CONFIDENTIAL

CITY OF GUELPH NATURAL ASSETS

INVENTORY, CONDITION, RISK AND SERVICE ATTRIBUTION

Prepared by Green Analytics and Grounded Solutions

June 29, 2022

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1 Introduction

The concept and practice of asset management is not new – it has been around in some form for several centuries. Municipalities in Ontario and elsewhere in Canada have been using asset management processes to manage their engineered infrastructure and other built assets for decades. However, it has only been over the past five to ten years that the idea of incorporating natural assets (e.g., wetlands, forests, meadows, watercourses) into this framework has started to evolve. This shift has been triggered in part by:

- the growing need to repair aging municipal "grey" or built infrastructure with limited municipal tax dollars, which has pushed governments and others to start to explore alternative and complementary solutions,
- ever-advancing climate change which, among other things, is putting municipal infrastructure at greater risk of failure, and
- a growing recognition of the essential services provided by natural assets to communities in providing exposure and access to natural areas and greenspaces at the local scale.

In Ontario, this shift is also being driven by Ontario Regulation 588/17 (Asset Management Planning for Municipal Infrastructure) under the *Infrastructure for Jobs and Prosperity Act (2015)*, which came into effect January 1, 2018. O. Reg. 588/17 made Ontario the first Province in Canada to regulate asset management planning at the municipal level and to require consideration of both human-made and natural assets as part of this process. Ontario remains the only Province with this type of legislation.
Ont. Reg. 588/17 requires all municipalities in Ontario to:

- have a comprehensive asset management plan in place by July 1, 2025,
- consider options to reduce the life cycle costs of assets, including the potential use of green infrastructure solutions, and
- define and determine feasible desired levels of service in the context of climate change in Ontario.

The convergence of deteriorating grey infrastructure, climate change and new provincial requirements related to asset management has resulted in an unprecedented opportunity to advance the integration of natural assets into traditional municipal asset management systems in this Province, and potentially help guide similar initiatives elsewhere.

To address this new legislative requirement and explore this opportunity in Guelph, the City retained Green Analytics (GA) in association with Grounded Solutions Services Ltd. (Grounded Solutions) and Associated Engineering Limited (AE) to complete a natural asset inventory, condition and risk assessments and service attribution for publicly-owned natural assets in the City of Guelph. The City-wide inventory and assessment of natural assets in Guelph was based on available data and supplemented with limited field review on publicly accessible lands. An overview of the approach, rationale for and results of this work is provided in this report.

A GIS-based dashboard that presents the data and analyses compiled for this project has been provided under separate cover. The dashboard is a user-friendly and intuitive platform that allows the data to be viewed at the City-wide as well as at the individual asset scale. It is intended for the City's use and can be updating in the future as new data becomes available.

This consulting team was also commissioned to prepare Stormwater Management (SWM) hydrologic modeling and analysis of the Hanlon Creek Subwatershed to inform valuation of the water management services provided by the natural areas in the Subwatershed, and to allow for a comparison to the estimated costs of replacing these ecosystem services with engineered stormwater management facilities. This work was led by AE and has been provided under separate cover (AE 2022).

Context and Key Terms for Natural Asset Management

As natural asset management (often referred to as NAM) is a relatively new practice, standard terms and approaches for its integration into municipal asset management frameworks, which were originally designed exclusively for built and engineered assets are still evolving. However, there are some terms established by the Municipal Natural Asset Initiative (MNAI) that have become fairly widely adopted and were used for this project. In all cases, the overall intent was to try to align natural asset planning and management with approaches and practices already in place for built and engineered assets, recognizing that natural assets have some unique attributes and functions as well as very different life cycles that do not always allow them to fit neatly into the same "boxes" as built and engineered assets.

The term "publicly-owned natural assets" refers to the stock of natural resources or ecosystems that are relied upon, managed, or could be managed by a municipality, regional district, or other form of government for the sustainable provision of one or more local government services.

It is understood that the City can only directly maintain and manage natural assets on lands under its ownership, or through a shared management agreement (e.g., with another public agency such as a Conservation Authority). However, it is also understood that natural assets on all lands within the municipality provide services to the broader community (e.g., such as air pollution control, cooling, water quantity and quality management, mental health benefits associated with views of green – even if one does not have access to this greenery, etc.). Furthermore, it is understood that it is not unusual for natural areas in private ownership to be transferred into public ownership as part of the municipal planning process, such as, for example, in Guelph's south end many of the wetlands and forests currently privately held are expected to come into public ownership over the next few decades as this area becomes more intensively developed. Therefore, the inventory and assessment completed for this project has included all mapped natural assets in the City, irrespective of current land ownership.

This natural asset inventory, condition assessment, risk assessment and service attribution exercise for the City of Guelph were undertaken in close consultation with City of Guelph Project Team including staff from various departments representing different disciplines including asset management, environmental planning, forestry and engineering. Staff from other departments and/or disciplines (e.g., parks planning, GIS) were also consulted internally by the City Project Team for data and information as needed. The key objective of this collaboration was to ensure that the NAI and related dashboard developed as part of this project is aligned with the City's existing asset management framework and can also be readily understood and used by staff in different departments.

Report Structure

This report is organized as follows:

- Section 2: Overview of the Natural Assets Inventory (NAI) Structure – describes the key inventory components, how the inventory is organized and what data was used to create it.
- Section 3: Natural Asset Condition Assessment - contains an overview of the rationale and approach for the condition assessment metrics as well as the results of the condition assessment exercise.
- Section 4: Natural Asset Risk Assessment – contains an overview of the approach and findings of the risk assessment.
- Section 5: Natural Asset Service Attribution – presents the approach for attributing ecosystem services to natural assets as well as the results of that exercise.
- Section 6: Concluding Remarks - summarizes the contents of this report.
- Section 7: References - contains a list of the sources cited.

2 Overview of the Natural Assets Inventory (NAI) Structure

The NAI structure for the City of Guelph consists of three separate but linked inventories: (i) street and park tree assets; (ii) watercourse feature assets; and (iii) terrestrial natural features (including wetlands), as shown in Figure 1.

For the purposes of this inventory, and in accordance with the current applicable standards, each of these inventory types has been mapped as follows:

i. street and park trees are individual trees mapped as geo-referenced fixed points
ii. watercourses are dynamic continually moving systems whose boundaries have been based on a center polyline feature, and
iii. terrestrial natural features are fixed polygons delineated using the applicable standard for vegetation community classification - the Ecological Land Classification (ELC) system for southern Ontario (Lee *et al.,* 1998).

Please note the following caveats and limitations related to the inventory structure and mapping:

- OVERLAP BETWEEN CLASSES: While the three asset classes above are largely mutually exclusive, a small number of the individual trees captured in the street and park tree class fall within terrestrial natural features, so there is some overlap in this regard.
- SOIL: While developing the NAI, it was recognized that soil is an asset that relates to almost all the asset classes. For the purposes of this inventory, while soil is not captured as a stand-alone asset, it is acknowledged as relevant to all asset classes and as critical to the provision of services from natural assets.
- GROUNDWATER: It was also recognized that groundwater makes critical contributions to sustaining many of the wetland and watercourse features in the City of Guelph, and that as a community that relies on groundwater for its potable water supply, groundwater is an extremely valuable natural asset. However, there are many challenges to both mapping and quantifying groundwater as a natural asset, in large part due to its fluid nature and the fact that it primarily travels beneath the land surface in complex ways at multiple scales and depths that vary depending on the nature and condition of the local and regional geology and physiography. As a result of this complexity, approaches and tools for mapping and integrating groundwater into municipal natural asset frameworks are generally lacking. This was recognized as a gap to be filled as part of a subsequent project.

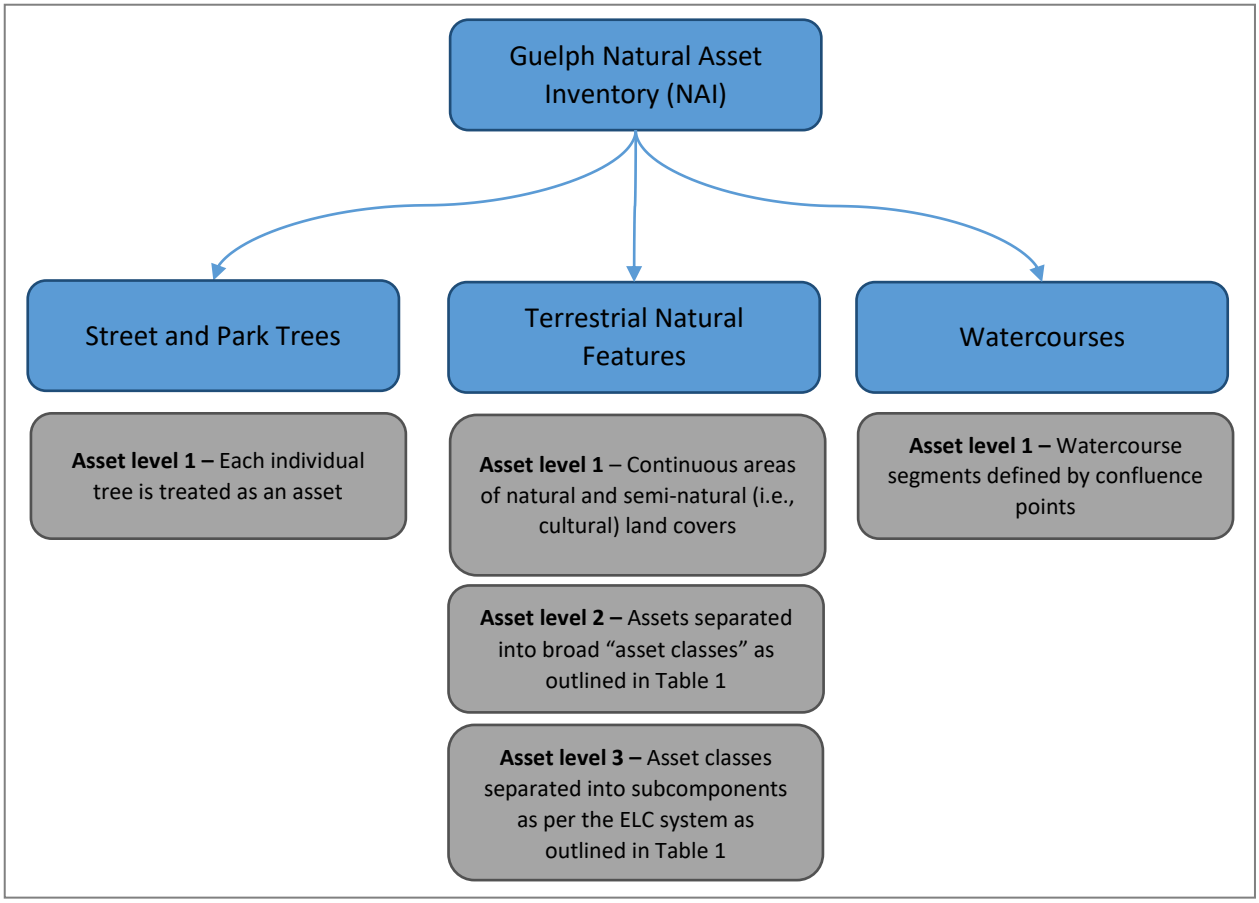

Figure 1. Diagram of Guelph's Natural Asset Inventory (NAI) components

The data sources used for this exercise have all been updated within the last five years. The NAI was built using the recently updated ELC mapping (2020) for the City of Guelph,[1] the street and park tree inventories were derived from the City's urban tree canopy assessment work completed in 2019 (Lallemand Inc./BioForest and KBM Group 2019), and the watercourse layer was based on recently refined mapping (2021) developed as part of the City's Stormwater Master Plan Update project (still in progress at the time of this report completion).

As noted in the Introduction (Section 1), the mapping and condition and risk assessments can and should be updated on a regular basis as new information becomes available to optimize the value of the natural asset inventory and dashboard as planning and management tools.

For the terrestrial natural features asset type, Table 1 summarizes how the available vegetation community mapping was used to establish a nested asset hierarchy aligned with those typically used in asset management. Figure 2 shows conceptually how the hierarchy is represented in the GIS data for a given natural asset.

[1] Updates to the ELC mapping were based on predominantly remote-sensing analysis supplemented with scoped field verification of selected features and areas undertaken in the fall of 2020. This layer should continue to eb updated as more current and/or detailed mapping becomes available.

Table 1. Asset hierarchy for the terrestrial natural features in Guelph's Natural Asset Inventory (NAI)

Asset Level 1	Asset Level 2	Asset Level 3 (ELC Series)	
Continuous area of natural and cultural land cover	Natural Asset Class	ELC Community Class	ELC Community Series
Natural Area	Meadow / Successional	Cultural	Cultural Meadow
Natural Area	Meadow / Successional	Cultural	Cultural Savannah
Natural Area	Meadow / Successional	Cultural	Cultural Thicket
Natural Area	Upland Forest	Cultural	Cultural Woodland
Natural Area	Upland Forest	Cultural	Cultural Plantation
Natural Area	Upland Forest	Forest	Deciduous Forest
Natural Area	Upland Forest	Forest	Coniferous Forest
Natural Area	Upland Forest	Forest	Mixed Forest
Natural Area	Swamp*	Swamp*	Coniferous Swamp*
Natural Area	Swamp*	Swamp*	Deciduous Swamp*
Natural Area	Swamp*	Swamp*	Mixed Swamp*
Natural Area	Swamp*	Swamp*	Thicket Swamp*
Natural Area	Marsh*	Marsh*	Meadow Marsh*
Natural Area	Marsh*	Marsh*	Shallow Marsh*
Natural Area	Open Water*	Open Water*	Open Aquatic*
Natural Area	Shallow Water*	Shallow Water*	Shallow Aquatic*
Natural Area	Shallow Water*	Shallow Water*	Submerged Shallow Aquatic*
Natural Area	Shallow Water*	Shallow Water*	Mixed Shallow Aquatic*
Natural Area	Shallow Water*	Shallow Water*	Floating-leaved Shallow Aquatic*
Natural Area	Hedgerow	Hedgerow	Hedgerow

ELC = Ecological Land Classification system for southern Ontario as per Lee et al., 1998.
* All of the following are different types of wetland communities under the ELC system: Swamp – coniferous and deciduous, marsh – meadow and shallow, open water / aquatic, and shallow water aquatic – floating-leaved, submerged and mixed.

