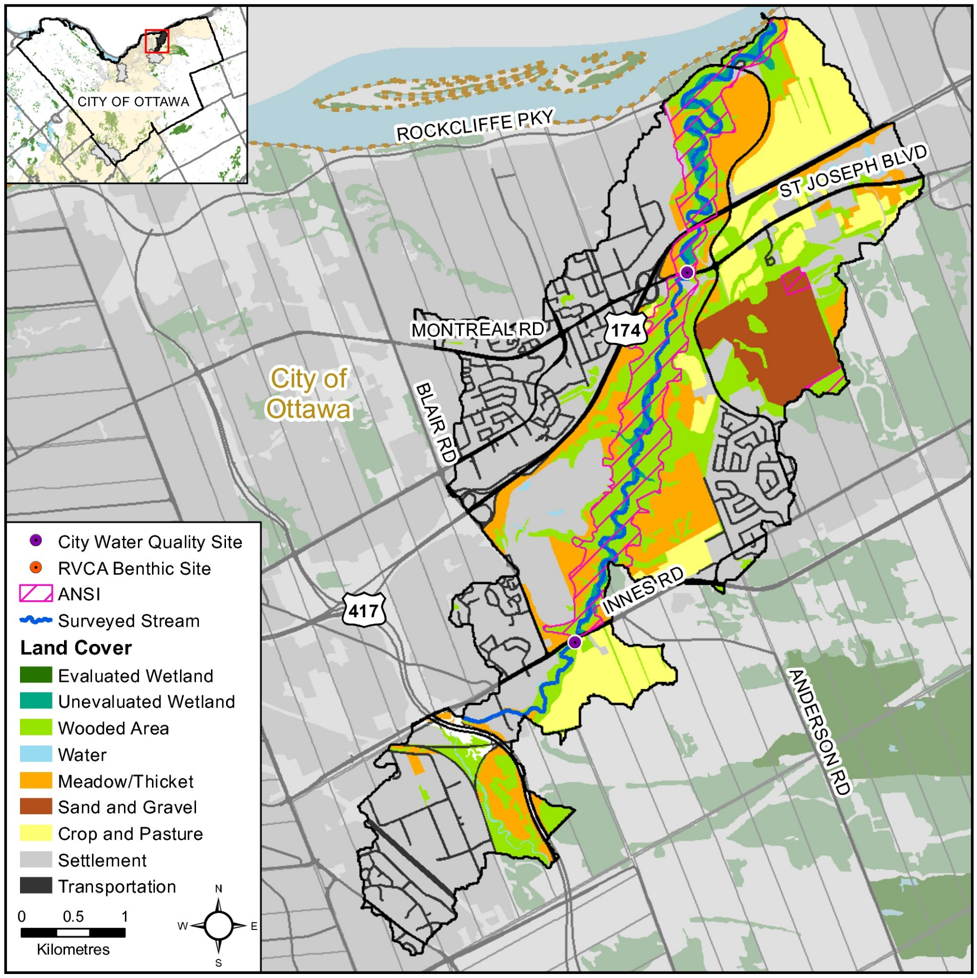
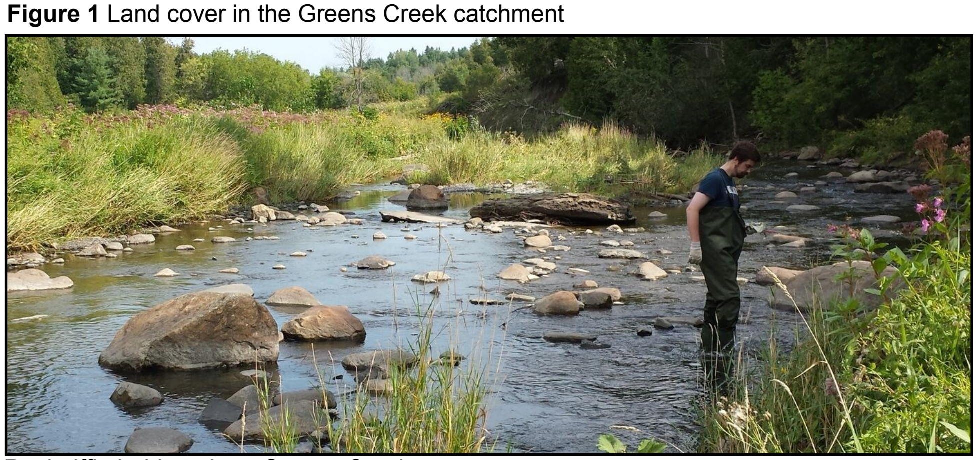


Figure 1 Land cover in the Greens Creek catchment



Rock riffle habitat along Greens Creek

The Rideau Valley Conservation Authority, in partnership with seven other agencies in Ottawa (City of Ottawa, Heron Park Community Association, Ottawa Flyfishers Society, Ottawa Stewardship Council, Rideau Roundtable, National Defence HQ - Fish and Game Club, and the National Capital Commission) form the 2016 City Stream Watch collaborative.

Drought Conditions - Rideau Valley Watershed

Low Water Conditions

During the summer of 2016, the Rideau Valley watershed experienced periods of *severe* drought. Precipitation levels were measured at less than 40% of the long-term average, as the water supply was unable to meet local demand. The lack of rainfall affected the success and function of farm crops, municipal and private wells, lawns and gardens, navigation and ultimately the health of our lakes, rivers and streams.

Low water conditions were readily observed throughout the watershed, as many of the streams were highly fragmented or completely dry. Aquatic species such as amphibians, fish and macroinvertebrates were affected, as suitable habitat may have been limited.

City Stream Watch

Low water levels and flows were common across many of our city streams, and is reflected in our overall evaluation. Given the atypical conditions, all assessments were subject to the effects of low water, and may not reflect the overall health of the systems. The City Stream Watch program will continue to monitor conditions over the long term to better understand the effects of climate and precipitation patterns.

Introduction

Greens Creek is located in the east end of Ottawa, and outflows directly into the Ottawa River east of the Sir George-Etienne Cartier Parkway. The creek is comprised of several smaller catchments, many conveying flow directly from the Mer Bleue bog. Borthwick Creek, Black Creek, Mud Creek and Ramsay Creek all flow from the bog and enter Greens Creek to form its headwaters. McEwan Creek is also part of the Greens Creek subwatershed, with connection to Ramsay Creek near the Hunt Club 417 overpass.

Greens Creek provides a crucial link between the Mer Bleue bog and the Ottawa River. The Greens Creek catchment supports a variety of provincially and regionally rare species, and is considered a Life Science Area of Scientific Interest (ANSI) for much of its extent. The complex and unusual geology in the region has resulted in a diverse variety of vegetative communities including mixed woodland, deciduous woodland, deciduous thicket swamp, wet meadows and mature deciduous swamp (Niblette Environmental Associates Inc., 2009). The Greens Creek valley provides essential habitat to birds and other wildlife, with over 500 plant species identified within the region.

Despite its extensive natural corridors, Greens Creek is highly prone to slumping and erosion. The unique geology in the region has resulted in significant instability as two types of leda clay are found within the subwatershed (JTB Environmental Systems Inc., 2009) . The reach between St. Joseph Blvd and Innes Rd is particularly affected with frequent instances of slope failure and land slides. This issue is further exacerbated by increased flows due to urban/ agricultural inputs (ie. stormwater, tile-drainage). In an effort to reduce further impairment, the NCC has recently commissioned a series of studies aimed at evaluating watershed health and potential rehabilitation/mitigation measures throughout Greens and Mud Creek (Groupe Rousseau Lefebvre, 2013).

In 2016, the City Stream Watch conducted surveys on 134 sections (13.4 km) of Greens Creek. The following is a summary of our observations and assessment.

Greens Creek Overbank Zone

Riparian Buffer Width Evaluation

The riparian zone is the interface between the water and the land surrounding a stream or river. Well-vegetated shorelines are of critical importance in protecting water quality and promoting for healthy aquatic habitats. Natural shorelines intercept sediments and contaminants that could impact water quality conditions and harm fish habitat. Furthermore, well established buffers protect the banks against erosion, improve habitat for fish by shading and cooling the water and provide protection for birds and other wildlife that feed and rear young near water. The recommended target (from Environment Canada's Guideline: How Much Habitat is Enough?) for the protection of aquatic habitat is to maintain a minimum 30 meter wide vegetated buffer along at least 75 percent of the stream length. Greens Creek was observed as having adequate buffer conditions over 82 percent of the left bank and 73 percent of the right bank and therefore partially meets the protection criteria (Figure 2). Efforts should be taken to improve upon the overall buffer conditions, particularly along the west shoreline.

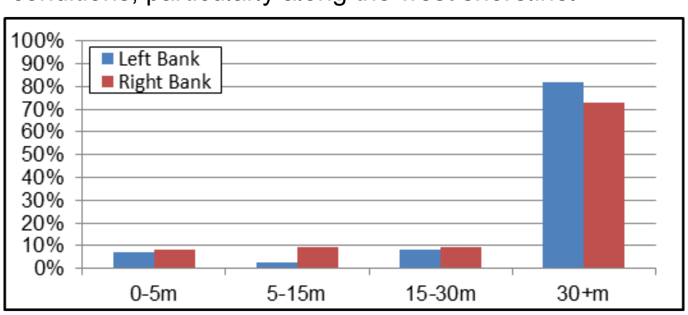


Figure 2 Vegetated buffer width along Greens Creek

Adjacent Land Use

Land use surrounding the creek is categorized into 11 classes, and assessed within 100m of each shoreline. These classes include: active and abandoned agriculture, pasture land, residential areas, forests, scrubland, meadows, wetlands, industrial /commercial zones, recreational areas, and infrastructure. Land use outside of this 100m buffer is not considered but will still have influence within the catchment.

Natural areas including forest, meadow and scrubland were identified in 50-80% of all surveyed sections in addition to wetland habitat in 11% of the surveyed stream (Figure 3). Infrastructure and industrial land use was observed in 16-25% of all sites, as well as minor instances of active agriculture (2%) and recreational use (2%).

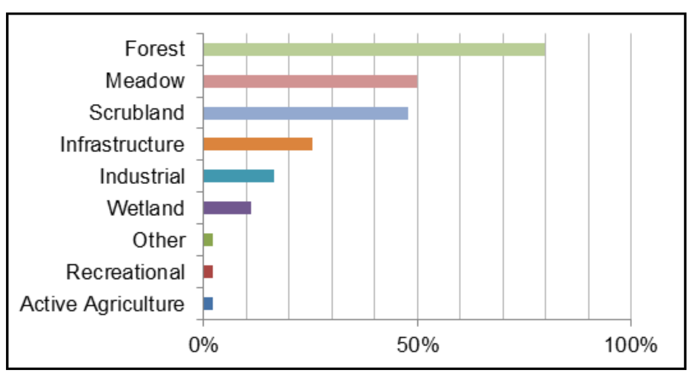


Figure 3 Land use presence along Greens Creek

Greens Creek Shoreline Zone

Erosion

Stream erosion is the process by which water erodes and transports sediments, resulting in dynamic flows and diverse habitat conditions. Excessive erosion can result in drastic environmental changes, as habitat conditions, water quality and aquatic life are all negatively affected. Bank stability was assessed as the overall extent of each section with “unstable” shoreline conditions. These conditions are defined by the presence of significant exposed soils/roots, minimal bank vegetation, severe undercutting, slumping or scour, and potential failed erosion control measures.

Greens Creek is dominated by steep forested slopes, which are prone to slumping due to the presence of extensive leda clays. These conditions are further exacerbated by unstable flows from storm-water and agricultural processes. During storm events, some reaches of Greens Creek exhibit extreme flow conditions, which may be a contributing source of instability. Sections between Innes Rd and St. Joseph Blvd are particularly affected, as sediment deposition and slope failure are common throughout (Figure 4).

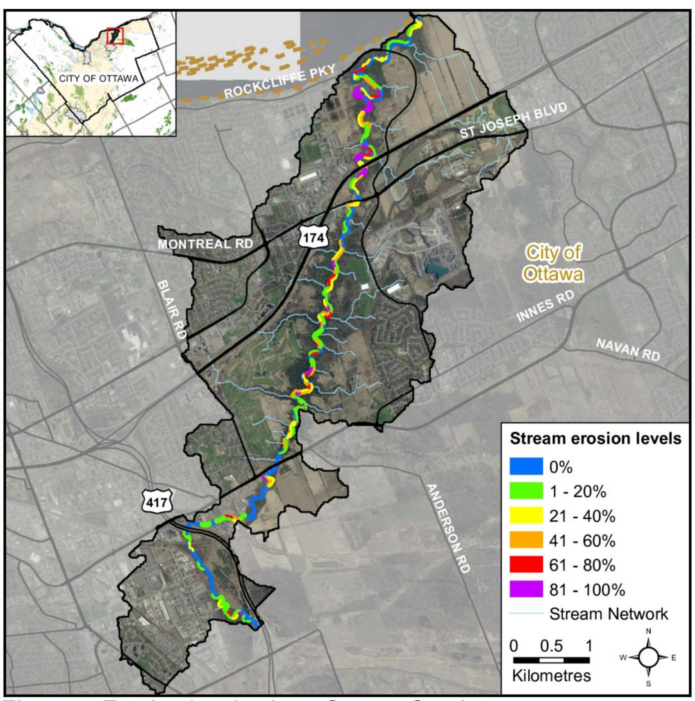


Figure 4 Erosion levels along Greens Creek

Stream bank erosion along Greens Creek

Undercut Stream Banks

Stream bank undercuts can provide excellent cover habitat for aquatic life however excessive levels can be an indication of unstable shoreline conditions. Bank undercut was assessed as the overall extent of each surveyed section with overhanging bank cover present. Bank undercut was identified in 26% of all surveyed sites, with an average coverage extent of only 5%-10% in those sections. Given that the geology in Greens Creek is prone to instability, this overall low presence is likely due to prevalent slumping of the materials that would otherwise provide stable undercut conditions. Some locations in the upper reaches were observed to have higher levels of bank undercut in proximity to development (Figure 5). These sections include instances of stable habitat cover as well as significant erosion and instability.