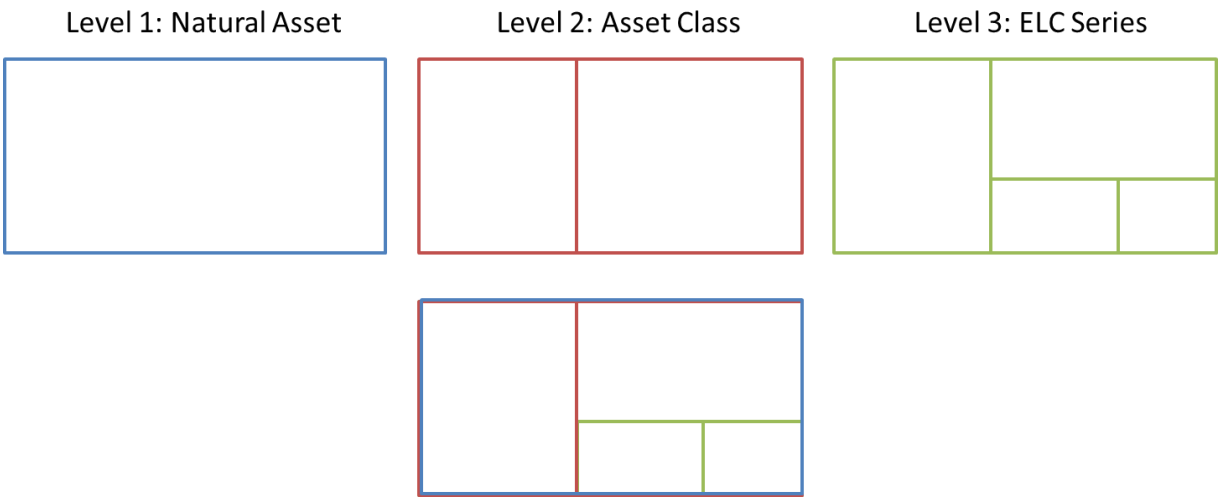

Figure 2. Conceptual diagram how the three natural asset levels are linked, where Level 1 represents the boundaries of a natural asset, Level 2 the asset class, and Level 3 the asset component.

The relative level of coverage of each natural asset type across the City of Guelph was calculated based on the synthesis of the available data. Figure 3 shows the breakdown of terrestrial natural features within Guelph based on the available information, with wetlands split into: swamps, marsh, shallow aquatic and open water types.

The total area of terrestrial natural features is 2,442 hectares. This area is comprised of a combination of asset classes with meadow successional (36%), swamp (22%) and upland forest (33%) being the most prevalent.

Notably, this natural asset mapping should not be confused with the City's Natural Heritage System (NHS) mapping in its Official Plan. While the natural assets mapped for this project have a high degree of overlap with the City's NHS, this asset inventory includes all of the natural assets within the City's designated NHS as well as mapped natural areas not captured within the NHS (e.g., because they do not meet the established criteria, or have not yet been assessed in detail and confirmed as meeting the established criteria).

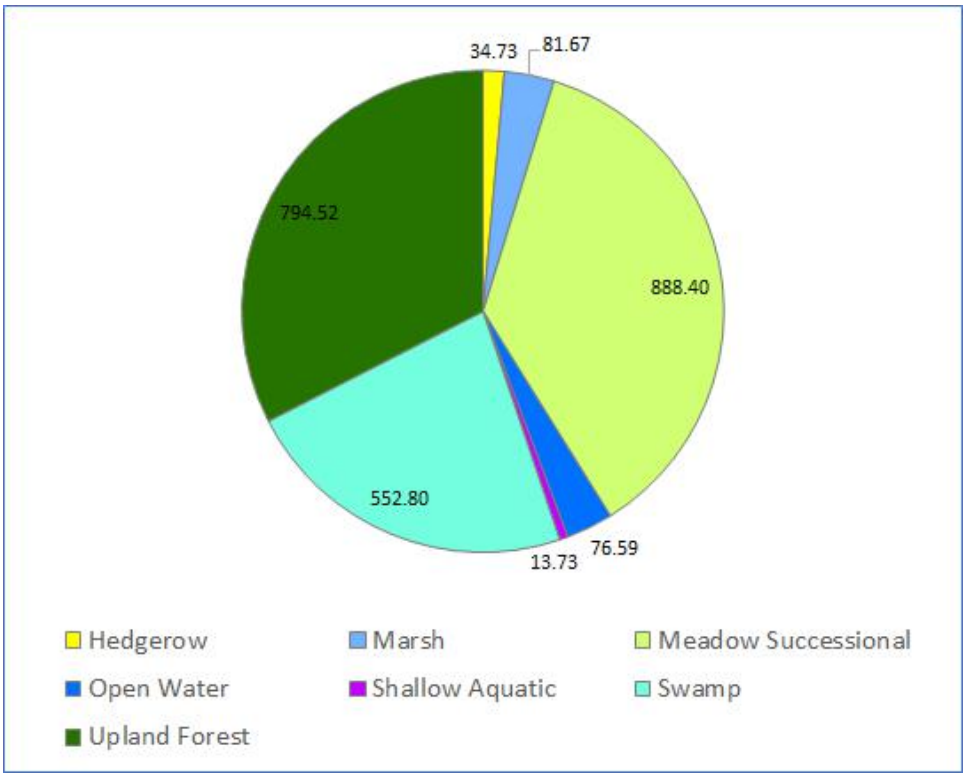

Figure 3. Relative proportions of natural asset classes (hectares) (Level 2) in Guelph.

Figure 4 shows the locations of the Level 1 natural assets across the City. These assets consist of continuous natural asset polygons and unique assets separated by roads and/or built areas. Figure 5 demonstrate the locations of the Level 2 natural assets across the City.

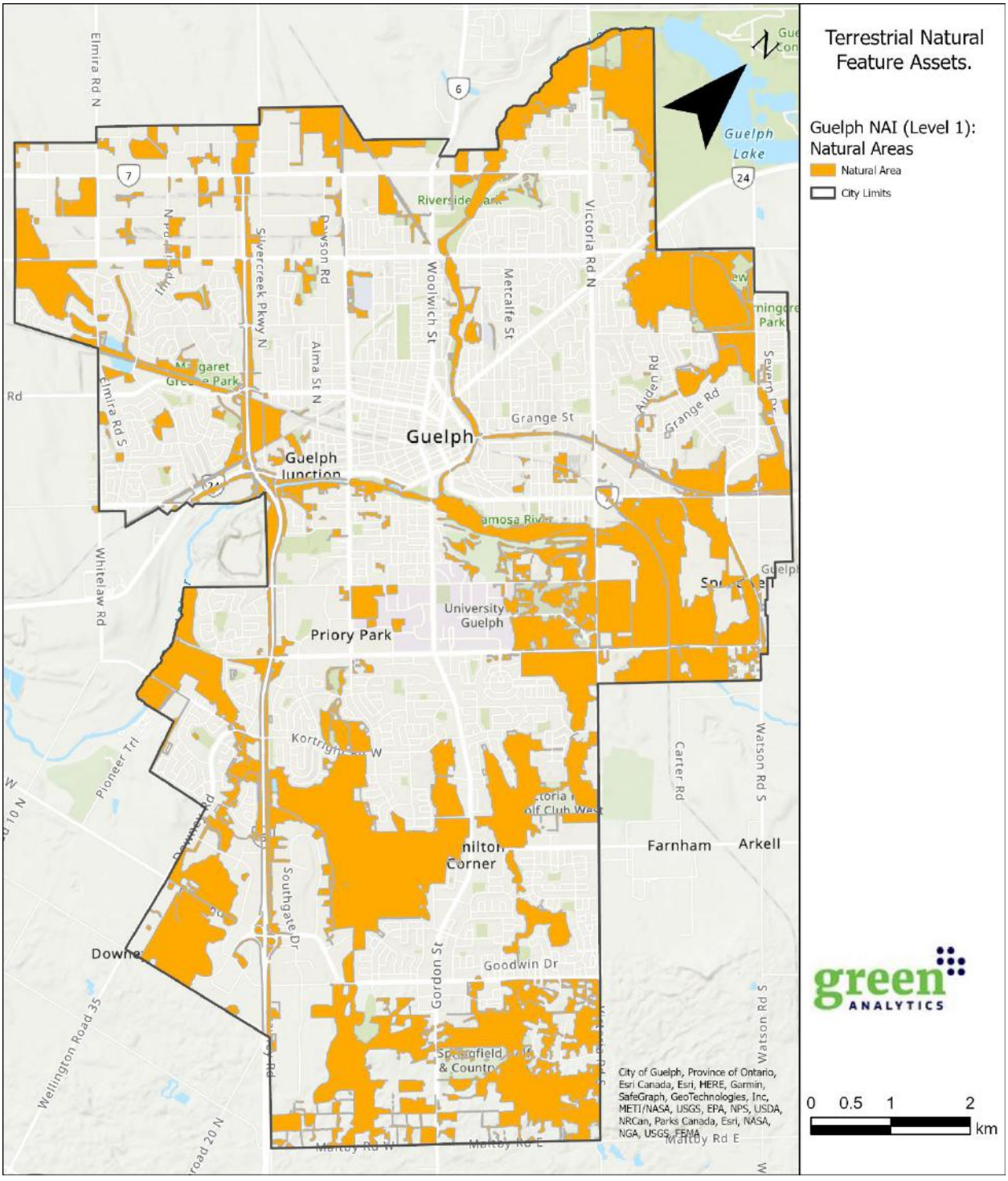

Figure 4. Location, extent and class of terrestrial natural features (Level 1).

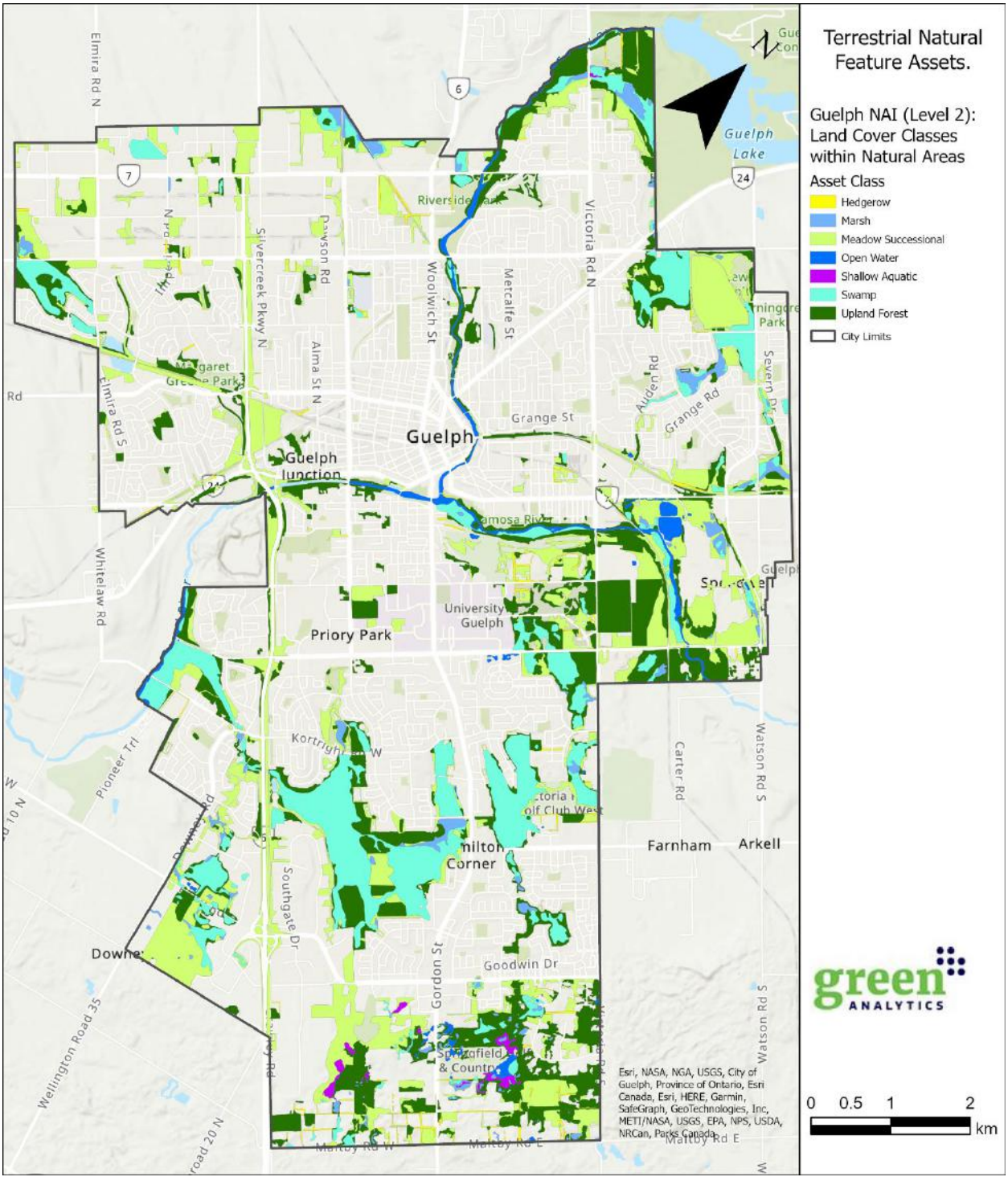

Figure 5. Location, extent and class of terrestrial natural features (Level 2).

3 Natural Asset Condition Assessment

The objective of the condition assessment in the context of NAM is to develop a high-level assessment of each asset class or component's ability to provide ecological services, which are valued by the municipality and / or community (e.g., air pollution filtration, storm water attenuation, urban heat island mitigation, etc.). For natural assets, this is more difficult to assess than for engineered assets because (a) service provision can be more difficult to measure, and (b) levels of service can be challenging to determine. However, the underlying assumption for this part of the assessment is that a natural asset that is assessed as being in a "good" condition from an ecological perspective, is anticipated to be able to provide a "good" level of ecological services.

Ideally, assets (natural or engineered) are assessed for condition based on *in situ* inspection, which in the case of natural assets requires field assessments of ecosystem components and their functions (e.g., vegetation type and cover, wildlife use). For the purpose of this project, it was not feasible to undertake an *in situ* assessment of all natural assets City-wide. Instead, available information from other work / studies was synthesized and screened using a series of desktop condition metrics developed based on current landscape ecology principles and science, as well as a good understanding of the nature of the City's natural assets.[2] The metrics generated provide surrogates for field condition assessments and serve as a starting point for assessing Guelph's natural assets in a manner consistent with the asset management framework.

The following presents and describes seven condition variables developed for Guelph's natural assets based on the available data, consideration of landscape ecology and a knowledge of the nature and scale of the City's natural heritage. These include five variables related to the intrinsic condition of a given asset as well as two variables related to potential impacts to the condition of an asset from extrinsic (i.e., adjacent land use) factors. Variables have also been scaled and selected to reflect the condition of features and / or functions that are distinct from each other so as not to "double-count".