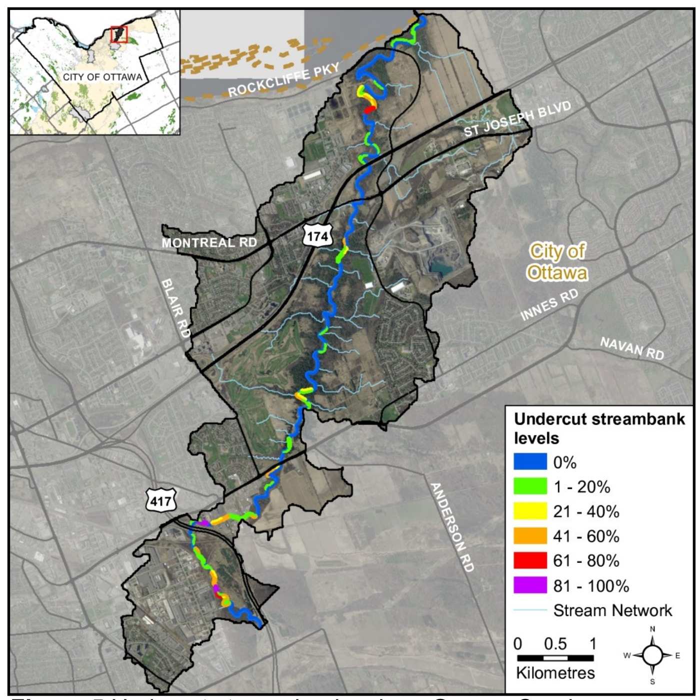


Figure 5 Undercut stream banks along Greens Creek

Bank destabilization and slumping along Greens Creek

Stream Shading

Grasses, shrubs and trees all contribute towards shading a stream. Shade is important in moderating stream temperature, contributing to food supply and helping with nutrient reduction within a stream. Stream shading is assessed as the total coverage area in each section that is shaded by overhanging trees/grasses and tree canopy, at greater than 1m above the water surface. Greens Creek was characterized by relatively low direct cover, with shading at or below 30% within the 75th percentile. The most frequent cover level was assessed at 20%, and accounts for approximately 32% of the surveyed stream (Figure 6). Despite having significant forested sections, the low cover extent is likely associated with a high relative surface area and the characteristic unstable shoreline conditions. Stream shading was found to be most prevalent in regions with extensive forest cover (Figure 7).

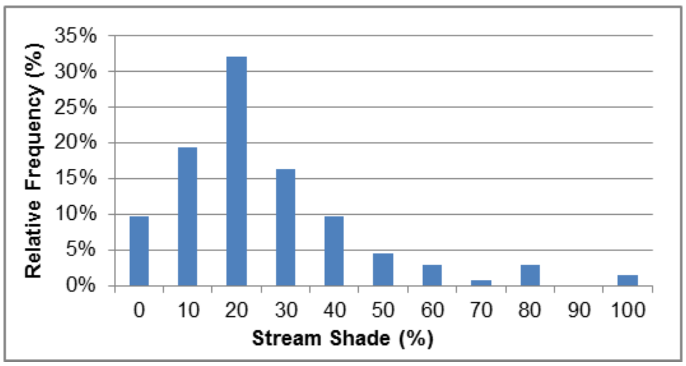


Figure 6 Distribution of stream shade levels on Greens Creek

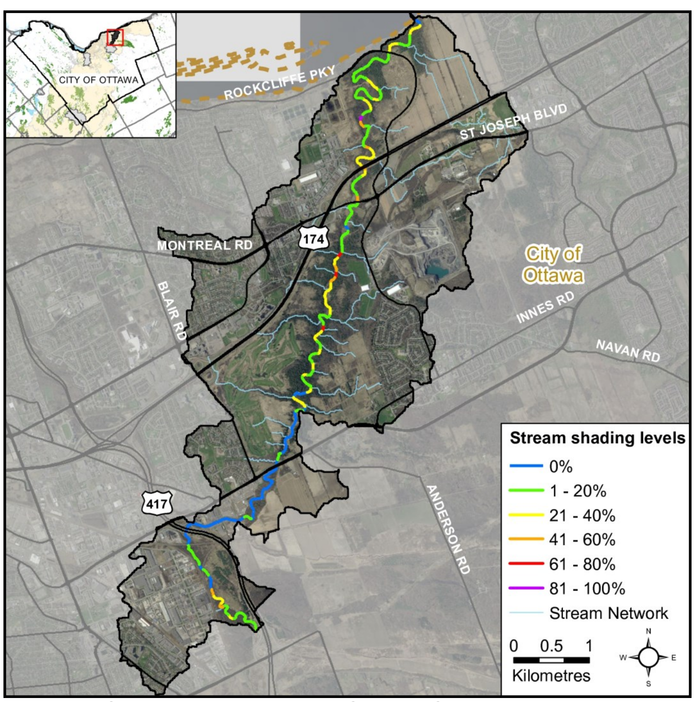


Figure 7 Stream shading along Greens Creek

Riparian Buffer Alterations

Alterations within the riparian buffer were assessed within three distinct shoreline zones (0-5m, 5-15m, 15-30m), and evaluated based on the dominant vegetative community and/or land cover type (Figure 8). The riparian buffer zone along Greens Creek was found to be predominantly natural, with 90% of the left bank and 84% of the right bank evaluated as having natural vegetative communities. Alterations to the shoreline accounted for 10% of the left bank and 16% of the right bank, with highly altered conditions assessed at 6% for the left bank and 7% for the right bank, inclusively. These alterations were generally associated with road crossings, shoreline hardening and commercial/ industrial land use.

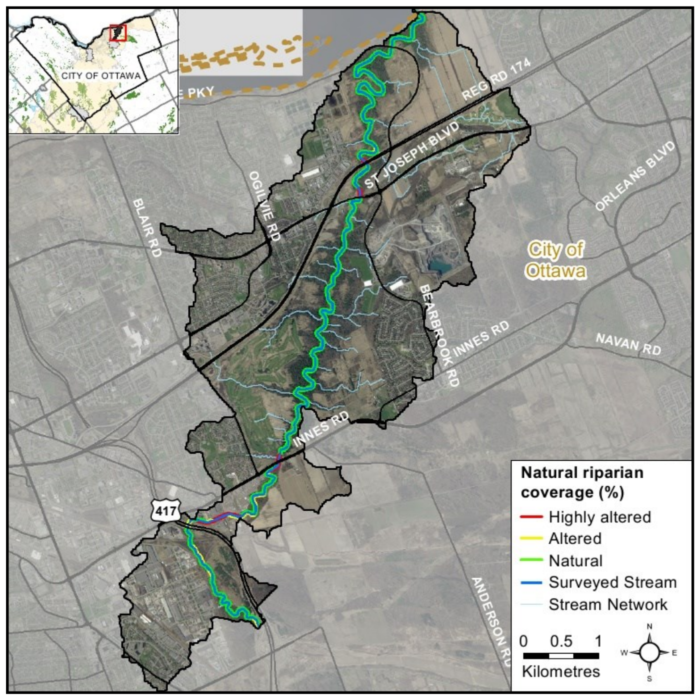


Figure 8 Riparian buffer alterations within Greens Creek

Shoreline alterations (ie. channel hardening) upstream of Innes Rd

Overhanging Trees and Branches

Trees and branches that are less than one meter from the surface of the water are defined as overhanging. At this proximity to the water, trees and branches provide a food source, nutrients and shade which helps to moderate instream water temperatures. Overhanging trees and branches were identified in 72% of all surveyed sites with an average coverage extent of 15% in those sections (Figure 9). Relatively high tree/branch cover was identified downstream of the Sir George-Etienne Cartier parkway, as backflow from the Ottawa River had inundated the surrounding woodland.

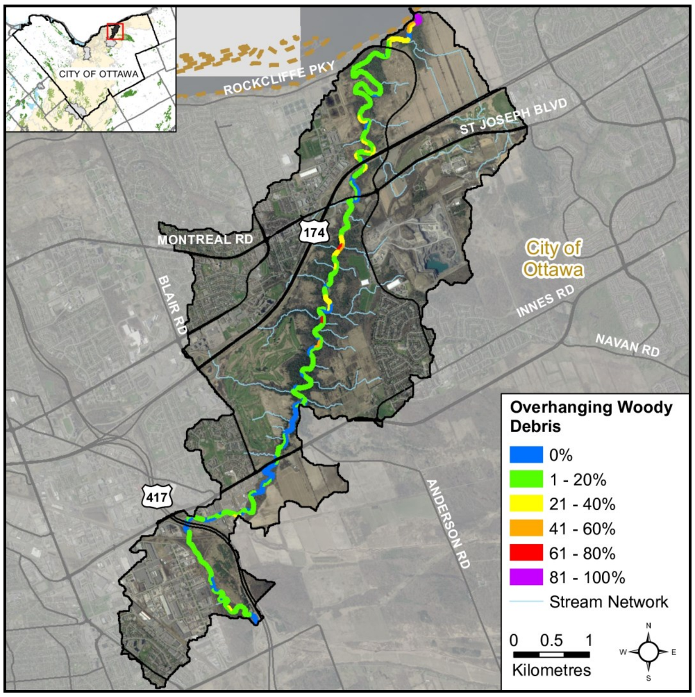


Figure 9 Overhanging trees and branches along Greens Creek

Overhanging trees and branches on Greens Creek

Anthropogenic Alterations

Stream alterations are classified based on specific functional criteria associated with the flow conditions, the riparian buffer, and potential human influences (Figure 10). Greens Creek is considered unaltered for 42% of its length, with only minor alterations observed in 27% of sections. Altered classes (ie. Altered & Highly Altered) account for approximately 31% of the stream length, with the extensive alterations identified in 10% of the surveyed stream.

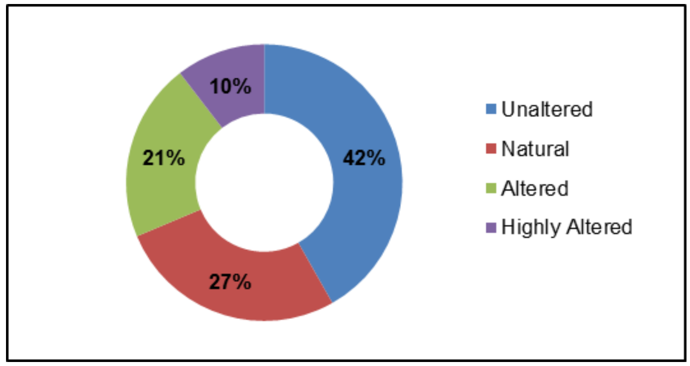


Figure 10 Anthropogenic alterations along Greens Creek

A highly altered section of Greens Creek (Innes Rd crossing)

An unaltered section of Greens Creek

Greens Creek Instream Aquatic Habitat

Habitat Complexity

Habitat complexity is a measure of the overall diversity of habitat types and features within a stream. Streams with high habitat complexity support a greater variety of species niches, and therefore contribute to greater diversity. Factors such as substrate, flow conditions (pools, riffles) and cover material (vegetation, wood structure, etc) all provide crucial habitat to aquatic life. Habitat complexity is assessed based on the presence of boulder, cobble and gravel substrates, as well as the presence of instream woody material.

Diverse habitat cover was identified throughout Greens Creek, with considerable coverage across the surveyed stream (Figure 11). Many of these sections represent potentially crucial habitat for resident species. Regions with reduced habitat complexity were observed in the lower reaches, and may be associated with sedimentation and shoreline erosion.