- STREET AND PARK TREE ASSETS
  - Arboricultural tree condition rating (Section 3.1.1)
- WATERCOURSE ASSETS
  - Extent of watercourse that has riparian vegetation (Section 3.2.1)
- NHS ASSETS
  - Presence of Interior Habitat (Section 3.3.1)
  - Habitat Quality (Section 3.3.2)
  - Internal Disturbance Level (Section 3.3.3)
  - Intensity of Impervious Surface in Adjacent Lands (Section 3.3.4)
  - Intensity of Adjacent Land Uses (Section 3.3.5)

All types of assets identified in Guelph (i.e., trees, terrestrial natural features and watercourses) have been assigned an overall condition rating on a scale from 1 to 5 (i.e., 1 = excellent, 2 = good, 3 = fair, 4 = poor and 5 = very poor) based on the established metrics and the approaches described in more detail below. Condition ratings can be assigned at the Level 1, Level 2 or Level 3 of the inventory (see Table 1) and have been applied at the level deemed most appropriate for each asset type. Notably, condition ratings are only as accurate as the data being used to generate the rating.

[2] City of Guelph Natural Heritage Strategy 2009; City of Guelph Ecological Land Classification updates November 2020; Clair-Maltby Comprehensive Environmental Impact Study Phase 3 (Wood *et al.,* 2021)

The metrics identified above and the results of the condition assessment are described in the sub-sections below.

3.1 Street and Park Trees

For street and park trees a single measure was used to assess tree condition. The metric is based on the City's established protocols for determining tree condition.

3.1.1 Arboricultural Tree Condition Rating

The City of Guelph, like many municipalities, has an established condition rating system for the street and park trees under its jurisdiction (Table 2). The rating system is already aligned with the five-scale asset management condition rating system. This system, as described below, was simply carried into the NAI as part of this project.

Table 2. Summary of tree condition ratings.

Ranking	Trunk	Crown / structure	Roots
Excellent (1)	Sound and solid	Full, balanced and structurally sound	Roots able to grow within the dripline plus a setback with no constraints
Good (2)	Generally sound, small areas of decay and/or missing bark	Full but unbalanced	Roots able to grow within the dripline with no constraints
Fair (3)	Sections of bark missing, some decay	One major or several minor limbs dead, broken or missing	Roots able to grow within the dripline with less than 25% of area constrained
Poor (4)	Large sections of bark missing, some decay	Unbalanced and lacking a full crown	Roots able to grow within the dripline with about 26% to 50% of area constrained
Very Poor (5)	Extensive decay, hollow and most bark missing	Most limbs dead, broken or missing	Roots able to grow within the dripline with more than 50% of area constrained

3.2 Watercourses

For watercourses, as with individual trees, a single measure was used to generate condition ratings.

3.2.1 Watercourse Condition

METRIC: Extent of watercourse that has naturalized riparian vegetation (i.e., naturalized areas; manicured areas and lands with impervious cover such as sidewalks and roads are excluded).

RATIONALE: According to Environment Canada's (2013)[3] guidance for southern Ontario, at least 75% of watercourses should have at least 30 m wide naturally vegetated riparian strips or buffers on each side to provide and protect aquatic habitat at a local scale.

[3] How Much Habitat Is Enough - 3rd Edition (Environment Canada 2013)

APPROACH: Using this guidance, the proportion of a given segment of watercourse with at least 30 m of riparian vegetation on either side has been used as a general proxy for watercourse condition in Guelph. To apply this measure, Guelph's watercourses were segmented at the main points of confluence. Each segment was assessed for percent of the overall reach with at least 30 m of riparian vegetation on either side and scored as follows:

- 90% to 100% = Excellent
- 75% to 89% = Good
- 50% to 74% = Fair
- 25% to 49% = Poor
- 0% to 25% = Very Poor

Notably, 75% was set as the threshold for "good" to align with the Environment Canada (2013) guidance.

RESULTS: Figure 6 demonstrates the watercourse condition assessment results. As noted by City staff, this mapping may also be useful for applications beyond natural asset management.

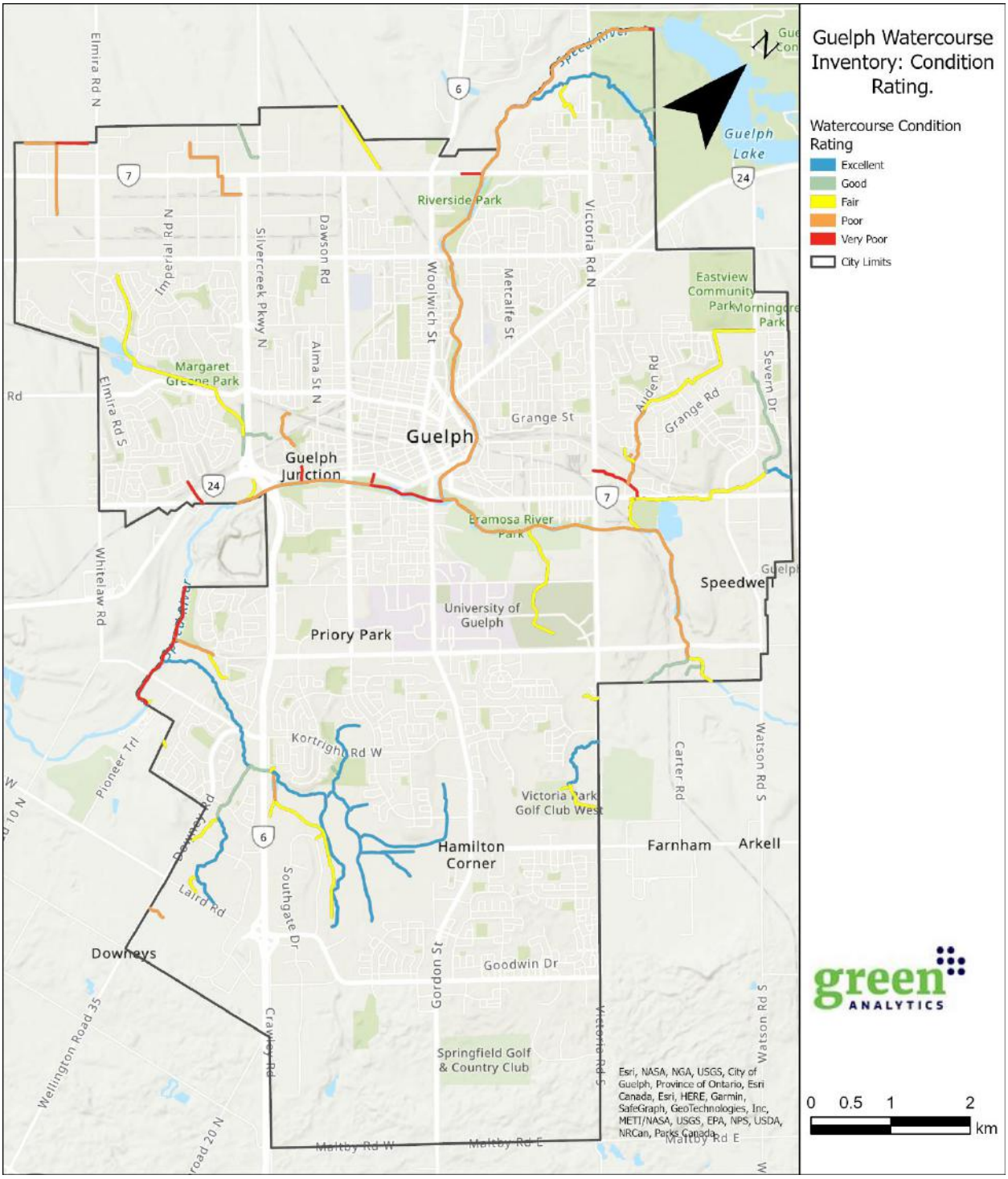

Figure 6. Map of the City's watercourse assets with current condition ratings.

3.3 Terrestrial Natural Features (including Wetlands)

As noted above, a total of five measures were used to generate a cumulative condition assessment for the various natural and semi-natural (a.k.a., cultural) terrestrial natural features in the City (including wetlands), as shown in Figure 3 and Figure 5. Each of these measures has been equally weighted and

were considered cumulatively to generate an overall condition score for the terrestrial natural feature assets.

3.3.1 Presence of Interior Habitat

METRIC: Amount of interior natural area estimated at the Level 1 inventory (see Table 1 and Figure 1).

RATIONALE: The objective of this indicator is to create a proxy for condition based on the terrestrial natural features relative size and shape. In general, larger blocks of habitat (whether they be meadow, forest, or wetland) tend to support a greater diversity of plants and wildlife, including what are referred to as "interior" habitat specialists that require or benefit from conditions only found away from the edges of a feature. "Interior" habitat is typically measured from 100 m of the habitat patch edge (e.g., Environment Canada 2013) and is also typically measured separately for forests, wetlands and/or meadow / grassland habitats. One of the reasons for this is that there are some species, such as certain birds, that only tend to occur when there is a "block" of continuous habitat of a particular type. These are sometimes referred to as "forest specialists" or "grassland specialists" as opposed to habitat "generalists".

In urban settings there are generally very few large blocks of any one type of habitat that provide genuine interior conditions, and this is the case in Guelph where the largest contiguous blocks of habitat tend to be mixtures of wetlands (e.g., swamp and marsh) and upland habitats (e.g., cultural meadows, woodlands and forests). Given this context and recognizing the landscape ecology principle of large "blocks" of habitat generally provide a greater range of habitats of better quality, the rating system was tailored for application to Guelph. Assets with "interior" measured at 100 m from the overall consolidated features edge were deemed to have the highest quality and quality was incrementally reduced for each 25 m less of interior. Contiguous blocks of any habitat type were assumed to have a higher level of ecological function due to being larger in size, having less edge and having more "interior" habitat.

APPROACH: This condition variable was applied at Level 1 (see Table 1 and Figure 3) of the inventory so that each "block" or continuous natural area not intersected by one or more roads or otherwise developed area was assessed. The extent of interior area of natural area patches was assessed for these natural area "blocks" on a sliding scale based on the amount of distance in from the edge of the overall area, and then transferred to each individual asset class (at Level 2 of the inventory) within each natural area "block". Specifically, the scores were allocated as follows:

- Any asset with an interior area measured 100 m from the feature edge was considered to be in "excellent" condition.
- Any asset with an interior area measured 75 m from the feature edge and not already captured as "excellent" was considered in "good" condition.
- Any asset with an interior area measured 50 m from the feature edge and not already captured as "excellent" or "good" was considered in "fair" condition.
- Any asset with an interior area measured 25 m from the feature edge and not already captured as "excellent", "good", or "fair" was considered in "poor" condition.
- Any asset with no interior area measured at 25 m from the feature edge was considered in "very poor" condition.

RESULTS: The results of this condition assessment are shown in Figure 7.

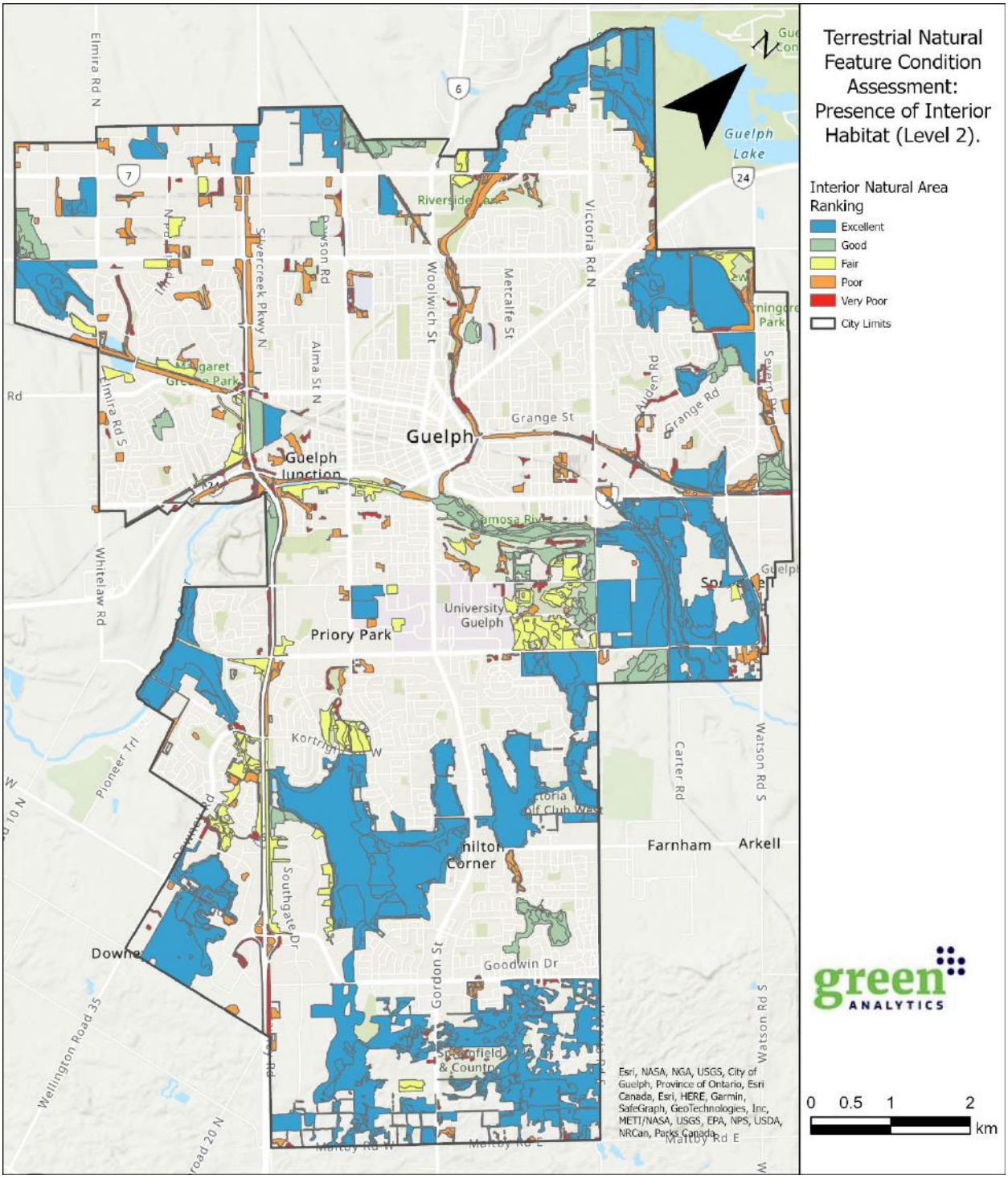

Figure 7. Map of terrestrial natural features with interior habitat condition rating (assessed at Level 2, by asset class).

3.3.2 Habitat Quality

METRIC: Relative portion of natural versus cultural area in a given terrestrial natural feature asset class.

RATIONALE: This metric was used as a proxy for habitat quality. Although virtually all vegetation communities across southern Ontario have experienced some type of anthropogenic disturbances over the past few hundred years as a result of logging and/or farming practices, often compounded by more recent urbanization, the ELC system generally distinguishes between communities that are considered "natural" as compared to those considered "cultural." A cultural community is defined in the ELC as: "*a vegetation community originating from, or maintained by, anthropogenic influences and culturally based disturbances, often containing a large proportion of non-native species*" (Lee *et al.,* 1998). From an ecological perspective, features that are cultural tend to be of lower vegetative quality and, thus, lower habitat value, than features considered "natural". The objective of this indicator is to provide a proxy for an asset's relative quality as a measure of its condition, and therefore the level of ecological services it can provide.

APPROACH: Due to both the nature of the ELC system and the nature of the ELC communities in Guelph, a slightly different approach needed to be taken when applying this metric to a) meadow / successional communities, b) hedgerows, c) wetlands, and d) forests. The various approaches are described below:

- MEADOW/SUCCESSIONAL AND HEDGEROWS: The ELC system recognizes some grasslands / meadows in Ontario as "natural" communities (i.e., Tallgrass Prairies) and most others as "cultural". In Guelph, however, there are no known natural grassland communities (note they are rare in Ontario). Furthermore, there was insufficient data to assess the relative quality of the identified cultural / successional communities in the City. Therefore, all "cultural" meadow / successional communities (i.e., meadows, thickets, and savannahs) were given a "poor" ranking assuming that they are likely recently disturbed habitats dominated by invasive and non-native species. This assessment could be refined if and when additional City-wide data on these communities becomes available. The vegetative quality and condition of the remaining hedgerows in the City is variable. These may be remnants of pre-existing woodlands but are more typically rows of trees originally planted with the specific intent of providing wind breaks (e.g., for agricultural crops, homesteads, farm lanes etc.). Although these features may contain trees that are in good condition, from ecological perspective hedgerows tend to have limited habitat value but may provide secondary foraging habitat or support movement for some species. Therefore, for the purposes of this assessment, they were assigned a "poor" condition rating.

- WETLANDS (Swamps, Marsh, Shallow Aquatic Asset Classes): Under the ELC system there is no classification for "cultural" wetlands (e.g., sewage lagoons, naturalized but maintained stormwater management ponds) although wetlands can vary substantially in their quality as measured both by their water quality and their relative proportion of native biodiversity. Based on what is known about wetlands in the City of Guelph, the swamp wetlands and many of the open and shallow aquatic communities are among some of the best quality habitats in the City, while the marsh habitats are more mixed and tend to include communities with greater proportions of invasive and non-native species. Therefore, swamps and aquatic assets were placed in the "excellent" category, while marshes were placed in the "good" category. Although

there is more refined wetland classification available in parts of the City, this information is not available City-wide. This assessment could be refined when additional data on these communities becomes available.

- FOREST: The ELC system has several clear definitions and classification schemes for distinguishing forest communities considered "cultural" versus those considered more "natural". The approach used for this project built on the ELC framework and considered "cultural communities" as those including Cultural Woodland and Cultural Plantation, whereas "natural" communities included Deciduous Forest, Coniferous Forest and Mixed Forest. Scoring was then assigned based on the relative proportion of "cultural" versus "natural" forest communities in each asset, as per Table 3. This assessment could be refined when additional City-wide data on these wooded areas becomes available.

Table 3. Habitat quality condition rating assumptions applied to each terrestrial natural feature asset class.*

Ranking	Meadow / Successional[1] and Hedgerows	Wetland[2]	Forest[3]
Excellent (1)		Swamp Shallow Aquatic (Open, Submerged, Mixed, Floating-leaved)	81 - 100% natural (0 – 19% cultural)
Good (2)		Marsh (Shallow, Meadow)	61 – 80% natural (20 – 39% cultural)
Fair (3)			41 – 60% natural (40 – 59% cultural)
Poor (4)	Cultural Meadow Cultural Savannah Cultural Thicket Hedgerows		21 – 40% natural (60 – 79% cultural)
Very Poor (5)			0 – 20% natural (80 – 100% cultural)

* This corresponds to Level 2 of the NAI as per Table 1.

[1] There was insufficient data to assess the relative quality of cultural / successional communities (including Hedgerows) in the City and so they were all given a "poor" ranking assuming that they are likely recently disturbed habitats dominated by invasive and non-native species. If this data gap is addressed the categorization of these asset types should be revisited.

[2] Under the ELC system there is no classification for "cultural" wetlands although wetlands can vary substantially in their proportion of native biodiversity. Based on what is known about wetlands in the City, the swamp wetlands and many of the open and shallow aquatic communities are among some of the best quality habitats in the City while the marsh habitats are more mixed and tend to include communities with greater proportions on invasive and non-native species. Therefore, Swamps and Aquatic assets were placed in the "excellent" category while Marshes were placed in the "good" category.

[3] For the forest category "cultural communities" included Cultural Woodland and Cultural Plantation; "natural" communities included Deciduous Forest, Coniferous Forest and Mixed Forest.

RESULTS: Figure 8 demonstrate the results of the condition assessment for the habitat quality metric.

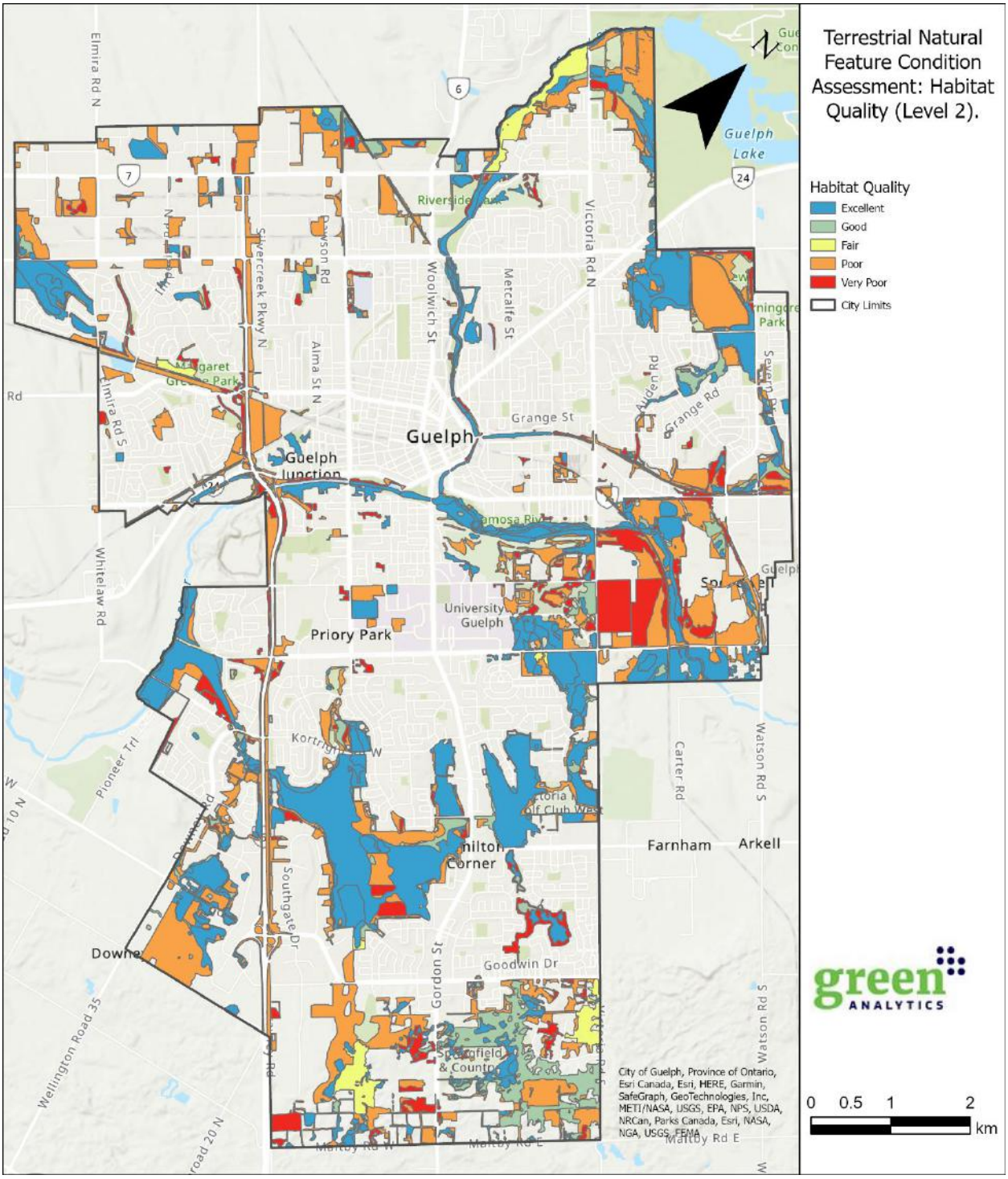

Figure 8. Map of terrestrial natural features with habitat quality condition rating (assessed at Level 2, by asset class).

3.3.3 Internal Disturbance Level

METRIC: Ratio of informal trails to formal trails in terrestrial natural features, assessed at the ELC Community Series scale (i.e., Level 3 of the NAI inventory, as per Table 1).

RATIONALE: The objective of this indicator is to provide an indication of the extent to which an asset is being accessed beyond its' carrying capacity. As described in Wikipedia, "*the carrying capacity of an environment is the maximum population size of a biological species that can be sustained by that specific environment, given the food, habitat, water, and other resources available*". Google's English Dictionary provided by Oxford Languages defines ecological carrying capacity as "the number of people, other living organisms, or crops that a region can support without environmental degradation" (https://languages.oup.com/google-dictionary-en/). Biological or environmental carrying capacity is quite complex and a definitive threshold is difficult to define, in part because of the number of both intrinsic biological variables involved in any given habitat or ecosystem as well as the number of extrinsic anthropogenic factors having impacts on a given ecosystem.

More recently, the term managerial carrying capacity has been used to try and frame and establish limits on sustainable levels of use of natural areas by people (e.g., Park 2020). Research on this topic gathered by Park (2020) characterized managerial carrying capacity as "*the amount of physical space, staffing and financial resources available to achieve a park's vision and goals*" as compared to ecological or environmental carrying capacity defined as "*how resilient the ecosystem is to the demands placed on it. Associated attributes may include: vegetation, soil, wildlife behaviour, biodiversity, hydrology, air and water quality, climatic conditions, presence of snow or mud, naturalness, scenic integrity and/or tranquility*".

A fulsome review and discussion of both ecological and managerial carrying capacity is outside the scope of this project, but the concepts can be useful to municipalities (and other natural areas managers) in trying to understand and communicate the complex relationship between levels of use, levels of ecological function, and the role good planning and targeted management can play in mitigating at least some of the negative impacts associated with human use of natural areas.

It is recognized that in the City of Guelph, as in most urbanizing jurisdictions, there is a need to both accommodate certain levels of human access to public natural and open spaces, and to protect and sustain the ecological features in these areas and the functions they provide. Therefore, this measure considers the presence of formal trails within municipal natural areas as an indication that efforts are being made to achieve this balance, and the presence of informal trails as an indication of inadequate management and / or overuse beyond at least the managerial carrying capacity of that feature.

While it is recognized that from a strictly ecological perspective, all trails introduce impacts and facilitate human access, it is also understood that it is part of the City's mandate to support at least limited access to public natural areas and open spaces, and that well designed and managed trails are a key component to providing an appropriate balance between human use and protection. Well designed and sited trails can also be considered impact mitigation in cases where access would occur regardless of the presence or absence of formal trails. It is also recognized that features with greater densities of informal trails are subject to greater human disturbances, which tend to negatively impact their condition. Therefore, a terrestrial natural feature (at the ELC Community Series scale, Level 3 – see Table 1) with a lower ratio of formal to informal trails is assumed to be subject to a lower degree of human disturbance, and therefore more likely to be in better condition, and vice-versa.

Although the mapping of formal trails in the City provided for this project is quite current and reasonably comprehensive, it is understood that the presence of both formal and informal trails will evolve over time and that the mapping of informal trails may have some gaps. Therefore, the base data should be updated as more current / comprehensive data is collected, and as new formal trails are approved and installed.

APPROACH: The City of Guelph recently completed City-wide mapping of both formal and informal trails in its' natural areas. This mapping was used to determine the length of formal trails and informal trails within each terrestrial natural feature asset at the ELC Community Series scale (i.e., at Level 3 as per Table 1).

The condition rating system is based on the ratio of formal to informal trails in each terrestrial natural feature assets at the ELC Community Series scale (i.e., Level 3 as per Table 1) as per the following:

- Excellent = no informal trails in the terrestrial natural feature asset
- Good = ratio of 3:1 or more formal to informal trails by length per terrestrial natural feature asset
- Fair = about 1:1 formal to informal trails by length per terrestrial natural feature asset
- Poor = ratio of 1:3 or less formal to informal trails by length per terrestrial natural feature asset
- Very Poor = only informal trails in the terrestrial natural feature asset

RESULTS: Figure 9 presents the results of the internal disturbance rating assessment.