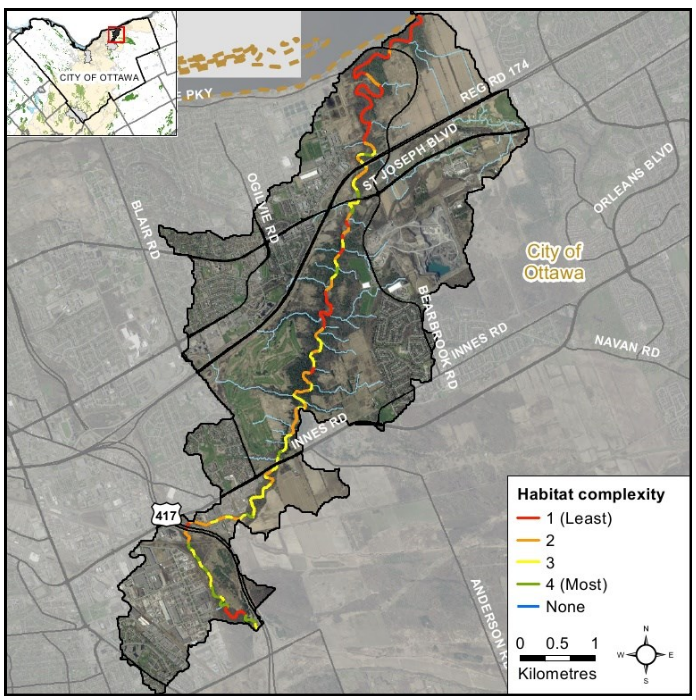


Figure 11 Instream habitat complexity in Greens Creek

Diverse habitat cover observed on Greens Creek

Instream Substrate

Diverse substrate is important for fish and benthic invertebrates as many species rely on specific substrate types to complete their life cycles. The absence of diverse substrate types may limit the overall diversity of species within a stream.

Clay was identified in 72% of all surveyed sites, as Greens Creek is characterized by extensive regions of exposed consolidated clays (Figure 12 & 13). Gravel and cobble were identified in greater than 50% of all surveyed sections. Sand and silt were common throughout the system (>40%), with only minor instances of bedrock observed (7%). Boulder was also identified, with most observations isolated to the middle and upper reaches. Boulder was identified in 29% of all surveyed locations. Clay substrate was dominant throughout much of the surveyed extent, with a drastic transition to rock/bedrock substrates in proximity to Innes Rd (Figure 13).

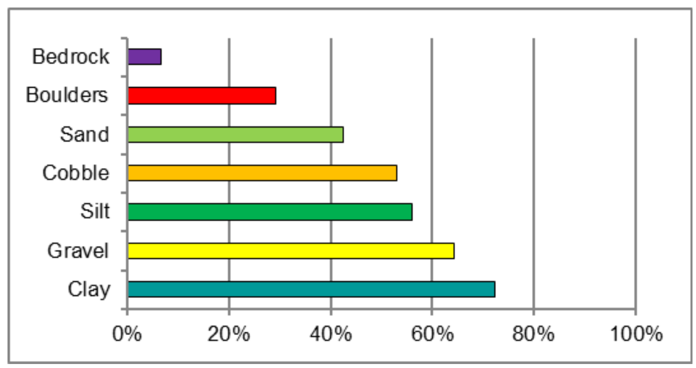


Figure 12 Instream substrate along Greens Creek

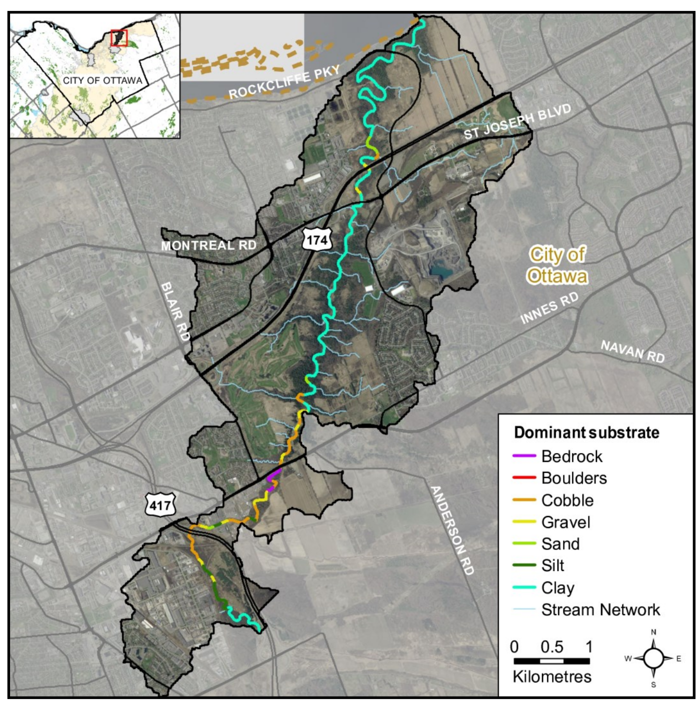


Figure 13 Dominant instream substrate in Greens Creek

Instream Morphology

Pools and riffles are important habitat features for aquatic life. Riffles are fast flowing areas characterized by agitation and overturn of the water surface. Riffles play a crucial role in contributing to dissolved oxygen conditions and directly support spawning for some fish species. Pools are characterized by minimal flows, with relatively deep water and provide thermal, habitat and flow refuge for aquatic species. Runs are moderately shallow, with unagitated surface flow and areas where the thalweg (deepest part of the channel) is in the center of the channel.

Riffle zones on Greens Creek were largely isolated to a 4km segment flowing between Innes Rd and HWY 417 (Figure 14 & 15). Riffle habitat was identified in 37% of all surveyed sites and may have been reduced as a result of shoreline instability in the middle to lower reaches. Pool habitat was common throughout the system and was identified in approximately 80% of all surveyed sites.

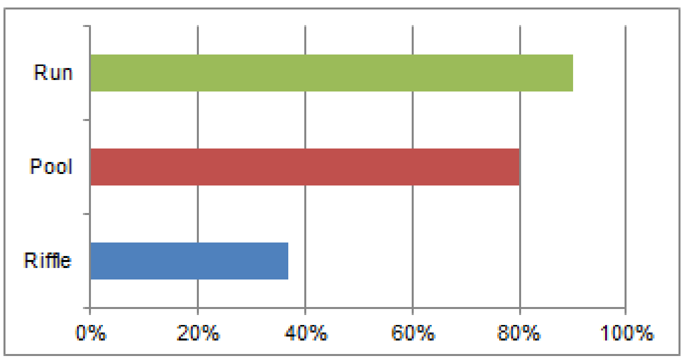


Figure 14 Instream morphology along Greens Creek

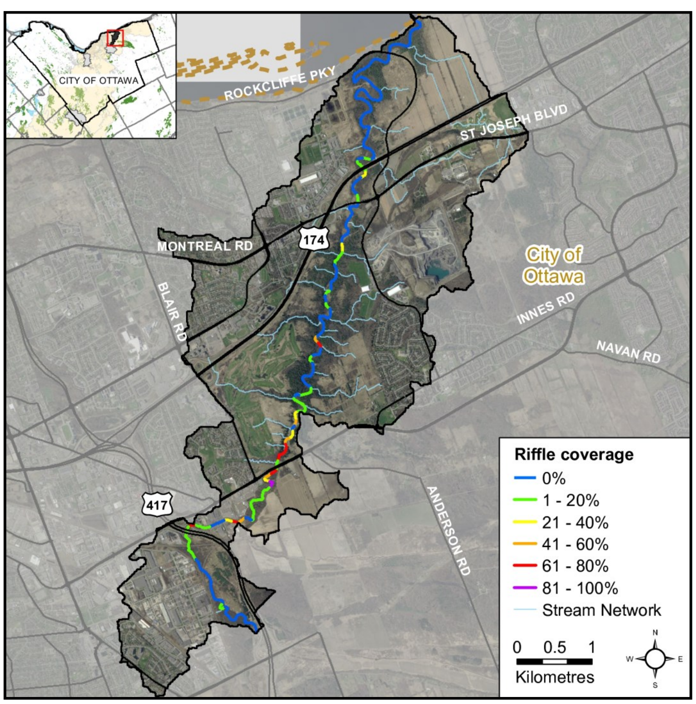


Figure 15 Riffle coverage in Greens Creek

Vegetation Type

Instream vegetative communities are a crucial component of aquatic ecosystems, providing both direct and indirect support to aquatic life. Aquatic plants promote for stream health by:

- Providing direct riparian/instream habitat
- Stabilizing flows/reducing shoreline erosion
- Contributing to dissolved oxygen through photosynthesis
- Maintaining temperature conditions through shading

Submergent plant types were identified in 68% of all surveyed sites, however many of the observations may have included the presence of the invasive *curly-leaf pondweed* (Figure 16 & 17). These species have the potential to reduce overall diversity, despite the fact that they may provide some ecosystem function. Emergent plant communities were identified in approximately 40%-60% of all sites, but also include invasive species observations. *Flowering rush* and *yellow iris* were observed and account for some of the emergent observations. Significant algal growth was uncommon and identified in only 36% of all surveyed sites. Floating plants such as water lilies were identified in 19% of all sites, with minor instances of free-floating plants observed (4%).

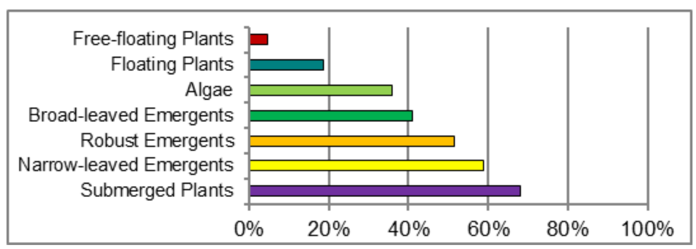


Figure 16 Aquatic vegetation presence along Greens Creek

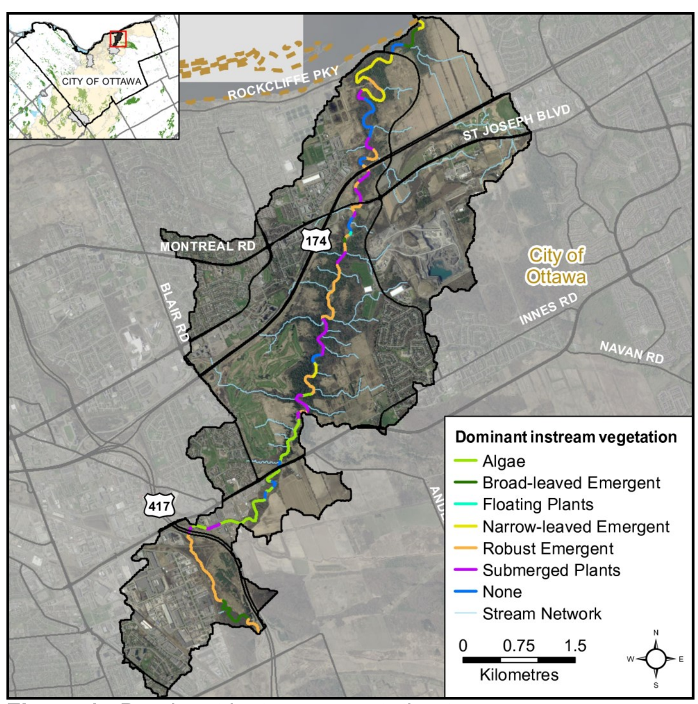


Figure 17 Dominant instream vegetation types

Instream Vegetation Abundance

Instream vegetation is an important factor for a healthy stream ecosystem. Vegetation helps to remove contaminants from the water, contributes oxygen to the stream, and provides habitat for fish and wildlife. Too much vegetation can also be detrimental.

Instream vegetation abundance was found to be relatively sparse overall, with “normal” levels identified within only 18% of the instream surface area (Figure 18). Low to absent (ie. low, rare, none) levels accounted for the majority of observations at greater than 70%, with less than 10% considered to be potentially harmful (ie. extensive/common). These observations are consistent with the substrate and erosion conditions identified. Consolidated substrates and unstable flows have the potential to limit aquatic plant growth.

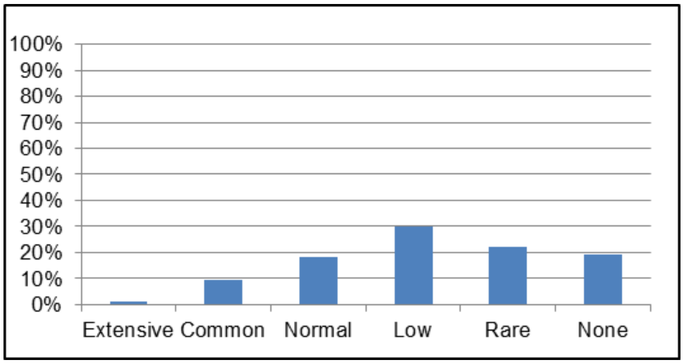


Figure 18 Instream vegetation abundance in Greens Creek

Contrasting sites with low (above) and common/extensive (below) instream vegetation abundance

Greens Creek Stream Health

Invasive Species

Invasive species can have major implications on streams and species diversity. Invasive species are one of the largest threats to ecosystems throughout Ontario and can outcompete native species, having negative effects on local wildlife, fish and plant populations. Invasive species were observed along 97% of the surveyed stream, with a total of 19 species identified (Figure 19).