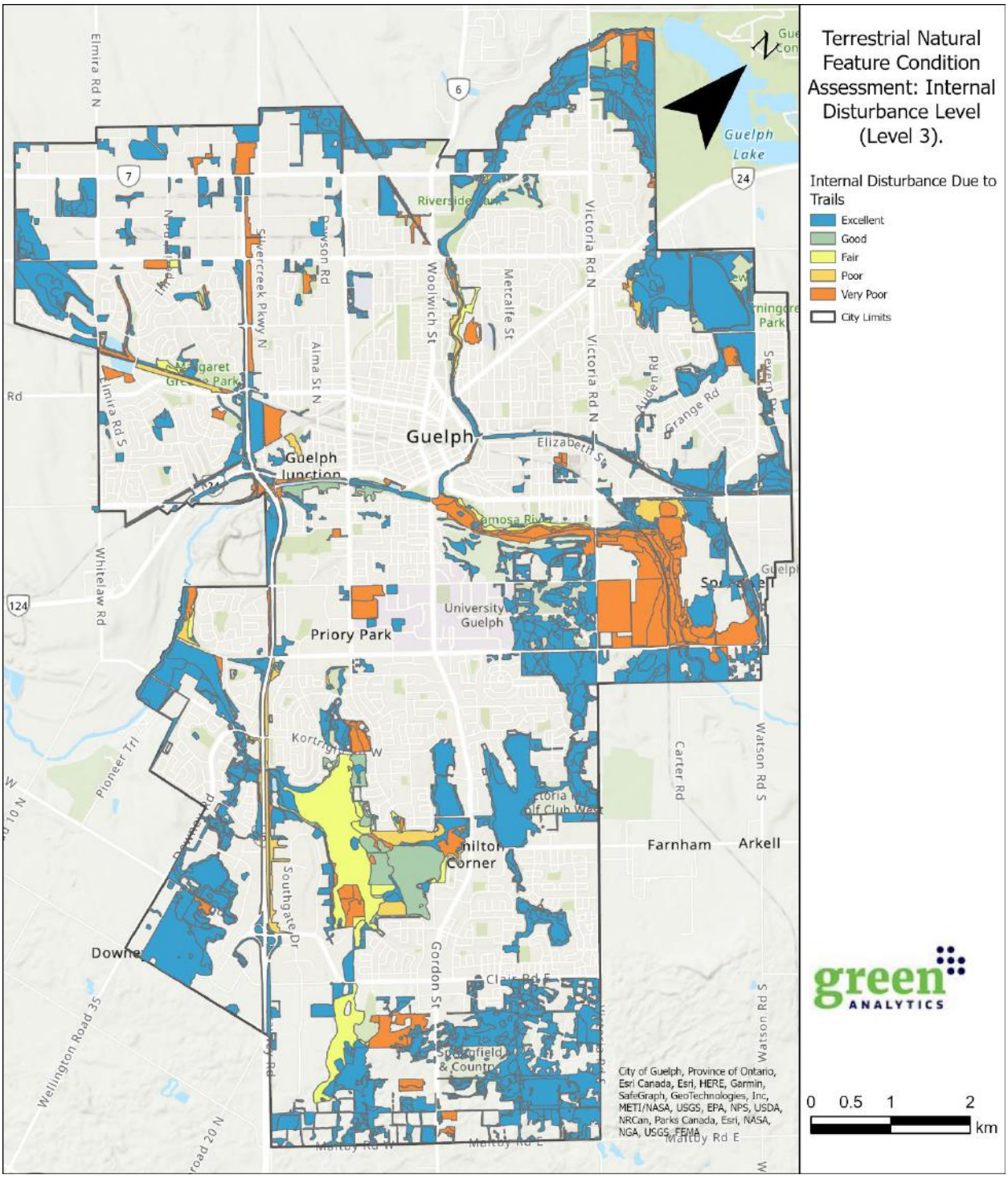

Figure 9. Map of terrestrial natural features with internal disturbance condition ratings (assessed at Level 3, by ELC Community Series).

3.3.4 Intensity of Impervious Surface in Adjacent Lands

METRIC: Proportion of impervious cover in adjacent lands to terrestrial natural features.

RATIONALE: How and the extent to which a given natural area is influenced by the drainage in the adjacent landscape varies depending on factors such as the local topography and soils, where the feature "sits" in the landscape (e.g., upland versus lowland, position in the watershed) and the size and nature of the feature itself. However, it is well-established that the condition of a terrestrial natural feature (including wetlands) in an urban context tends to be negatively impacted when more of the surrounding land uses are impervious (i.e., paved, concrete or buildings) as this tends to alter pre-existing drainage and infiltration pathways, which can cause a natural area to receive much more or much less drainage than prior to being in an urban context. Urban runoff also typically carries a host of sediments and contaminants, and when such runoff is directed to natural areas and not properly treated, it can also negatively impact the feature and its functions for plants and wildlife.

One of the challenges with natural asset condition assessments is the measures must be associated with physical geographic units on a jurisdiction-wide scale. Initially, the use of watershed / sub-watershed boundaries was considered as a logical unit for assessing the relative extent of impervious surfaces. However, the City of Guelph includes several watershed / sub-watershed areas that are only partially in the City and partially in the adjacent County of Wellington, making this analysis difficult to apply to the City alone. The use of catchment areas was also explored as a logical unit for assessing the relative extent of impervious surfaces. However, upon review of the updated catchment mapping being developed for the City as part of a City-wide Stormwater Master Plan Update, there were several challenges identified with the use of this approach including: the lack of stormwater catchment areas in the older parts of the City (i.e., much of the central and northern portions of the City), and the very fine scale of the catchments that were identified in the southern portion of the City between Stone Road and Clair Road in comparison to much broader catchments identified in the central and northern portions, which would be likely to skew results and not provide a useful or representative outcome.

Ultimately it was decided that in the context of the City of Guelph it would be appropriate to use a 120 m "buffer" around terrestrial natural features (including wetlands) (at the Level 2 scale, as per Table 1) and assess the relative proportion of impervious surfaces in those adjacent lands to infer which natural assets are more likely to be negatively impacted by urbanization in the surrounding lands.

Increases in the extent of impervious surfaces within a given watershed or catchment area are generally known to have negative impacts to natural features in that watershed or catchment area, particularly for features downstream of the impervious areas, resulting in a push towards planning that limits impervious surfaces and incorporates low impact development measures that facilitate local infiltration (e.g., Government of Ontario 2018[4]). Environment Canada's (2013) guidance for streams/watercourses in urbanized watersheds in southern Ontario states that "*impairment in stream water quality and quantity is highly likely above 10% impervious land cover and can often begin before this threshold is reached. In urban systems that are already degraded, a second threshold is likely reached at the 25 to 30% level*". The Oak Ridges Moraine Conservation Plan Technical Paper 13 for Subwatersheds – Impervious Surfaces (2002) (https://www.oakridgesmoraine.org/educational-resources/) also supports 10% as an appropriate threshold above which impacts to a range of natural features related to stormwater runoff start to accelerate on moraines. Notably, all of Guelph south of Clair Road and portions of the City west of the Hanlon expressway are on the Paris Moraine. Therefore, these metrics were considered generally appropriate for Guelph and informed the thresholds developed for this measure, which has been applied to all terrestrial natural features, including wetlands.

[4] *Watershed Planning in Ontario: Guidance for land-use planning authorities*, Draft, Government of Ontario, Feb. 2018, 159 p.

APPROACH: The extent (measured a percent) of impervious surface within 120 m (i.e., the standard measure of adjacent lands used in Ontario[5]) of an asset assessed at the Level 2 inventory was identified as an appropriate and feasible approach for gauging the extent of impervious area adjacent to a natural asset. Within the adjacent lands, the percent of imperious cover was measured and scored as follows:

- 0% = Excellent
- From up to 10% = good
- From 11 to 30% = Fair
- From 31 to 50% = poor
- More than 50% = very poor

RESULTS: Figure 10 demonstrates the results of the intensity of impervious surface in adjacent lands assessment. Notably, this analysis should be updated as development progresses in the City and particularly after the last planned greenfield development areas (e.g., Clair-Maltby Secondary Plan and Guelph Innovation District) are built out.

[5] As per the *Natural Heritage Reference Manual* for Ontario (MNRF 2010) accessed at: https://www.ontario.ca/document/natural-heritage-reference-manual

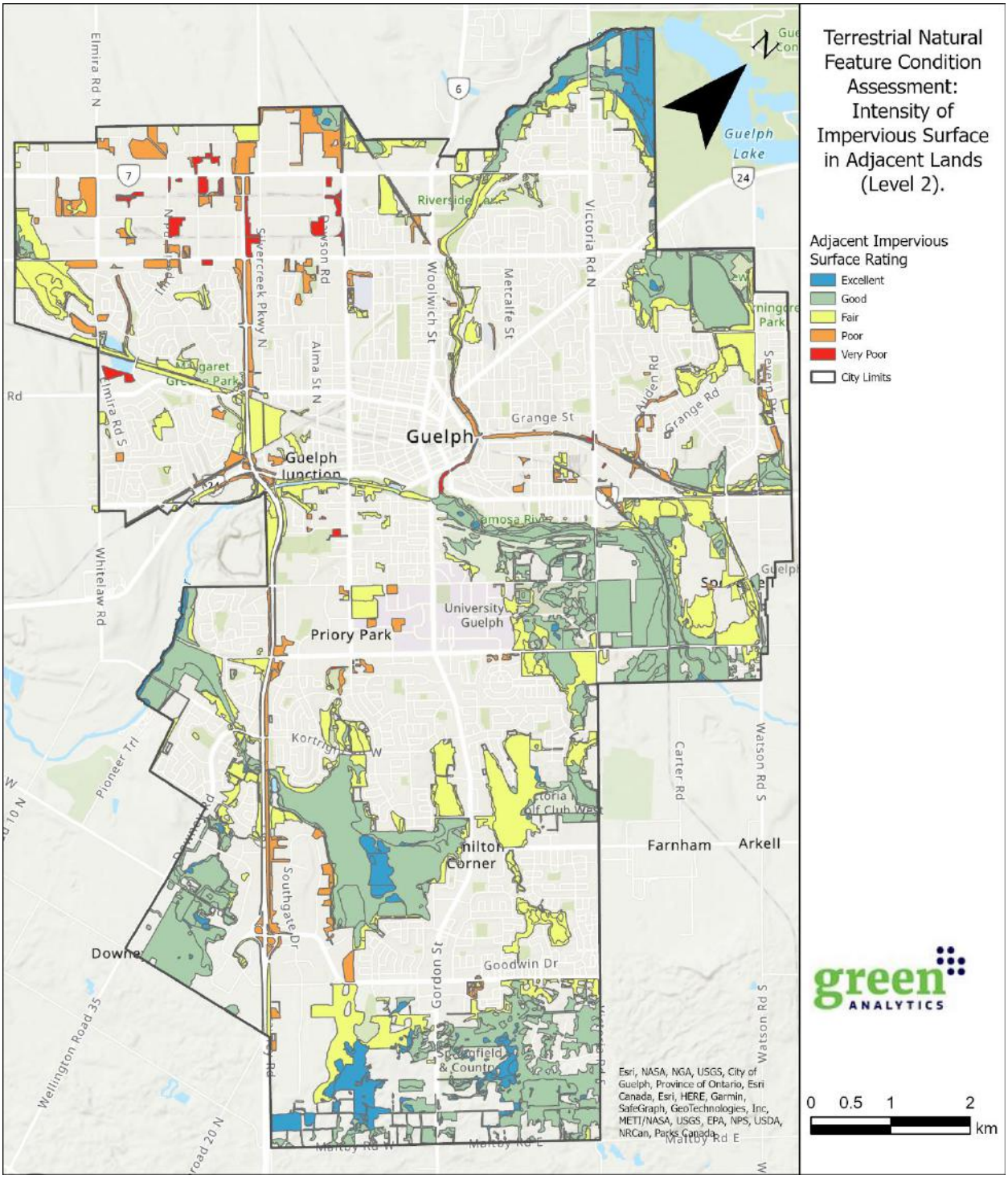

Figure 10. Map of terrestrial natural features with intensity of impervious surface in adjacent lands condition ratings (assessed at Level 2, by asset class).

3.3.5 Intensity of Adjacent Land Uses

METRIC: Density of roads within 120 m of the terrestrial natural feature asset (Assessed at the Level 1 of the NAI, as per Table 1)

RATIONALE: Roads both adjacent to and within natural areas are known to cause negative impacts to natural features and their functions because they contribute directly to fragmentation, introduce noise and pollutants associated with vehicles, and provide vectors that facilitate human access to these features, which can result in additional encroachments and impacts (e.g., Environment Canada 2013, Government of Ontario 2010).

The objective of this indicator is to capture the relative level of human use / activity occurring in the lands adjacent to terrestrial natural features (including wetlands) as reflected in road density which is being used as a proxy for the intensity of human activity adjacent to the terrestrial natural features.

Road density weighted by type of road was considered but was determined not to add value to the measure and was therefore not used. While arterial roads tend to carry more vehicles and thus create more noise and pollution, in the context of a city like Guelph, it is primarily the smaller local roads that provide direct access to most of the local terrestrial natural features. Residential subdivisions with greater densities of local roads are also areas where there are greater concentrations of people who are more likely to access nearby terrestrial natural features.

Furthermore, natural assets adjacent to residential areas are known to be impacted (sometimes quite significantly) by encroachments and disturbances from adjacent land uses. Therefore, an unweighted road density was considered an appropriate measure to use as a surrogate for or indication on the intensity of adjacent land uses.

To develop locally appropriate road density ranges aligned with the five condition score ratings (i.e., excellent, good, fair, poor and very poor the range of local road densities were assessed at two scales; (a) road densities adjacent to natural asset “blocks” (i.e., Level 1, as per Table 1) and (b) road densities adjacent to natural asset classes (i.e., Level 2, as per Table 1). Histograms of the road density data are presented in Figure 11.

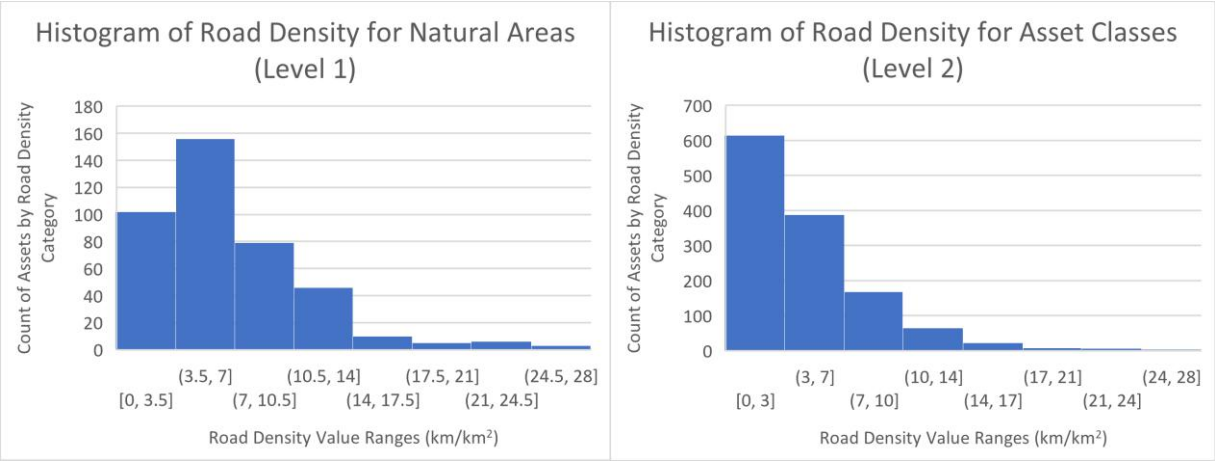

Figure 11. Histograms of road density for natural areas at Level 1 scale (left) and Level 2 scale (right).

APPROACH: Similar to the intensity of surrounding impervious land use, road density was assessed within 120 m of the natural assets. Rankings were assigned as per the following:

- 0 to 1.9 km/km^2 = Excellent
- 2 to 4.9 km/km^2 = Good
- 5 to 7.9 km/km^2 = fair
- 8 to 10 km/km^2 = poor
- > 10 km/km^2 = very poor

RESULTS: Results of the intensity of adjacent land use metric are illustrated in Figure 12.

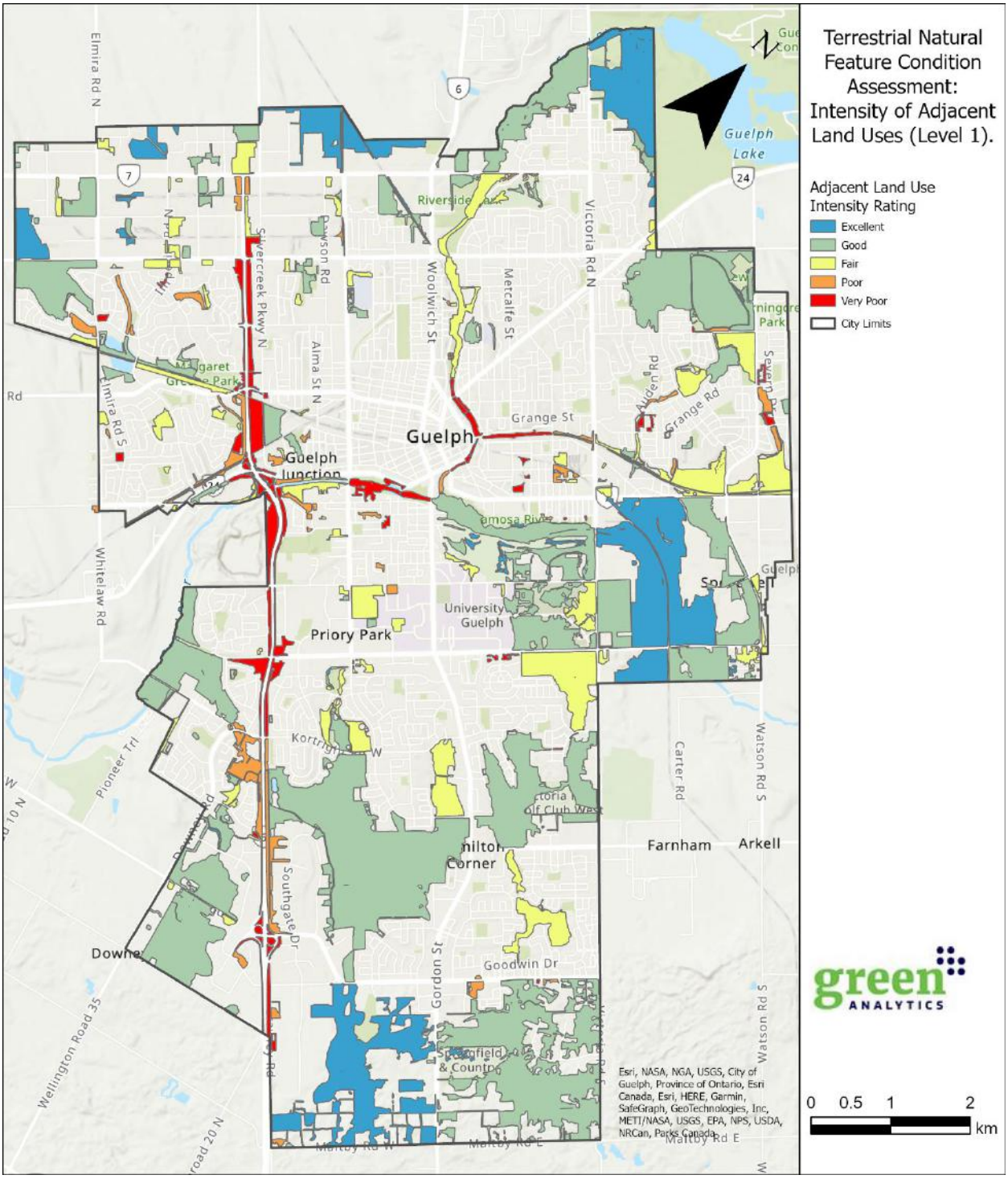

Figure 12. Map of Terrestrial Natural Features with Intensity of Adjacent Land Uses Condition Ratings (Assessed at Level 2, by Asset Class).

4 Natural Asset Risk Assessment

To complete the natural asset risk assessment, the project team collaborated with key City of Guelph staff members to first establish a list of major risks to natural assets in the City of Guelph, and then to group and define these into the 13 hazards as per Table 4. The Canadian Public Health Association defines risk as "the possibility that something bad or unpleasant (such as injury or a loss) will happen" and a hazard as "*a potential source of harm or danger*" where danger is "*something that may cause injury or harm*" (https://www.cpha.ca/risk-hazard-and-play-what-are-risks-and-hazards). Therefore, the items listed in Table 4 are considered hazards

Table 4. List and definition of natural asset hazards.

Hazards to Natural Assets	Definition	Locally Appropriate Examples
Invasive plants and wildlife	Invasive plant and wildlife species (including fish) able to negatively impact a natural asset such that its' ability to provide the services for which it is being assumed / maintained is impaired.	FORESTS - Buckthorn, Garlic Mustard; WETLANDS - Phragmites
Native and invasive pests and diseases	Native and invasive pests (primarily insects) and diseases able to negatively impact a natural asset such that its' ability to provide the services for which it is being assumed / maintained is impaired.	TREE & FOREST PESTS - Emerald Ash Borer, Asian Long-horned Beetle, Spruce Budworm; TREE DISEASES - Butternut Canker, Beech Bark Disease, Dutch Elm Disease, Oak Wilt
During construction impacts	Impacts resulting from activities during construction within or adjacent to natural assets able to negatively impact the natural asset such that its' ability to provide the services for which it is being assumed / maintained is impaired.	WATERCOURSES & WETLANDS - Silt going into asset due to absent or poor ESC maintenance; TREES & FORESTS - Individual trees or trees on the edge of a feature is damaged / killed by machinery due to absent or poor tree protection
Encroachment (around the edges of features)	Impacts resulting from activities adjacent to natural assets (post-construction) able to negatively impact the natural asset such that its' ability to provide the services for which it is being assumed / maintained is impaired.	ALL ASSETS - Dumping of yard or other waste from adjacent land use, repeated damage by mowers and trimmers; FORESTS, WETLANDS & MEADOWS / SUCCESSIONAL - Installation of forts, sheds and gardens.
Overuse or inappropriate use (within natural areas or on individual trees)	Impacts resulting from activities within natural assets (post-construction) able to negatively impact the natural asset such that it's' ability to provide the services for which it is being assumed / maintained is impaired.	FORESTS, WETLANDS & MEADOWS / SUCCESSIONAL – Jumps for motorized and non-motorized bicycles, or other structures; Mowing or other gardening; Creation of informal trails, widening of formal trails and / or off-trail activities; TREES - Intentionally vandalized / damaged saplings.
Urban intensification	Impacts resulting from intensification of existing land uses adjacent to previously protected natural assets able to negatively impact the natural asset such that it's' ability to provide the services for which it is being assumed / maintained is impaired.	ALL ASSETS - Approved expansion of an existing road or introduction of an overpass resulting in removals of trees and / or part or all of an adjacent natural asset. (Which even with compensation will result in a temporary service reduction / loss).

Flooding	Naturally occurring hazard exacerbated by both urbanization (i.e., reduced permeable surfaces with inadequate stormwater management controls in some areas of the City or upstream) and climate change (i.e., increased frequency and intensity of storm events) that, if large and / or sustained enough, can impact the natural asset such that its' ability to provide the services for which it is being assumed / maintained is impaired.	WATERCOURSES - Overtopping existing top of banks and inundating adjacent lands. WETLANDS - Exceeding typical range of water levels for extended periods - resulting in loss of riparian habitats and associated functions including erosion control and water quality control, increased sedimentation.
Shifts in hydrologic regime	Impacts to natural assets, and in particular wetlands and watercourses, but also potentially to forests, meadows and individual trees, as a result of changes in land use that alter catchment areas, overall water levels, hydroperiod and water quality. This can result in localized flooding / inundation or localized drying out, causing decline and / or die-back of the asset.	Changes to the pre-development hydrology and drainage of a natural asset resulting in either much less or much more water (at one time or for an extended period of time) than the feature or asset can tolerate without decline. WETLANDS – discharge of stormwater from development areas into the feature causing a shift in vegetation community and wildlife habitat
Erosion and sedimentation	Naturally occurring hazard exacerbated by flooding, urbanization (i.e., reduced permeable surfaces with inadequate stormwater management controls in some areas of the City or upstream) and climate change (i.e., increased frequency and intensity of storm events).	WATERCOURSES - Erosion along banks and sedimentation in waterways, loss of riparian habitats.
Extreme Weather Events	Naturally occurring hazard exacerbated by climate change related to the increased frequency and intensity of storm events (e.g., including rain, wind and ice storms).	TREES & FORESTS - Severe and / or extensive mechanical damage cause to individual trees and/or wooded areas.
Drought	Naturally occurring hazard exacerbated by urbanization (i.e., changes in drainage and infiltration) and climate change (i.e., increased frequency and intensity of heat events).	TREES & FORESTS - Severe and / or extensive drying of substrates / soils resulting in extensive die-back and / or mortality. WETLANDS & WATERCOURSES - limited flows resulting in warming and / or loss of habitats and related functions.
Contamination	Introduction of pollutants and /or chemicals to the asset that can seriously impair the function of or kill the asset.	ALL ASSETS - Metals and oils from urban road run-off, salt runoff and/or spray, leaching of chemicals from current or former industrial uses or landfill.
Fire (of natural or anthropogenic origin)	Fire of natural or human origin that occurs within the asset able to negatively impact the natural asset such that its' ability to provide the services for which it is being assumed / maintained is impaired.	UPLAND FORESTS - Forested asset decimated by an unauthorized campfire that got out of control or caused by a lightning strike in a plantation.

Once the hazards were defined, City staff experts worked through the list of hazards and allocated a risk score based on the City of Guelph's standard asset risk rating (Figure 13). Using this rating system, an impact score was allocated on a scale of 1 to 4, where 1 is a minor impact and 4 is a catastrophic impact. Table 5 contains impact rating definitions for the physical environment from the City of Guelph's asset

management plan (City of Guelph's Enterprise Risk Management Framework, 2012). These were used as a guide to assign impact ratings to the various hazards. Similar definitions exist for service delivery, employees, public, reputation, financial and regulatory. The physical environment definitions were deemed most applicable to Guelph's natural features.

Table 5. Impact Ratings for the Physical Environment from Guelph's Enterprise Risk Management Framework.

Scale	Impact	Physical Environment
4	Catastrophic	- Potential to cause long term environmental damage with lasting consequences. - Consequences of not including environmental considerations has potential to create long environmental damage.
3	Major	- Potential to cause short term repairable environmental damage impacting a large area.
2	Moderate	- Potential to cause short term repairable environmental damage impacting a small area.
1	Minor	- Potential to cause non-lasting damage to environmental assets.

In addition to an impact score, for each hazard, a likelihood score was allocated on a scale of 1 to 5, where 1 is rare and 5 is almost certain. The overall risk score was then determined by multiplying the impact score by the likelihood score.

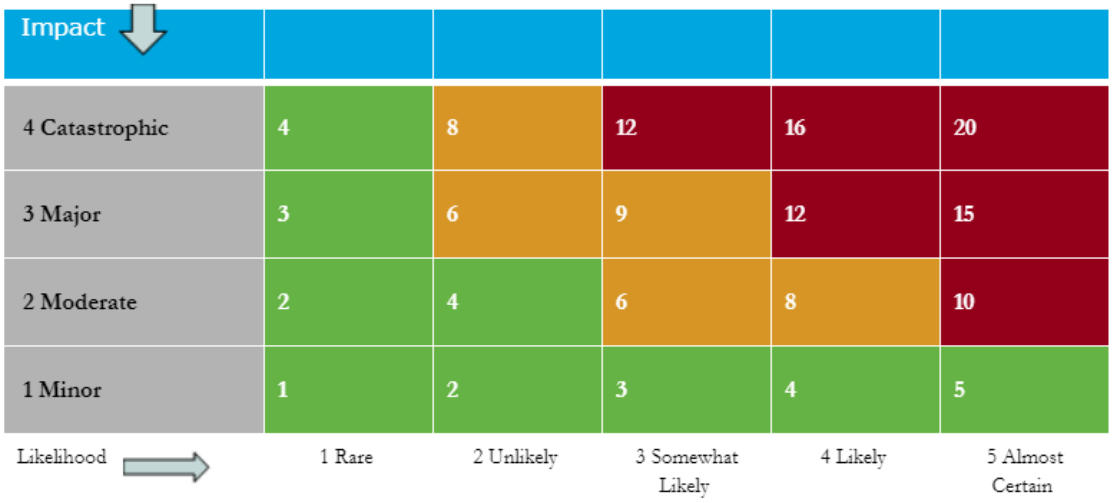

Figure 13. Risk impact – likelihood matrix for the City of Guelph.

The results of this process are presented in Table 6. The highest ranked risks to natural assets (including NHS, street and park trees, and watercourse assets) were extreme weather events, followed by invasive species, overuse, urban intensification, and shifts in hydrologic regime.

Table 6. Final risk ratings for natural asset hazards.

Potential Hazards to Natural Assets**	Risk Impact Rating	Risk Likelihood Rating	Risk Score
Extreme weather events	4	4	16
Invasive plants and wildlife	3	5	15
Overuse or inappropriate use	3	5	15
Urban intensification	3	5	15
Shifts in hydrologic regime	3	5	15
Erosion and sedimentation	2	5	10
Native and invasive pests and diseases	2	5	10
During construction impacts	2	5	10
Encroachment	2	5	10
Contamination)	2	5	10
Flooding	3	3	9
Drought	2	4	8
Fire	4	2	8

**See Table 4 for descriptions and examples of each hazard

With the risks ranked, the next step was to determine which natural assets in the City were exposed to these different risks. This was accomplished using the assumptions laid out in Table 7.

Table 7. Assumptions used to allocate risk to individual assets.