Invasive species abundance (ie. the number of observed invasives per section) was assessed to determine the potential range/vector of many of these species. Approximately 72% of Greens Creek had 4 or fewer invasive species identified within each section. Higher density (5—7 species) and/or isolated invasive communities were identified in the lower, middle and upper reaches of the system. Invasive abundance was determined to be high upstream of the Sir George-Etienne Cartier parkway, and isolated to downstream of HWY 174. Invasive *yellow iris* was associated specifically with this reach, and was not identified anywhere else in the system. High density patches of *garlic mustard* and *Himalayan balsam* were identified adjacent to the Blackburn Hamlet community and may be associated with storm-water influences. High invasive species abundance was also identified upstream of HWY 417. This region was resident to extensive growth of *Himalayan balsam, flowering rush and buckthorn spp.*

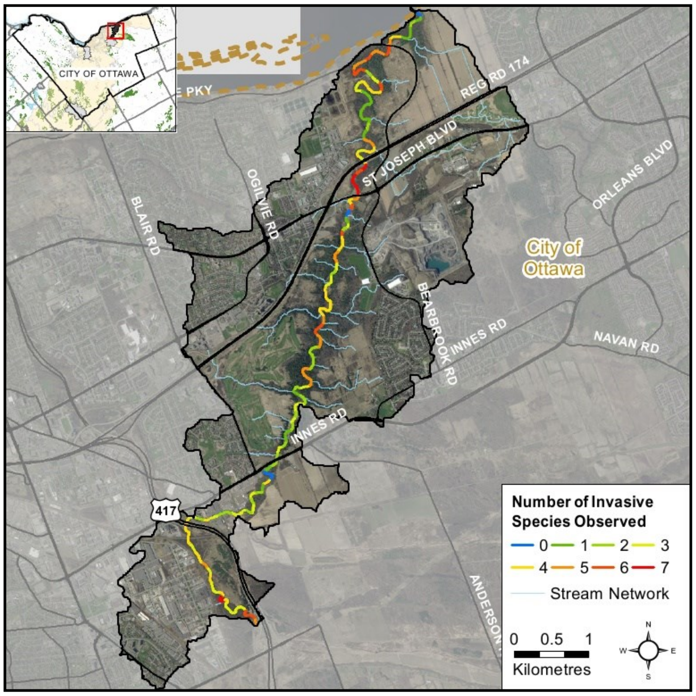


Figure 19 Invasive species abundance along Greens Creek

Pollution

Pollution was identified in 54% of all surveyed sections of Greens Creek (Figure 20). Common waste identified included hazardous waste containers (ie. paint, oil, etc.), lumber and general domestic products (ie. plastic bottles, bags, etc). Garbage was identified along the stream bottom in 38% of all sites, with floating debris identified in 25% of all surveyed locations. Unusual colouration was observed in 1% of all sites, as well as some instances of commercial/industrial waste dumping (ie. Other—3%).

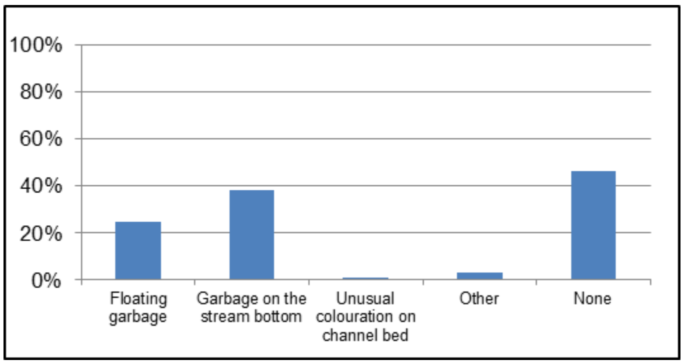


Figure 20 Pollution observed within Greens Creek

Volunteers collecting garbage on Greens Creek

Hazardous waste products collected from Greens Creek

Wildlife

The diversity of fish and wildlife populations can be an indicator of water quality and overall stream health (Table 1). Wildlife observations are noted during standard monitoring and survey activities, and do not represent an extensive evaluation of species presence/ absence. Species of note or special consideration include: *northern map turtle* and *snapping turtle* .

Table 1 Wildlife observed along Greens Creek in 2016

Birds	American crow, American goldfinch, American robin, belted kingfisher, black-capped chickadee, blue jay, Canada goose, grackle, gray catbird, great blue heron, green heron, mallard, mourning dove, northern cardinal, pileated woodpecker, raven, red-tailed hawk, red-winged black bird, sandpiper spp, sparrow spp, turkey vulture, woodpecker spp
Reptile & Amphibians	bull frog, green frog, leopard frog, mink frog, northern map turtle, snapping turtle, wood frog
Mammals	chipmunk, coyote, muskrat, North American beaver, raccoon, red squirrel, white-tailed deer
Mussels	eastern floater, eastern lampmussel, fatmucket, giant floater, mucket, plain pocketbook
Aquatic Insects	amphipoda, crayfish spp, trichoptera, water boatmen, water scorpion, water striders, whirligig beetle
Other	aphids, bees, cabbage white butterfly, cicada, ebony jewelwing, midges, mosquito, snail spp, spider spp, swallowtail butterfly

Northern map turtle basking on woody material

Greens Creek Water Chemistry

Water Chemistry Assessment

During the stream characterization survey, a YSI probe is used to collect water chemistry information. Dissolved oxygen (DO), specific conductivity (SPC) and pH are measured at the start and end of each section.

Volunteers measuring water chemistry

Dissolved Oxygen

Dissolved oxygen is a measure of the amount of oxygen dissolved in water. Guidelines supported under the Canadian Council of Ministers of the Environment (CCME) suggest that for the protection of aquatic life the lowest acceptable dissolved oxygen concentration should be 6 mg/L for warmwater biota (red line in Figure 21) and 9.5 mg/L for coldwater biota (blue line in Figure 21) (CCME, 1999).

Warmwater conditions were largely maintained throughout the summer months, with only few reaches showing signs of lower oxygen conditions and/or depletion. Stream sections 21-30 (located centrally between the Sir George-Etienne Cartier parkway & HWY 174) experienced periods of low oxygen and may indicate impairment. Regions upstream of HWY 417 were also found to be below the accepted warmwater threshold and may represent impairment throughout the

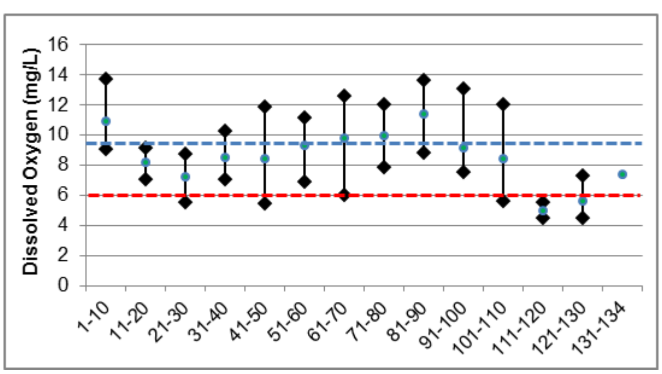


Figure 21 Dissolved oxygen ranges in Greens Creek

Conductivity

Conductivity in streams is primarily influenced by the geology of the surrounding environment, but can vary drastically as a result of surface water runoff. Currently there are no CCME guidelines for stream conductivity, however readings which are outside the normal range observed within the system are often an indication of unmitigated discharge and/or storm-water input. The average specific conductivity observed within Greens Creek was 1646 µs/cm (green line in Figure 22).

Peak conductivity levels were identified downstream of the Innes rd crossing (2230 µs/cm), with elevated levels extending over approximately 3km. These elevated levels can likely be attributed to storm-water influence from nearby land-use. Elevated levels were also observed downstream of HWY 174, and are likely associated with storm-water from the adjacent commercial properties. The relatively high baseline levels observed in Greens Creek are likely influenced by the extensive marine clay coverage, as carbonate compounds are known to affect stream conductivity.

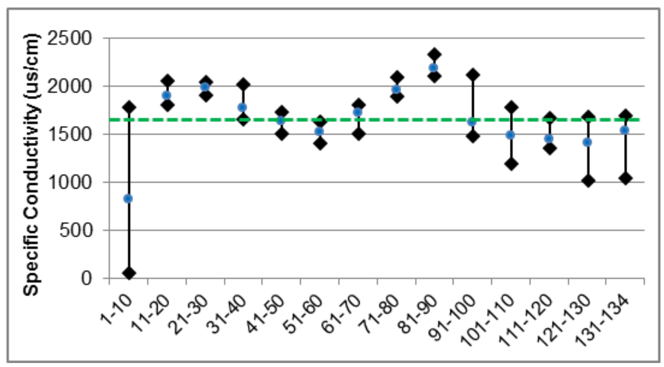


Figure 22 Conductivity ranges in Greens Creek

pH

Based on the Provincial water quality objectives for pH, a range of 6.5 to 8.5 should be maintained for the protection of aquatic life.

Average pH throughout Greens Creek was approximately 7.9, with some minor exceedances above the Provincial standard (Figure 23). Variation in pH was occasionally found to parallel high conductivity readings, however several isolated instances were observed. This association may indicate potential impairment and/or environmental instability.

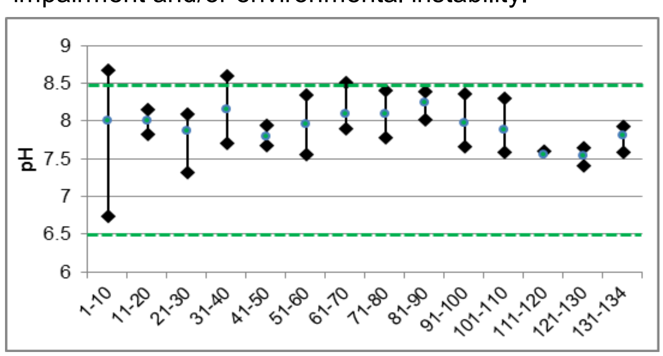


Figure 23 pH ranges in Greens Creek

Oxygen Saturation (%)

Oxygen saturation is measured as the ratio of dissolved oxygen relative to the maximum amount of oxygen that will dissolve based on the temperature and atmospheric pressure. Well oxygenated water will stabilize at or above 100% saturation, however the presence of decaying matter/pollutants can drastically reduce these levels. Oxygen input through photosynthesis has the potential to increase saturation above 100% to a maximum of 500%, depending on the productivity level of the environment. In order to represent the relationship between concentration and saturation, the measured values have been summarized into 6 classes.

1) <100% Saturation / <6.0 mg/L Concentration

- Oxygen concentration and saturation are not sufficient to support aquatic life and may represent impairment.

2) >100% Saturation / <6.0 mg/L Concentration

- Oxygen concentration is not sufficient to support aquatic life, however saturation levels indicate that the water has stabilized at its estimated maximum. This is indicative of higher water temperatures and stagnant flows.

3) <100% Saturation / 6.0—9.5 mg/L Concentration

- Oxygen concentration is sufficient to support warmwater biota, however depletion factors are likely present and are limiting maximum saturation.

4) >100% Saturation / 6.0—9.5 mg/L Concentration

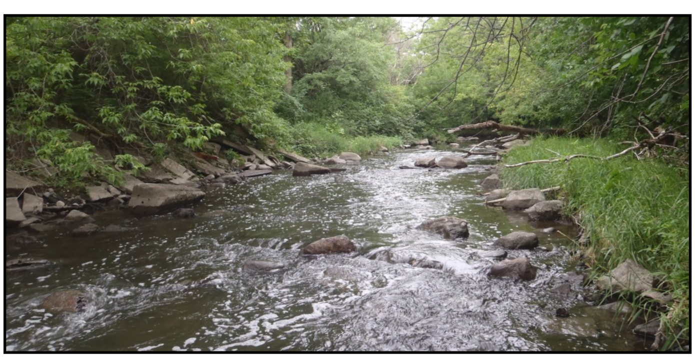
- Oxygen concentration and saturation levels are optimal for warmwater biota.

5) <100% Saturation / >9.5 mg/L Concentration

- Oxygen concentration is sufficient to support coldwater biota, however depletion factors are likely present and are limiting maximum saturation.

6) >100% Saturation / >9.5 mg/L Concentration

- Oxygen concentration and saturation levels are optimal for warm and coldwater biota.



Site on Greens Creek with optimal oxygen conditions

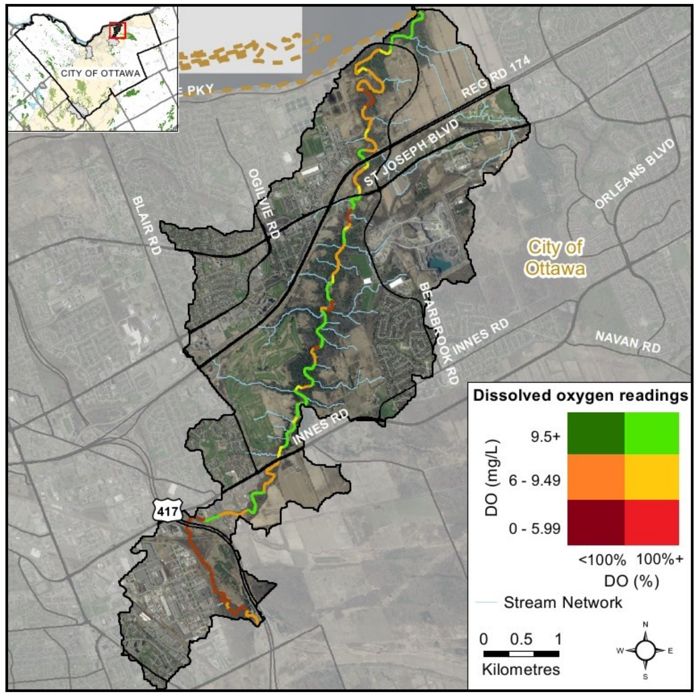


Figure 24 A bivariate assessment of dissolved oxygen concentration (mg/L) and saturation (%) on Greens Creek

Dissolved oxygen conditions on Greens Creek are generally sufficient for both warm and coldwater species, however several regions exist with potential impairment (Figure 24). The most severe conditions were identified in the upper reaches, as the oxygen concentration and saturation were not sufficient for the protection of aquatic life. Furthermore, potential impairment was also identified between St. Joseph blvd and the Sir George-Etienne Cartier parkway. Optimal conditions were observed throughout the middle reaches of Greens Creek, with some minor instances of oxygen depletion identified.

Site on Greens Creek with depleted oxygen conditions

Specific Conductivity Assessment

Specific conductivity (SPC) is a standardized measure of electrical conductance, collected at or corrected to a water temperature of 25ºC. SPC is directly related to the concentration of ions in water, and is commonly influenced by the presence of dissolved salts, alkalis, chlorides, sulfides and carbonate compounds. The higher the concentration of these compounds, the higher the conductivity. Common sources of elevated conductivity include storm water, agricultural inputs and commercial/industrial effluents.

In order to summarize the conditions observed, SPC levels were evaluated as either normal, moderately elevated or highly elevated. These categories correspond directly to the degree of variation (ie. standard deviation) at each site relative to the average across the system.

Normal levels were maintained from approximately HWY 174 into the middle reaches of Greens Creek, with moderately elevated levels observed in approach of Innes Rd (Figure 25). Highly elevated conditions were identified throughout the system, and generally correspond with proximity to agriculture, storm water input and commercial/industrial development.

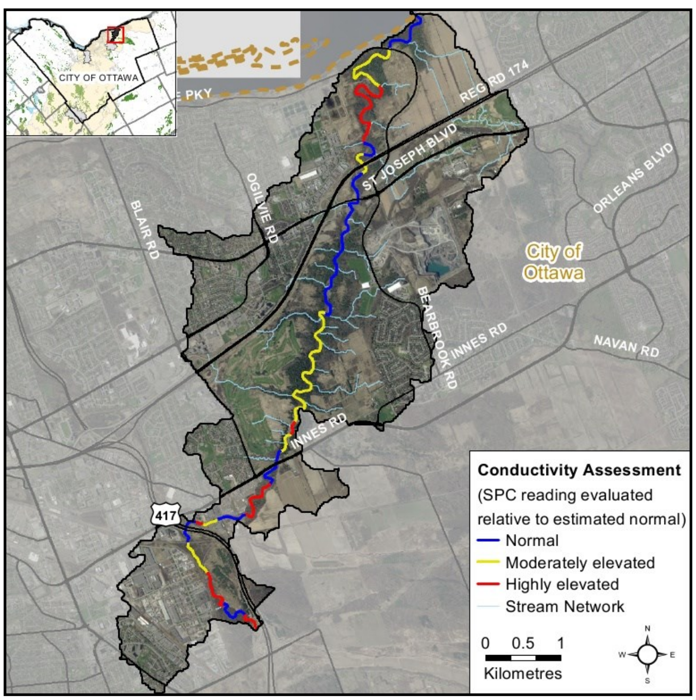


Figure 25 Relative specific conductivity levels on Greens Creek

Areas of Concern

Based on an overall evaluation of the water quality results, several areas of Greens Creek show potential impairment. These regions generally correspond with outflow and/or proximity to developed areas. The following sites are associated with inadequate oxygen conditions, elevated conductivity and variable pH levels (Figure 26).

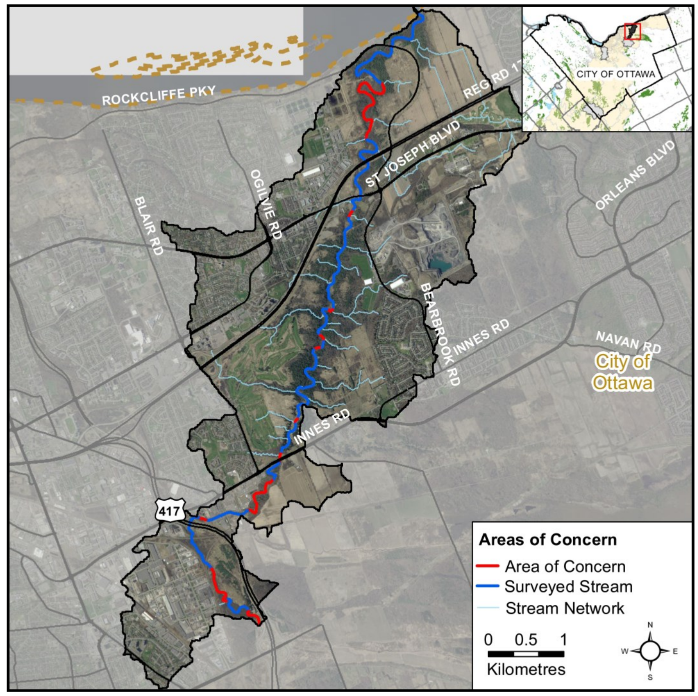


Figure 26 Greens Creek areas of concern based on water chemistry evaluation

Tributary conveying storm water from an adjacent subdivision

Greens Creek Thermal Classification

Thermal Classification

Many factors can influence fluctuations in stream temperature, including springs, tributaries, precipitation runoff, discharge pipes and stream shading from riparian vegetation. Five loggers were deployed in late April to monitor water temperatures in Greens Creek (Figure 27). Water temperatures are used along with the maximum air temperature (using a revised Stoneman and Jones method) to classify sampling reaches into one of five categories that correspond to the thermal preferences of local fish communities (Figure 29). Greens Creek is primarily a warmwater system, with slightly cooler temperatures towards its upper reaches. Temperatures at the Leeds Avenue site stabilized within the cool-warmwater range, with all other sites evaluated as warmwater. Only 4 of the 5 deployed loggers were evaluated, as logger ID-1 was compromised due to an out-of-water condition.

Groundwater

Groundwater discharge areas can influence stream temperature, contribute nutrients, and provide important stream habitat for fish and other biota. During stream surveys, indicators of groundwater discharge were assessed and identified (Figure 28) Groundwater observations were primarily identified within the upper reaches of the stream, and correspond with the presence of the underlying bedrock boundary (Hugenholtz, C.H. *et.al,* 2004). Some observations included seeps directly from the exposed clay shorelines, as surface flows may have been initiated through slumping and/or slope failure.

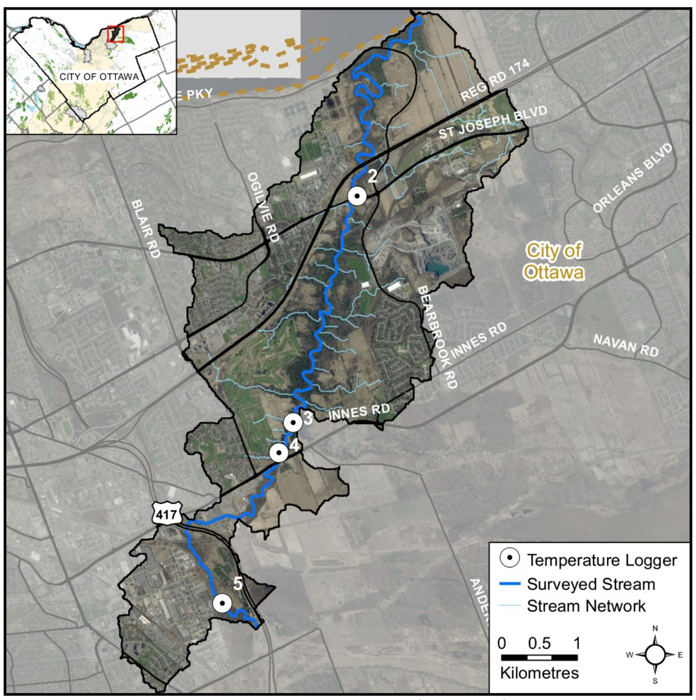


Figure 27 Temperature loggers along Greens Creek

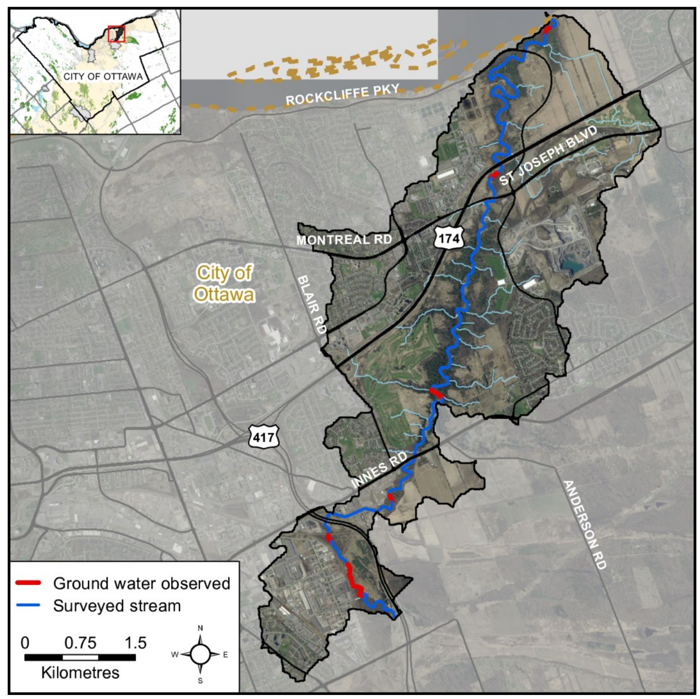


Figure 28 Groundwater indicators observed in Greens Creek

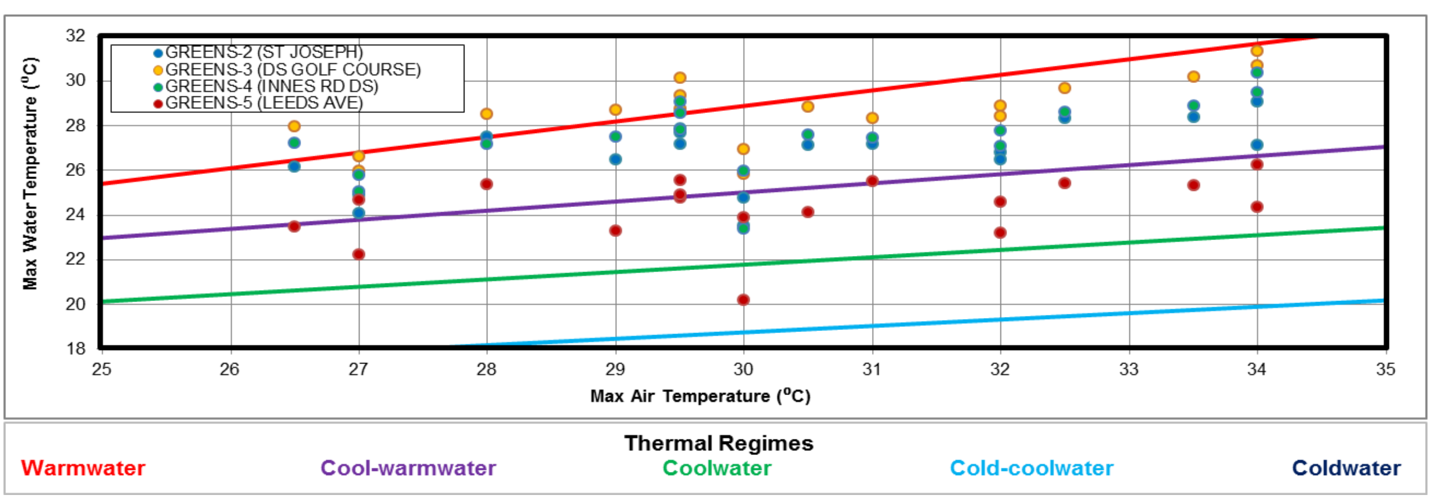


Figure 29 Thermal Classification for Greens Creek

Greens Creek Fish Community

Fish Community

Historic fish sampling records indicate the presence of 44 distinct species within Greens Creek (Table 2). RVCA fish sampling efforts have identified 41 of the listed species, but unable to verify the presence of *mimic shiner, northern pearl dace* and *sauger.* Species of note or special consideration include: *common carp* (invasive), *goldfish* (invasive) and *river redhorse* (SAR).

Fish sampling records include data from 88 separate sampling events and 13 sites (Figure 30).