Potential Hazards to Natural Assets**	Applicability by Natural Asset Class						Spatial Distribution Assumptions	Selection Criteria
	Street and Park Trees	Watercourse	Meadow / Successional Habitats	Upland Forests	Wetlands	Hedgerows		
Invasive plants and wildlife	N	Y	Y	Y	Y	Y	All relevant asset classes	All relevant asset classes
Native and invasive pests and disease	Y	N	N	Y	Y	Y	All relevant asset classes	All relevant asset classes
During construction impacts	Y	Y	Y	Y	Y	Y	Potential future development areas	Housing Supply 2020
Encroachment	N	N	Y	Y	Y	N	Buffer around existing private property areas	20 m
Overuse or inappropriate use	N	Y	Y	Y	Y	N	All assets with known access	Assets with trails
Urban intensification	Y	Y	Y	Y	Y	Y	Potential future development areas	Intensification Corridors
Flooding	N	Y	N	N	Y	N	Assets in GRCA regulated flood zone	Assets within flood zone
Shifts in hydrologic regime	N	Y	Y	Y	Y	N	Not applied due to lack of City-wide data set or an appropriate surrogate	
Erosion and sedimentation	N	Y	N	N	Y	N	Assets in GRCA's Erosion hazard mapping	Overlay with erosion hazard area
Extreme Weather Events	Y	Y	Y	Y	Y	Y	All relevant asset classes	All relevant asset classes
Drought	Y	Y	Y	Y	Y	Y	All relevant asset classes	All relevant asset classes
Contamination	N	Y	Y	Y	Y	N	Buffer around roads and industrial areas	15 m buffer
Fire	N	N	Y	Y	N	N	All relevant asset classes	All relevant asset classes

*See Table 4 for descriptions and examples of each hazard

4.1 Street and Park Trees Risk Assessment

Street and park tree risk scores are depicted in Figure 14. The map represents the combined risk score of each tree, as per the risks specified in Table 4. Total combined risk scores were determined by summing the relevant risk scores (Table 6) for each tree and dividing by the total possible risk score. This creates a normalized risk score on a scale of 0 to 100.[6]

[6] A normalized risk score is required to facilitate comparison across different asset types. Each asset type has a different number of relevant risks as indicated by the Y's in Table 7. The max possible score for each hazard is 16 (4 x4). But if one asset type has only 5 relevant hazards and another asset type has 10 relevant hazards, simply summing the risk scores would make the asset type with 10 relevant hazards seem higher rated even if the all the hazards were rated lower on the risk scale due to the number of hazards being considered. Therefore, the summed risk score is normalized by the maximum possible risk score (16 x the number of relevant hazards).

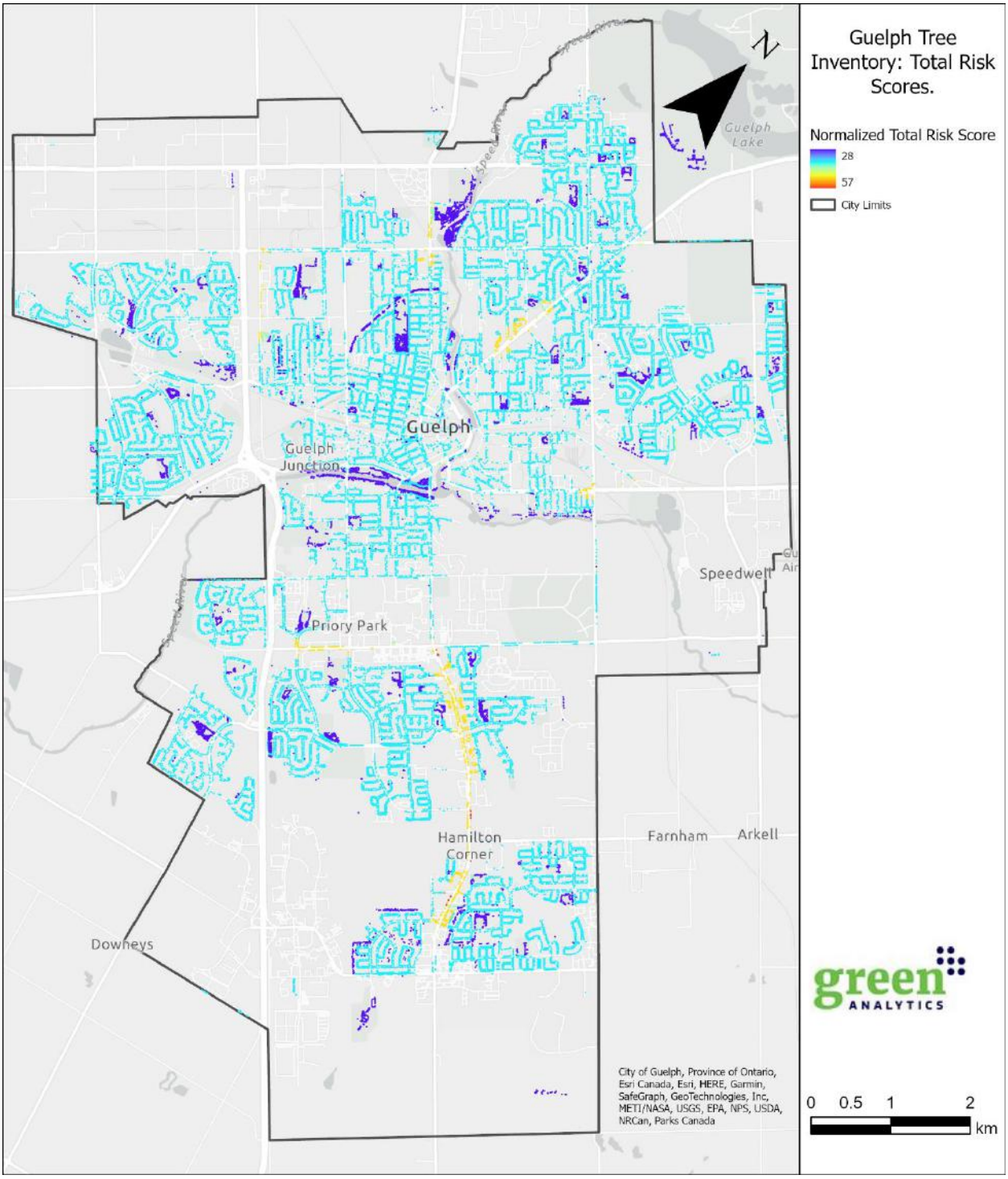

Figure 14. Map of combined risk scores for street and park tree assets.

4.2 Watercourse Risk Assessment

Risk scores for watercourse assets are shown in Figure 15. Each watercourse asset is coloured to indicate the combined risk score, based on the assumptions specified in Table 7. Total combined risk

scores were determined by summing the relevant risk scores (Table 6) for each watercourse and dividing by the total possible risk score. This creates a normalized risk score on a scale of 0 to 100. The higher risk score assigned to Clythe Creek around York Road is because this section of the creek intersects with a trail putting it at relatively higher risk of overuse or inappropriate use.

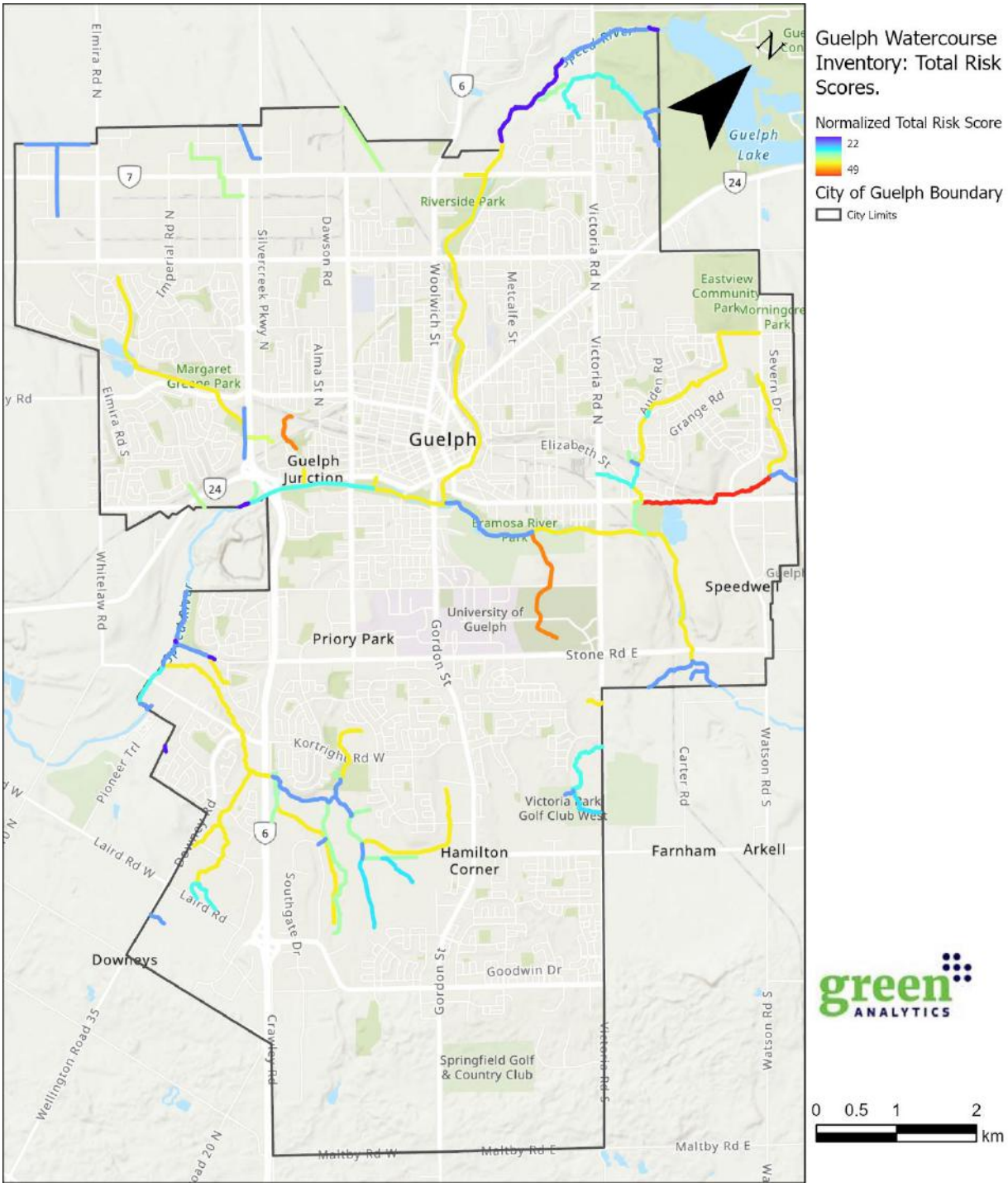

Figure 15. Map of combined risk score for watercourse assets.

4.3 Natural Heritage System Risk Assessment

Combined risk scores for the natural heritage system assets are mapped by Asset Class (Level 2) in Figure 16. The map displays the location and combined risk score for all natural assets as specified by the criteria in Table 7. Total combined risk scores were determined by summing the relevant risk scores (Table 6) for each asset and dividing by the total possible risk score. This creates a normalized risk score on a scale of 0 to 100. The areas of high risk around Gordon and Arkell are due to risks during construction impacts, overuse/inappropriate use, encroachment, urban intensification and contamination.

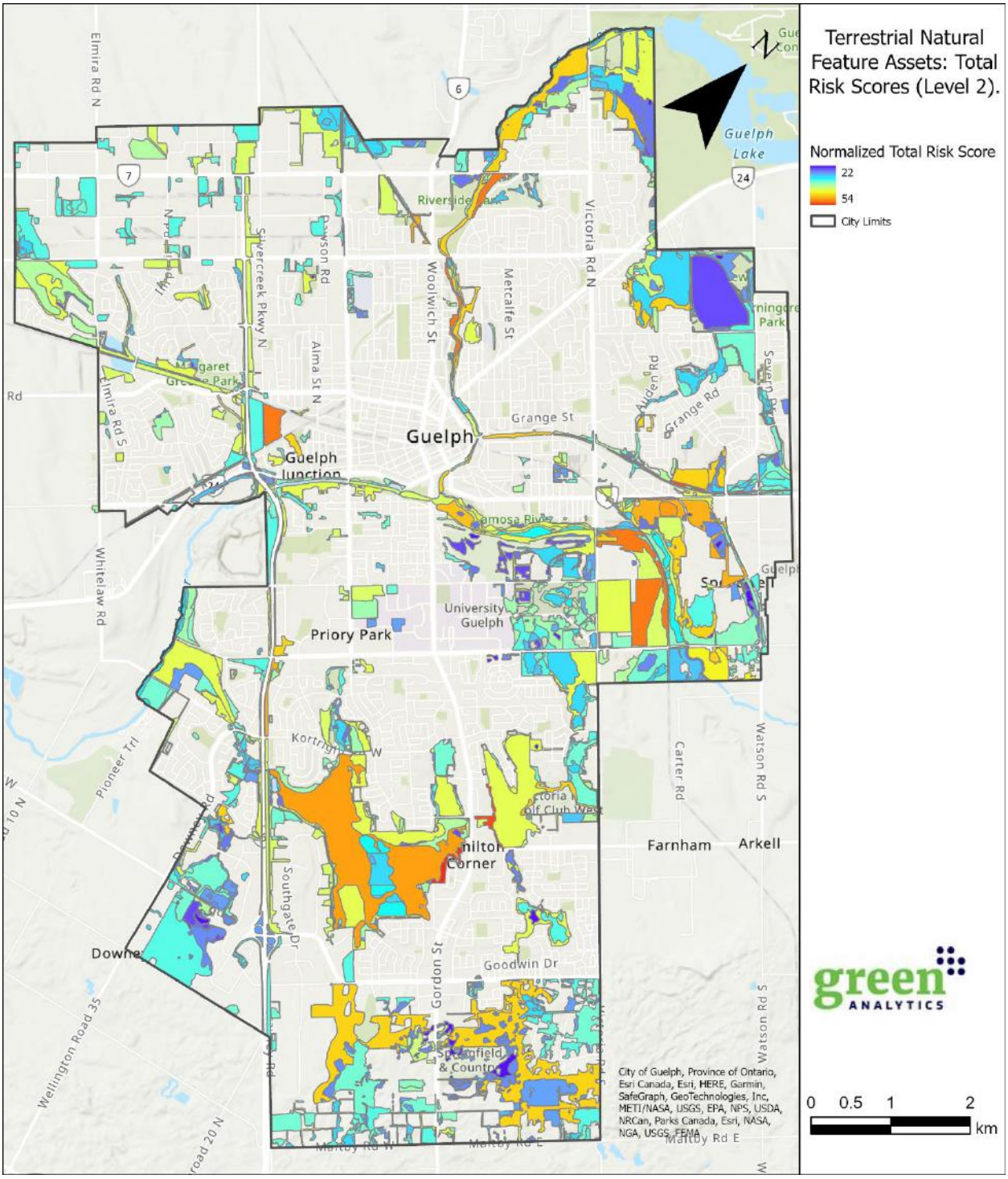

Figure 16. Map of combined risk score for natural heritage system assets.

5 Service Attribution

This section describes the approach used to attribute ecological services to the natural assets within Guelph's NAI. As was the case with the condition and risk assessment, the service attribution approach was developed in close consultation with City of Guelph staff from various departments representing different disciplines including asset management and environmental planning.

There were two steps to the approach:

1. Identify and confirm the relevant ecological services, and
2. Attribute services to natural assets.

Each of these steps is described in greater detail below.

5.1 Identify and Confirm Ecological Services

To identify and confirm the ecological services of relevance to Guelph's NAI, the project team worked with the client to identify the list of services considered most relevant and appropriate for the City of Guelph. Through this process, twelve services were identified. The services, along with the overarching ecosystem function to which they are linked, are described in Table 8.

Table 8. Priority ecological services identified for Guelph's natural assets.