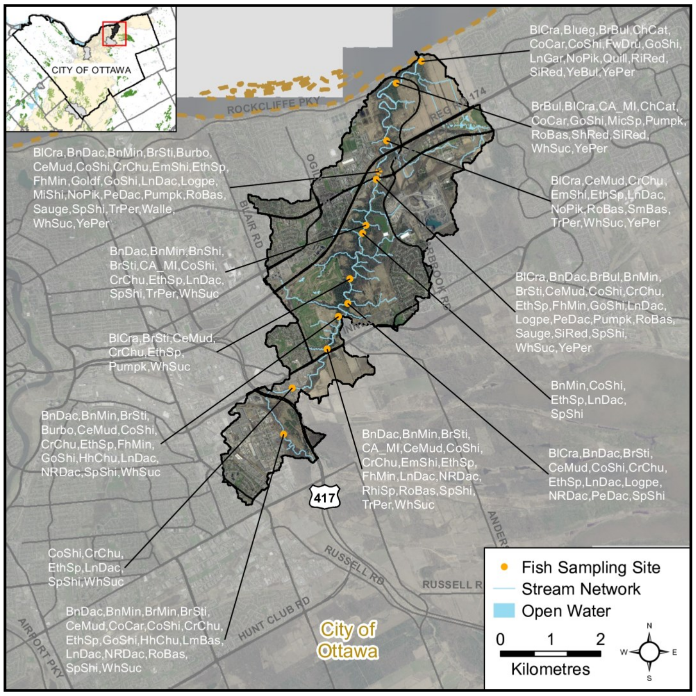


Figure 30 Greens Creek fish sampling locations

Large fyke net set along the shore of Greens Creek

Table 2 Fish species observed in Greens Creek (2000-2016)

Species	Code	Species	Code
Banded killifish	BaKil	Logperch	Logpe
Black crappie	BlCra	Longnose dace	LnDac
Blacknose dace	BnDac	Longnose gar	LnGar
Blacknose shiner	BnShi	Micropterus sp.	MicSp
Bluegill	Blueg	Mimic shiner	MiShi
Bluntnose minnow	BnMin	Northern pearl dace	PeDac
Brassy minnow	BrMin	Northern pike	NoPik
Brook stickleback	BrSti	Northern redbelly dace	NRDac
Brown bullhead	BrBul	Pumpkinseed	Pumpk
Burbot	Burbo	Quillback	Quill
Cyprinid sp.	CA_MI	Rhinichthys sp.	RhiSp
Central mudminnow	CeMud	River redhorse	RiRed
Channel catfish	ChCat	Rock bass	RoBas
Common carp	CoCar	Sauger	Sauge
Common shiner	CoShi	Shorthead redhorse	ShRed
Creek chub	CrChu	Silver redhorse	SiRed
Emerald shiner	EmShi	Smallmouth bass	SmBas
Etheostoma sp.	EthSp	Spotfin shiner	SpShi
Fathead minnow	FhMin	Trout-perch	TrPer
Freshwater drum	FwDru	Unknown	UNKN
Golden shiner	GoShi	Walleye	Walle
Goldfish	Goldf	White sucker	WhSuc
Hornyhead chub	HhChu	Yellow bullhead	YeBul
Largemouth bass	LmBas	Yellow perch	YePer

Quillback captured on Greens Creek

Golden shiners captured on Greens Creek

Migratory Obstructions

Migratory obstructions represent limitations to fish dispersal within a system and may restrict access to important spawning and rearing habitat. Barriers can be natural or man-made features, with either seasonal or permanent influence. Debris dams were common throughout Greens Creek, and are likely a result of the prominent instability within the region (Figure 31). Many of these obstructions were comprised of trees and branches of considerable size, and located adjacent to destabilized shorelines. A concrete grade barrier was identified approximately 1km upstream of Innes rd and appears to function as an access route across the stream. Significant debris accumulation was identified and removed at both St. Joseph Blvd and the HWY 174 crossing.

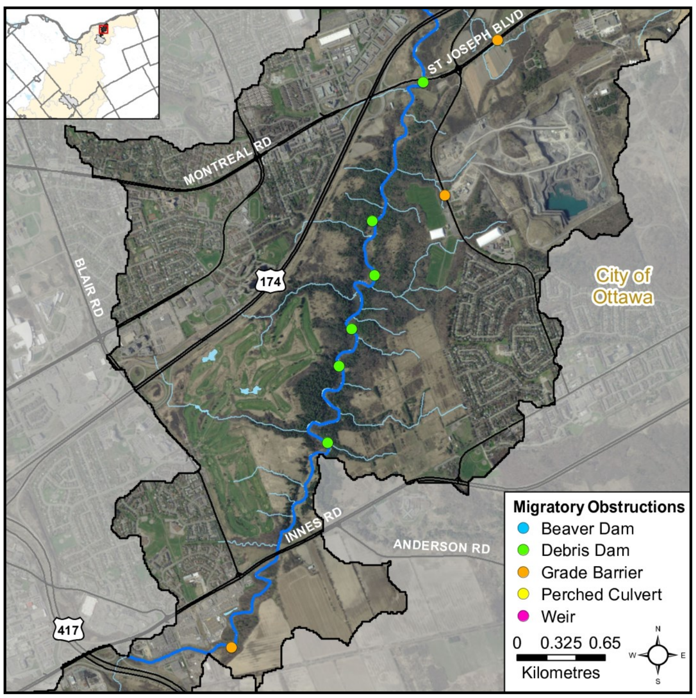


Figure 31 Greens Creek migratory obstructions

Debris dam located upstream of St Joseph blvd

Beaver Dams

Beaver dams are considered potential barriers to fish migration. Beaver dam presence was limited within Greens Creek, with a single breached dam identified downstream of Innes Rd (Figure 32). General beaver activity (ie. tree cropping, etc.) was identified throughout the system, however very few dam structures were observed.

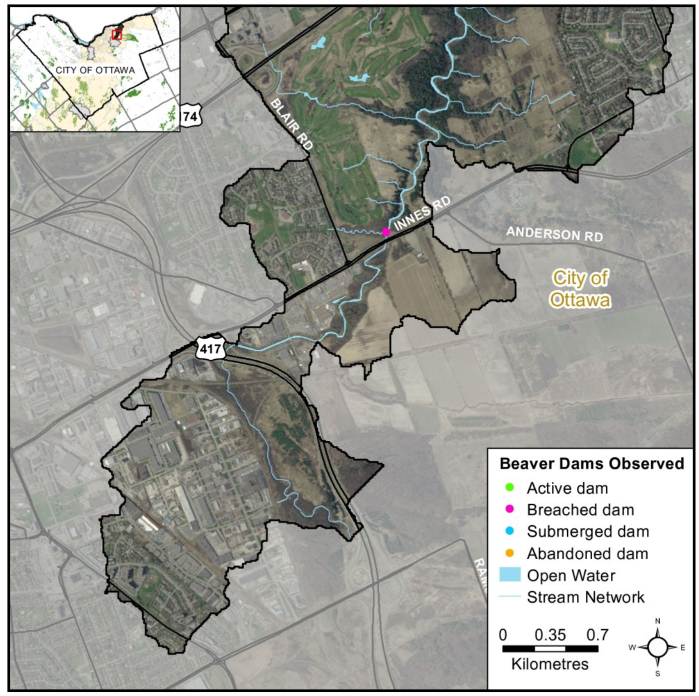


Figure 32 Beaver dams observed on Greens Creek

Concrete grade barrier identified upstream of Innes Rd

Headwater Drainage Feature Assessment

Headwaters Sampling

Headwater drainage features (HDF) represent the origin from which water enters a watershed. These features convey surface flows directly from groundwater discharge, rain and melt water to the greater catchment area. HDF's have not traditionally been a component of most monitoring efforts, as their form and function on the landscape are not well established. These features may provide direct and seasonal fish habitat, as well as thermal refuge as a result of groundwater influence (OSAP Protocol, 2013). Furthermore, HDF's may be important sources, conveyors and storers of sediment, nutrients and flow, and may have an important role for terrestrial and wetland species. The RVCA is currently working with other Conservation Authorities and the Ministry of Natural Resources and Forestry to implement a sampling protocol with the goal of providing standard datasets to support scientific development and monitoring of these features. This protocol provides a direct means of characterizing the sediment and flow capacity, connectivity, form and unique features associated with each HDF (OSAP Protocol, 2013). Features are evaluated through a rapid assessment protocol, and sampled at road crossings.

In 2016 the CSW program assessed 12 sites in the Greens Creek catchment area (Figure 33).

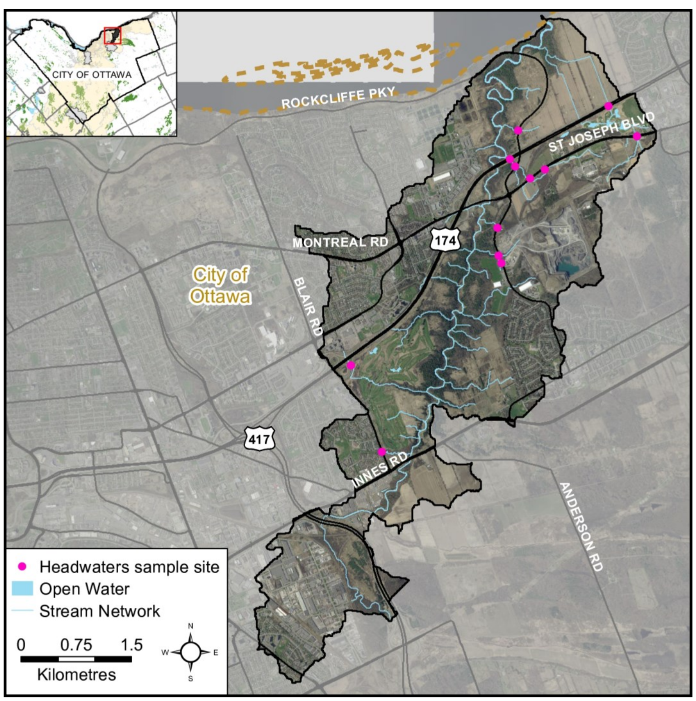


Figure 33 Greens Creek HDF sampling sites

Feature Type

The headwater sampling protocol assesses the feature type in order to understand the function of each feature. The evaluation includes the following feature classifications: defined natural channel, channelized or constrained, multi-thread, no defined feature, tiled, wetland, swale, roadside ditch and pond outlet. By assessing the form of the HDF, we can better understand the function it provides within the catchment as it relates to the hydrology, sediment transport capacity and habitat conditions.

The Greens Creek catchment is comprised of a variety of feature types, including natural channels, roadside ditches, channelized stream and piped/tiled features (Figure 34).

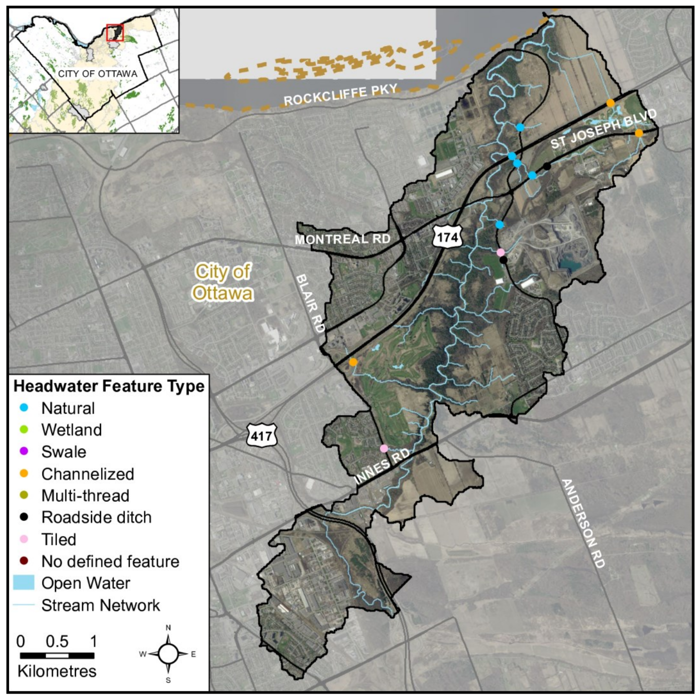


Figure 34 Greens Creek HDF feature types

Piped/tiled headwater drainage feature on Bearbrook Dr

Headwater Feature Flow

Flow conditions within an HDF can be highly variable as a result of seasonal factors, moisture conditions, rainfall events and snow-melt. Flow conditions are assessed in the spring and in the summer to determine if features are perennial and flow year round, if they are intermittent and dry up during the summer months or if they are ephemeral systems with irregular flow patterns that generally respond to specific rainstorm events or snowmelt. Flow conditions in headwater systems can change from year to year depending on local precipitation patterns.

Flow conditions in the Greens Creek catchment varied between perennial and intermittent flow (Figure 35). Two flow locations along Bearbrook Dr were associated with potential groundwater input as iron-staining and watercress were observed.

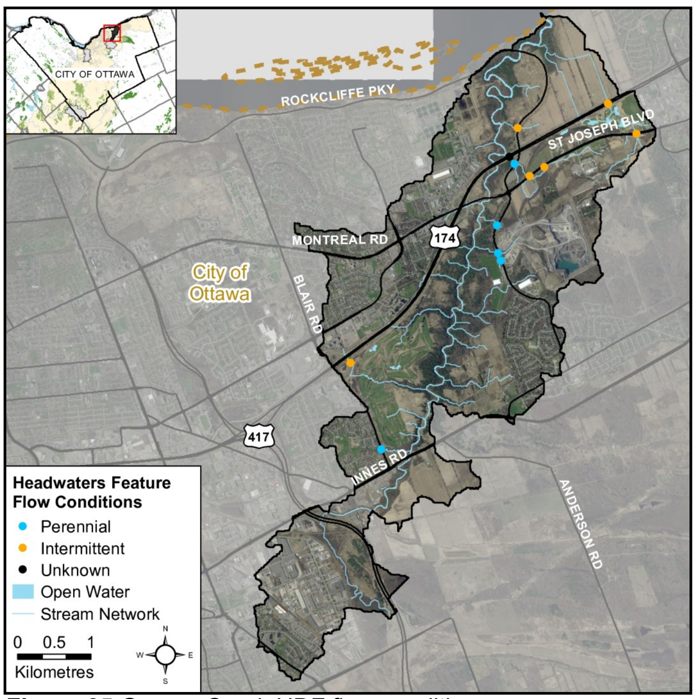


Figure 35 Greens Creek HDF flow conditions

Intermittent feature with spring (above) and summer (below) flows

Feature Channel Modifications

Channel modifications were assessed at each headwater drainage feature sampling location. Modifications include channelization, dredging, hardening and realignments.

The majority of drainage features in the Greens Creek catchment showed some level of modification, and included instances of dredging/straightening, channel hardening (ie. armor stone, gabions, etc) and channel entrenchment (Figure 36).

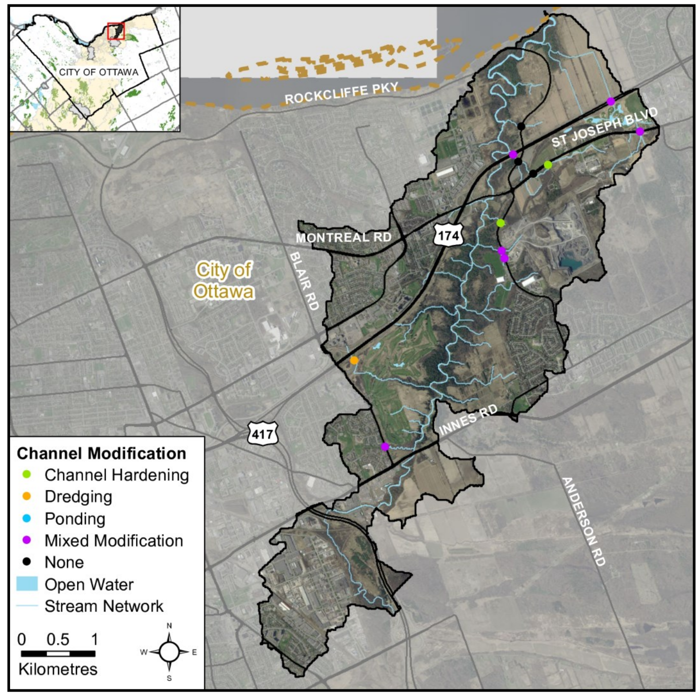


Figure 36 Greens Creek HDF channel modifications

Piped outflow and channel hardening along Blair Rd

Headwater Feature Vegetation

Feature vegetation is evaluated as the dominant vegetation type found directly within the stream channel. Vegetation within the feature plays a significant role in flow and sediment movement, as well as providing critical aquatic and terrestrial habitat. Vegetation types include: no vegetation, lawn, wetland, meadow, scrubland and forest.

Flow features within the Greens Creek catchment were identified as either wetland, meadow or as having no defined vegetation (Figure 37). Features with no vegetation (as defined by limited cover within 75% of the surface area) were the most common within the catchment and represent 50% of the surveyed sites.

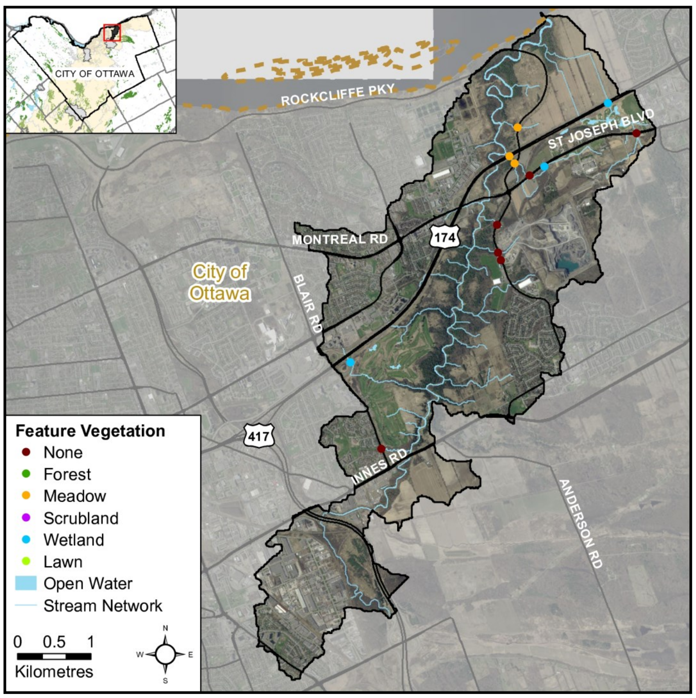


Figure 37 Greens Creek HDF feature vegetation

Wetland feature vegetation adjacent to HWY 174

Headwater Feature Riparian Vegetation

Riparian vegetation is evaluated as the dominant vegetation type observed within 3 standardized shoreline zones. The vegetative community is assessed at 0-1.5m, 1.5-10m and 10-30m from the stream bank.

Riparian conditions within the Greens Creek catchment were evaluated as altered in approximately 60% of survey sites (Figure 38). Riparian alterations were generally associated with cropland, municipal infrastructure and commercial/industrial land use.

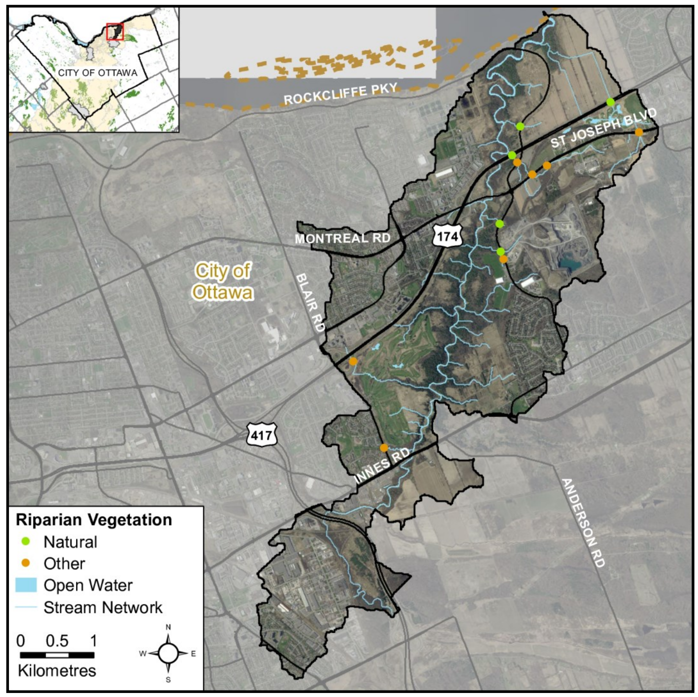


Figure 38 Greens Creek HDF riparian vegetation

Scrubland riparian buffer along HWY 174

Headwater Feature Sediment Deposition

Assessing the amount of recent sediment deposited in a channel provides an index of the degree to which the feature could be transporting sediment to downstream reaches (OSAP, 2013). Evidence of excessive sediment deposition might indicate the requirement for further assessment and potential implementation of best management practices.

Sediment deposition within the Greens Creek catchment was predominantly low, with 67% of sites categorized as having minimal to no immediate sedimentation (Figure 39). Extensive and substantial levels of deposition were identified at two sites, and represent a potential source of impairment. Moderate to extensive levels were also observed, and will be monitored for further potential impact.

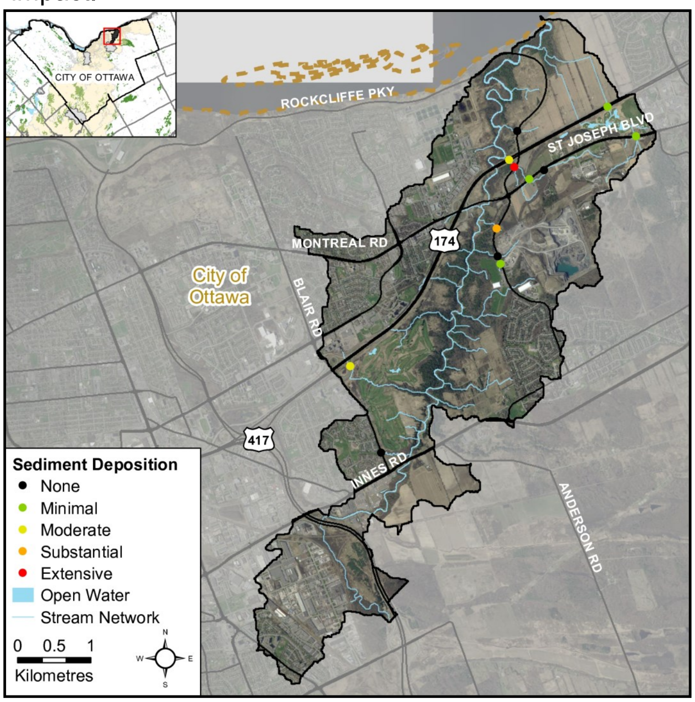


Figure 39 Greens Creek HDF sediment deposition

Sediment deposition along Greens Creek at St. Joseph Blvd

Headwater Feature Upstream Roughness

Feature roughness is a measure of the amount of material within the bankfull channel capable of slowing water velocity and stabilizing flows (OSAP, 2013). Materials on the channel bottom that provide roughness include vegetation, woody debris and boulders/cobble substrates. Roughness can promote for reduced erosion downstream of the feature, as well as providing important habitat to aquatic organisms.

Feature roughness varied between sites, with moderate to extreme levels common throughout the catchment (Figure 40). Minimal levels were limited and only identified at a single site along Bearbrook Dr.

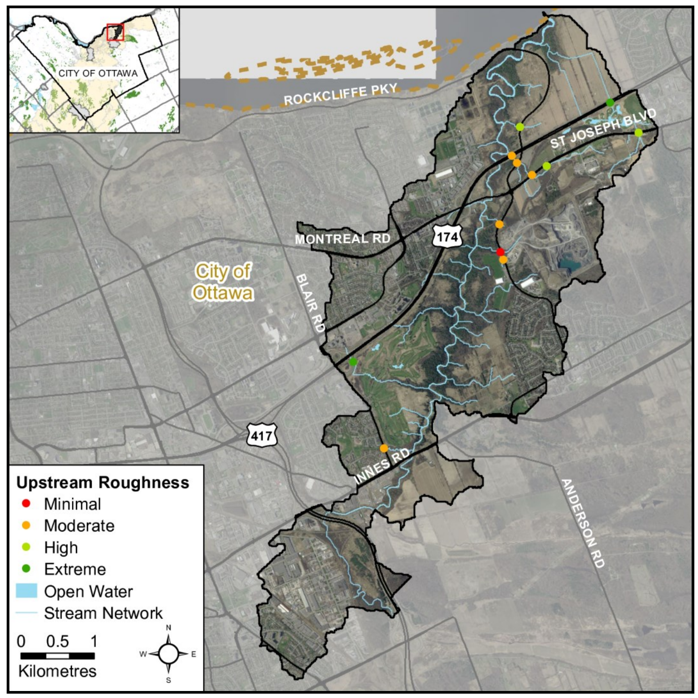


Figure 40 Greens Creek HDF feature roughness

Headwater feature with *extreme* roughness conditions along HWY 174

Stream Comparison Between 2010 and 2016

The following tables provide a comparison of observations on Greens Creek between the 2010 and 2016 survey years. Greens Creek was also surveyed in 2005, but the surveying protocol has changed significantly since that time so data from 2005 cannot be compared to data from 2010 and 2016. In order to accurately represent current and historical information, the site data was only compared for those locations which were surveyed in both reporting periods. In some instances, this resulted in changes to our overall summary information. This information is therefore only a comparative evaluation and does not represent the entirety of our assessment.

Water Chemistry

Water chemistry parameters are tracked throughout the entire surveyed stream and reflect the general conditions, stability and quality of the environment. Shifts in these conditions can be indicative of general ecological changes within the environment, but also enable us to better understand the natural level of variability within the system (Table 3).

Between 2010-2016, pH levels on Greens Creek were found to have decreased by an average of 0.12 units (+/- 0.03) overall. This represents an average increase in stream acidity of 132%. Stream conductivity was found to have increased by an average of 230 us/cm over the same study period. Furthermore, dissolved oxygen conditions were found to be in decline, with an average decrease in concentration of 2.23 mg/L overall. These parameters all indicate a potential shift towards reduced ecological function, however given the limited scale of the data set (2 sampling years), it is difficult to determine if this trend falls within a natural level of variability or is a result of impairment.

Table 3 Water chemistry comparison (2010 / 2016)

Water Chemistry (2010—2016)				
YEAR	PARAMETER	UNIT	AVERAGE	STND ERROR
2010	pH	-	8.05	+/- 0.03
2016	pH	-	7.93	+/- 0.03
2010	Sp. Conductivity	us/cm	1416	+/- 56
2016	Sp. Conductivity	us/cm	1646	+/- 36
2010	Dissolved Oxygen	mg/L	10.59	+/- 0.21
2016	Dissolved Oxygen	mg/L	8.36	+/- 0.21
2010	Water Temperature	ºC	21.71	+/- 0.25
2016	Water Temperature	ºC	21.84	+/- 0.27
2010	Standardized Stream Temperature[1]	ºC Water / 1ºC Air	0.89	+/- 0.08
2016	Standardized Stream Temperature[1]	ºC Water / 1ºC Air	0.89	+/- 0.05

[1] ***Standardized Stream Temperature:*** Temperature data is collected via logger and standardized based on the following conditions:

- Daily maximum air temperatures must exceed 24.5 ºC
- No precipitation for 3 days preceding measurement
- Measurements to be taken between 4:00PM—6:00PM
- All temperatures points to be collected in July/August
- Logger must be deployed in flowing waters

Stream temperatures were monitored via stationary temperature logger (*see thermal classification—Page 13)* and concurrently during stream sampling. General temperature observations identified little variation between study years, with average water temperatures remaining stable between 21.7 –21.8 ºC.
In order to account for differences in climate factors such as daily air temperature and precipitation, a standardized stream temperature assessment[1] was also utilized. Between 2010-2016, the stream temperature factor was found to be nearly equal, with the water maintaining an average temperature of 0.89ºC for every 1ºC of air temperature.

Invasive Species

Invasive species presence was compared between 2010-2016 to determine if the overall distribution of these species had changed (Table 4). In general, invasive species presence was observed to have increased dramatically within Greens Creek. Species such as *common buckthorn, curly-leafed pondweed, flowering rush, Himalayan balsam, honey suckle* and *yellow iris* were identified in more than double the amount of sites observed in the previous study year (2010). Conversely, *purple loosestrife* was found to be in decline and may be associated with on-going management efforts.

Table 4 Invasive species presence (2010 / 2016)

Invasive Species	2010 (%)	2016 (%)	+/-
Total	98%	97%	-
Common buckthorn	25%	55%	▲
Curly-leafed pondweed	10%	36%	▲
Dog-strangling vine	8%	11%	▲
European frogbit	3%	4%	-
Flowering rush	33%	63%	▲
Garlic mustard	10%	13%	▲
Himalayan balsam	6%	26%	▲
Honey suckle	1%	5%	▲
Manitoba maple	44%	51%	▲
Purple loosestrife	76%	41%	▼
Yellow Iris	4%	16%	▲

Pollution

Garbage accumulation on Greens Creek was found to be in decline from 2010 –2016 (Table 5). In 2010, garbage was identified in 89% of all surveyed sections. By comparison, only 54% of sites in 2016 were found to have some form of garbage/pollution. Extensive efforts were also undertaken in 2016 to further reduce potential waste within Greens Creek. Clean up efforts accounted for 43% of the identified waste areas, further reducing the overall levels observed.

Table 5 Pollution levels (2010 / 2016)

Pollution/Garbage	2010 (%)	2016 (%)	+/-
Total	89%	54%	↓
Floating garbage	39%	25%	↓
Garbage on stream bottom	60%	38%	↓
Oil or gas trails	1%	-	-
Discoloration of channel bed	1%	1%	-

Instream Aquatic Vegetation

Aquatic vegetation presence was compared between 2010-2016 to determine if the overall distribution of these plant communities had changed (Table 6). The presence of all emergent plant communities was found to have increased in 2016 and may be associated with favourable habitat due to low water. Furthermore, submerged plant presence was observed to have increased and is likely associated with the spread of invasive *curly-leafed pondweed.* Floating plants were found to be far less distributed across the system, as suitable depth zones were likely compromised by the low water conditions.

Table 6 Instream aquatic vegetation (2010 / 2016)

Instream Vegetation	2010 (%)	2016 (%)	+/-
Narrow-leaved emergents	36%	59%	↑
Broad-leaved emergents	31%	41%	↑
Robust emergents	25%	51%	↑
Free-floating plants	4%	4%	-
Floating plants	45%	19%	↓
Submerged plants	43%	68%	↑

Fish Community

Fish sampling was conducted on Greens Creek by the City Stream Watch program in 2005, 2010 and 2016 (Table 7). In total, 41 species of fish have been captured through City Stream Watch fish sampling efforts. In 2005, 11 species were captured at 2 sites with most species recaptured in the following sample sessions. In 2010, 31 fish species were identified across 6 sites, as sampling efforts were increased significantly. 2016 sampling resulted in the capture of 6 additional species, with a total of 28 species identified. Species of note or special consideration include: *river redhorse* (SAR), *goldfish* (invasive) and *common carp* (invasive).

Table 7 Fish species comparison from 2005 / 2010 / 2016

Species	Code	2005	2010	2016
Banded killifish	BaKil		X	X
Black crappie	BlCra		X	
Blacknose dace	BnDac	X	X	X
Blacknose shiner	BnShi			X
Bluegill	Blueg			X
Bluntnose minnow	BnMin		X	X
Brassy minnow	BrMin		X	
Brook stickleback	BrSti		X	X
Brown bullhead	BrBul		X	X
Burbot	Burbo		X	
Cyprinid spp	CA_MI	X	X	X
Central mudminnow	CeMud		X	X
Channel catfish	ChCat		X	X
Common carp	CoCar			X
Common shiner	CoShi	X	X	X
Creek chub	CrChu	X	X	X
Emerald shiner	EmShi	X		X
Etheostoma sp.	EthSp	X	X	X
Fathead minnow	FhMin		X	X
Freshwater drum	FwDru		X	
Golden shiner	GoShi		X	X
Goldfish	Goldf		X	X
Hornyhead chub	HhChu			X
Largemouth bass	LmBas		X	
Logperch	Logpe	X		
Longnose dace	LnDac		X	X
Longnose gar	LnGar		X	
Micropterus sp.	MicSp	X		
Northern pike	NoPik	X		X
Northern redbelly dace	NRDac		X	
Pumpkinseed	Pumpk		X	
Quillback	Quill		X	X
Rhinichthys sp.	RhiSp			X
River redhorse	RiRed			X
Rock bass	RoBas		X	
Shorthead redhorse	ShRed		X	
Silver redhorse	SiRed		X	X
Smallmouth bass	SmBas		X	
Spotfin shiner	SpShi	X		
Trout-perch	TrPer		X	X
Walleye	Walle		X	
White sucker	WhSuc	X	X	X
Yellow bullhead	YeBul		X	
Yellow perch	YePer			X

Monitoring and Restoration

Monitoring and Restoration Projects on Greens Creek

Table 8 highlights recent monitoring and restoration work that has been done on Greens Creek by the Rideau Valley Conservation Authority. Potential restoration opportunities are listed on the following page.

Table 8 Monitoring and restoration activities on Greens Creek

Accomplishment	Year	Description
City Stream Watch Stream Monitoring	2005	124 stream surveys completed on Greens Creek
	2010	135 stream surveys completed on Greens Creek
	2016	134 stream surveys completed on Greens Creek
City Stream Watch Fish Sampling	2005	2 fish community sites were sampled in Greens Creek
	2006	3 fish community sites were sampled in Greens Creek
	2010	6 fish community sites were sampled in Greens Creek
	2016	10 fish community sites were sampled in Greens Creek
City Stream Watch Thermal Classification	2005	2 temperature probes were deployed in Greens Creek
	2010	4 temperature probes were deployed in Greens Creek
	2016	5 temperature probes were deployed in Greens Creek
City Stream Watch Headwater Drainage Feature Assessment	2016	12 headwater drainage feature sites were sampled in the Greens Creek catchment
City Stream Watch Stream Cleanups	2016	City stream watch volunteers assisted in cleaning over 5.8km of shoreline over 7 cleanup sessions
City Stream Watch Invasive Species Removal	2010	City stream watch volunteers assisted in the removal of dog-strangling vine and yellow iris over 2 removal sessions
City Stream Watch Riparian Planting	2010	Two riparian planting projects were carried out along Greens Creek

Migratory Obstruction Removal—Greens Creek 2016

Significant debris accumulation was noted along St. Joseph Blvd and HWY 174 in the spring of 2016. Follow up monitoring confirmed that the accumulation was causing considerable backflow, with severely reduced water levels downstream. The City of Ottawa was consulted to assist in the removal of both debris dams. During the fall/winter of 2016, the City of Ottawa successfully removed the obstructions and re-stabilized flow conditions within the reach.

Debris accumulation along St. Joseph Blvd (Spring 2016)

Removal of debris dam along St. Joseph Blvd (Fall/Winter 2016)

Riparian Restoration Opportunities

Riparian restoration opportunities were assessed in field and include potential enhancement through riparian planting, erosion control, invasive species management and/or wildlife habitat creation (Figure 41). A comprehensive restoration plan has also been developed by Groupe Rousseau Lefebvre (2013), and includes enhancement through floodplain management, erosion control and the removal of non-natural materials/ structures from the stream (ie. grade barriers, etc).

Erosion Control
Erosion issues are common throughout the catchment, with key areas identified for potential enhancement. These regions included instances of outflow/deposition from adjacent land use, and destabilization in proximity to infrastructure.

Riparian Planting
Riparian planting locations were identified in regions of low relative diversity. Shoreline zones in proximity to Cyrville Rd and St. Joseph blvd could benefit from enhanced riparian cover.

Invasive Species Control
Invasive species were common throughout the entire catchment, with several smaller isolated communities identified. *Yellow iris* was identified upstream of the Sir George-Etienne Cartier Parkway, with all observed records isolated within this region. Several communities of *Himalayan balsam* were also identified, and may be effectively removed due to their isolated state.

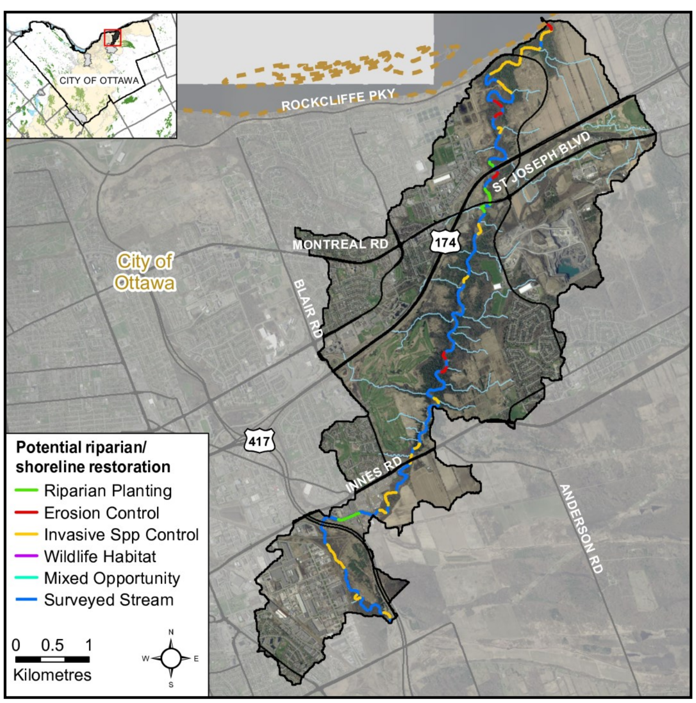


Figure 41 Potential riparian/shoreline restoration opportunities in Greens Creek

Instream Restoration Opportunities

Instream restoration opportunities were assessed in field and include potential enhancement through channel modification, stream cleanups, and fish habitat creation (Figure 42).

Fish Habitat
Fish habitat restoration was assessed based on low habitat cover within the stream, with a single site identified for habitat enhancement (ie. rock and wood cover installation).

Stream Cleanup
Efforts were employed to remove a considerable amount of garbage in 2016, however several locations still exist which could benefit from a cleanup. Garbage accumulation was identified in proximity to Cyrville Rd and HWY 417.

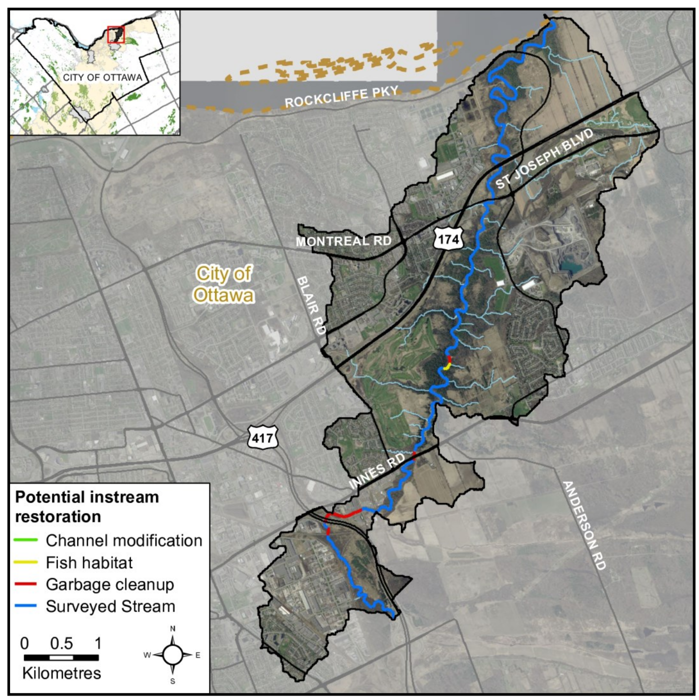


Figure 42 Potential instream restoration opportunities in Greens Creek

Proposed riparian planting opportunity on Greens Creek at St. Joseph Blvd



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For more information on the overall 2016 City Stream Watch Program and the volunteer activities, please refer to the City Stream Watch 2016 Summary Report.