Ecosystem Function	Ecological Service	Description
Water quantity and quality management	1. Contribution to water supply and filtration	The service provided by natural assets that capture, store and filter water.
Provision of natural vegetation and wildlife	2. Contribution to outdoor recreation	The provision of recreational opportunities in natural settings.
	3. Contribution to physical and mental health and well-being	The physical and mental health benefits provided by exercise and time spent in natural settings.
	4. Support of local gardens and food production	Assets that support the life stages of pollinators.
	5. Provision of amenity value/property value appreciation	The contribution of natural assets to increased property values and general amenity appreciation.
Maintenance of hydrologic cycle and flood regulation	6. Stormwater management - Water storage and management	Natural areas that provide on-going water storage and management services including reduced runoff through interception, evapotranspiration, and infiltration (even during non-flood events).
	7. Stormwater management - Flood risk reduction to property and human life	The conveyance and storage capacity of the river channel and floodplain.
Erosion regulation	8. Erosion risk reduction to property and human life	Reduced run-off and bank stabilization provided by natural assets.
Urban heat	9. Contribution to public	Reduced heat stress due to the presence of natural

management	health	assets that provide shade.
	10. Reduced energy consumption	For buildings near natural assets due to the provision of shade.
Air quality management	11. Contribution to public health	Improved local air quality due to the presence of natural assets that filter pollutants and hence reduce respiratory illnesses.
Carbon sequestration	12. Climate change mitigation	The sequestration and storage of carbon by natural assets.

Once identified, it was necessary to establish allocation assumptions to select the natural assets responsible for delivering the relevant services. The approach for doing so is described below.

5.2 Attribute Ecological Services to Natural Assets

The ecological services identified above were attributed to the natural assets within the City and contained within the asset inventory database.

The attribution exercise was completed for all assets within Guelph's municipal boundary, including those on private lands. However, assets can be filtered according to ownership as needed.

The objective was to first align the asset types with the services which they would reasonably be expected to provide based on their ecological form and function. The interpreted applicability of different services to different asset types is shown Table 9.

Table 9. Applicability of service to natural asset, by asset class type.

Ecological Service	Asset Class Type					
	Street and Park Trees	Watercourses	Meadow / Successional Habitats	Upland Forests	Wetlands	Hedgerows
Contribution to water supply and filtration	Y	Y	Y	Y	Y	Y
Contribution to outdoor recreation	Y	Y	Y	Y	Y	Y
Contribution to physical and mental health and well-being	Y	Y	Y	Y	Y	Y
Support of local gardens and food production (pollinators)	Y	Y	Y	Y	Y	Y
Provision of amenity value / property value appreciation	Y	Y	Y	Y	Y	Y
Stormwater management – Water storage and management	Y	Y	Y	Y	Y	Y
Stormwater management - Flood risk reduction to property and human life	N	Y	N	N	Y	N
Erosion risk reduction to property and human life	Y	Y	Y	Y	Y	Y
Contribution to public health (reduced heat stress, provision of shade)	Y	Y	Y	Y	Y	Y
Reduced energy consumption (for buildings near natural assets)	Y	N	N	Y	Y*	N
Contribution to public health (reduced asthma)	Y	N	N	Y	Y*	Y
Climate change mitigation	Y	N	Y	Y	Y	Y

Y = Asset type able to deliver this service; N = Asset type not able to deliver this service

* Swamp only

The next step was to develop and confirm a set of allocation assumptions that could be used to select the specific natural assets (within each asset type) providing the applicable services. To complete this task, the allocation assumptions presented in Table 10 were applied to asset class types for each ecological service, as summarized in Table 9. For example, all asset types with a 'Y' in Table 9 can provide the service under consideration, however there are also spatial criteria (e.g., such as proximity to residential units) that determine the areal "zone" within which assets of that type provide the particular service (e.g., not all forests will contribute to reduced energy consumption in occupied buildings). The allocation assumptions developed and applied for each service are presented in Table 10.

Table 10. Allocation assumptions for attributing ecological services to relevant natural assets.

ES #	Ecological Service	Allocation Assumption
1	Contribution to water supply and filtration	All relevant assets (assets with a Y in the table above).
2	Contribution to outdoor recreation	Natural assets that contain trails and all street trees in census tracts with residential zoning that have more that %15 canopy cover, trees located in parks and watercourse assets within 50 m of a trail.[7]
3	Contribution to physical and mental health and well-being	Natural assets that are accessible or in proximity to residential properties (i.e., assets within a 400m buffer of residential properties/within 400 m of residential zones).[8]
4	Support of local gardens and food production (pollinators)	All relevant assets (assets with a Y in the table above).
5	Provision of amenity value / property value appreciation	Natural assets within a 250m buffer of residential properties/all street tree assets within residential zoning.[9]
6	Stormwater management – water storage and management	All relevant assets (assets with a Y in the table above)
7	Stormwater management - Flood risk reduction to property and human life	All relevant assets (assets with a Y in the table above)
8	Erosion risk reduction to property and human life	All relevant assets within 120m of a watercourse, pond or wetland
9	Contribution to public health (reduced heat stress, provision of shade)	All relevant assets (assets with a Y in the table above)
10	Reduced energy consumption (for buildings near natural assets)	Natural assets within 15m of any building[10]
11	Contribution to public health (reduced asthma)	All relevant assets (assets with a Y in the table above)
12	Climate change mitigation	All relevant assets (assets with a Y in the table above)

[7] 15% canopy cover represents the midrange in the percent canopy covers for Guelph neighbourhoods. Assuming that people are more likely to recreate in neighbourhoods with more shade, 15% was chosen as a benchmark cut-off. This assumption can be revisited should suitable evidence of a more appropriate criterion value be available.

[8] The City of Guelph confirmed that their parks and recreation staff use a 400 m / 5 minute walk threshold (along with an 800 m / 10 minute walk threshold) in their assessments. This walk threshold is also used to support / define "transit-supportive land use development" in the City of Guelph's Official Plan 2018 Consolidation.

[9] Mazzotta, M. J., Besedin, E., & Speers, A. E. (2014). A meta-analysis of hedonic studies to assess the property value effects of low impact development. *Resources*, *3*(1), 31-61 and Sander, H., Polasky, S. and Haight, R.G., 2010. The value of urban tree cover: A hedonic property price model in Ramsey and Dakota Counties, Minnesota, USA. *Ecological Economics*, *69*(8), pp.1646-1656.

[10] Residential building energy conservation and avoided power plant emissions by urban and community trees in the United States (itreetools.org); https://www.itreetools.org/documents/749/Building_Energy_Nowak_2016.pdf

The assumptions shown in Table 10 were used to assign the various services to specific assets by type and location. The series of maps in the next section demonstrate the outcomes of this process.

5.3 Service Attribute Findings

The series of maps below demonstrates the results of the ecological service attribution exercise. Specifically, the maps show the specific assets (by type and location) that provide the service under consideration for each of the 12 ecological services identified for Guelph starting with the terrestrial natural features (including wetlands) inventory (Figures 17-25), then the street tree inventory (Figures 26-31), and the watercourses inventory (Figures 32-35).

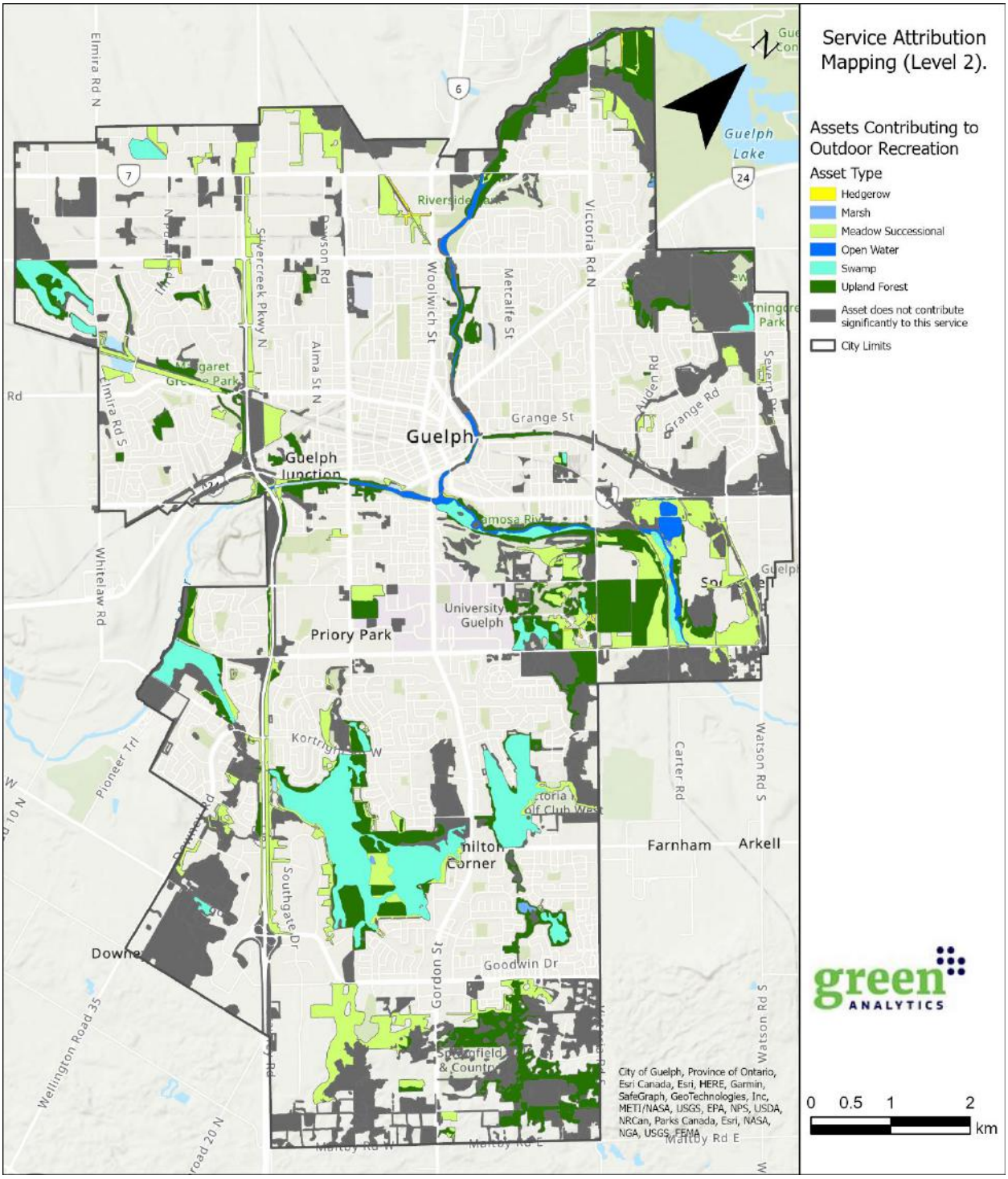

Figure 17. Natural assets providing outdoor recreation (ES#2).

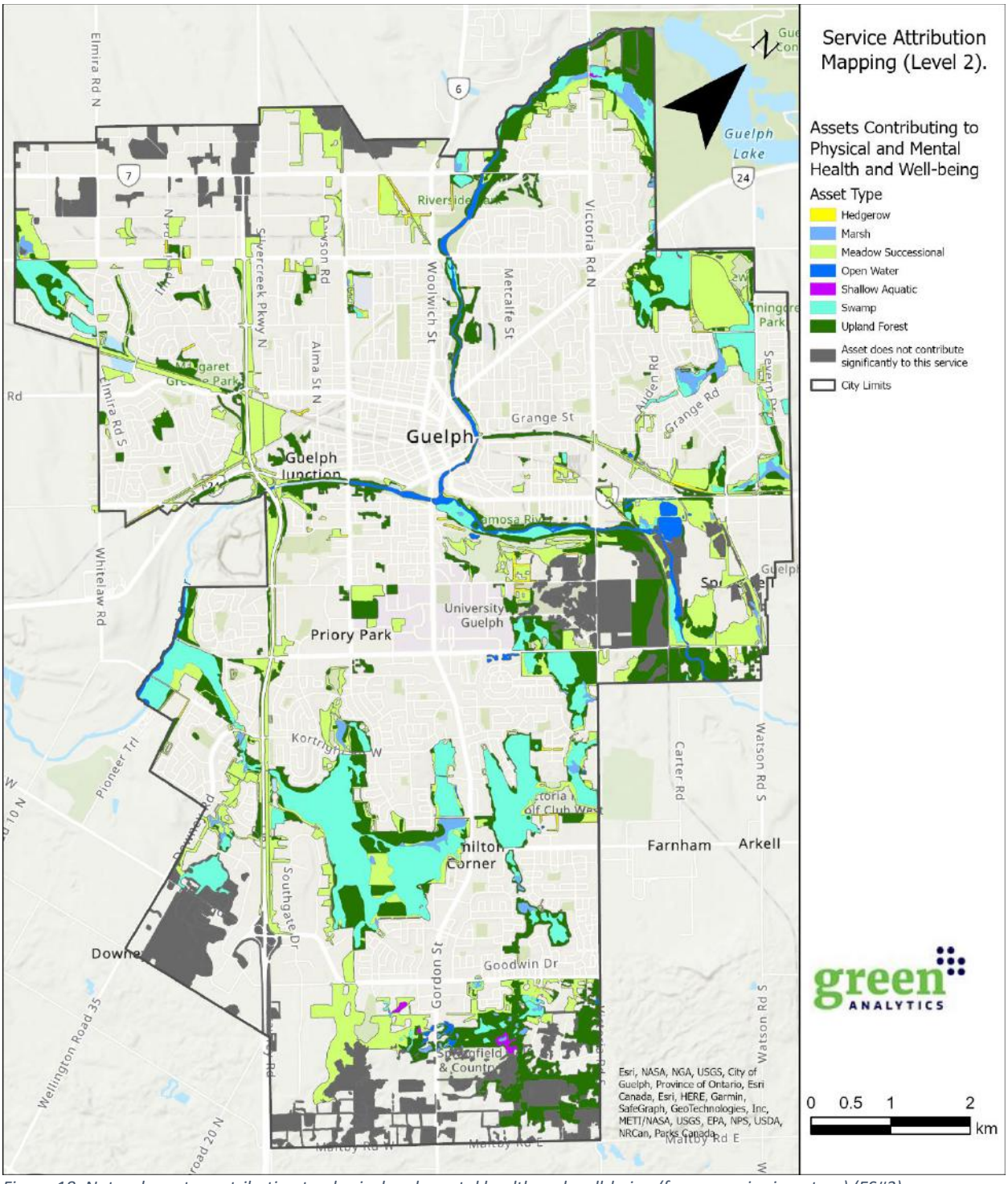

Figure 18. Natural assets contributing to physical and mental health and well-being (from exercise in nature) (ES#3).

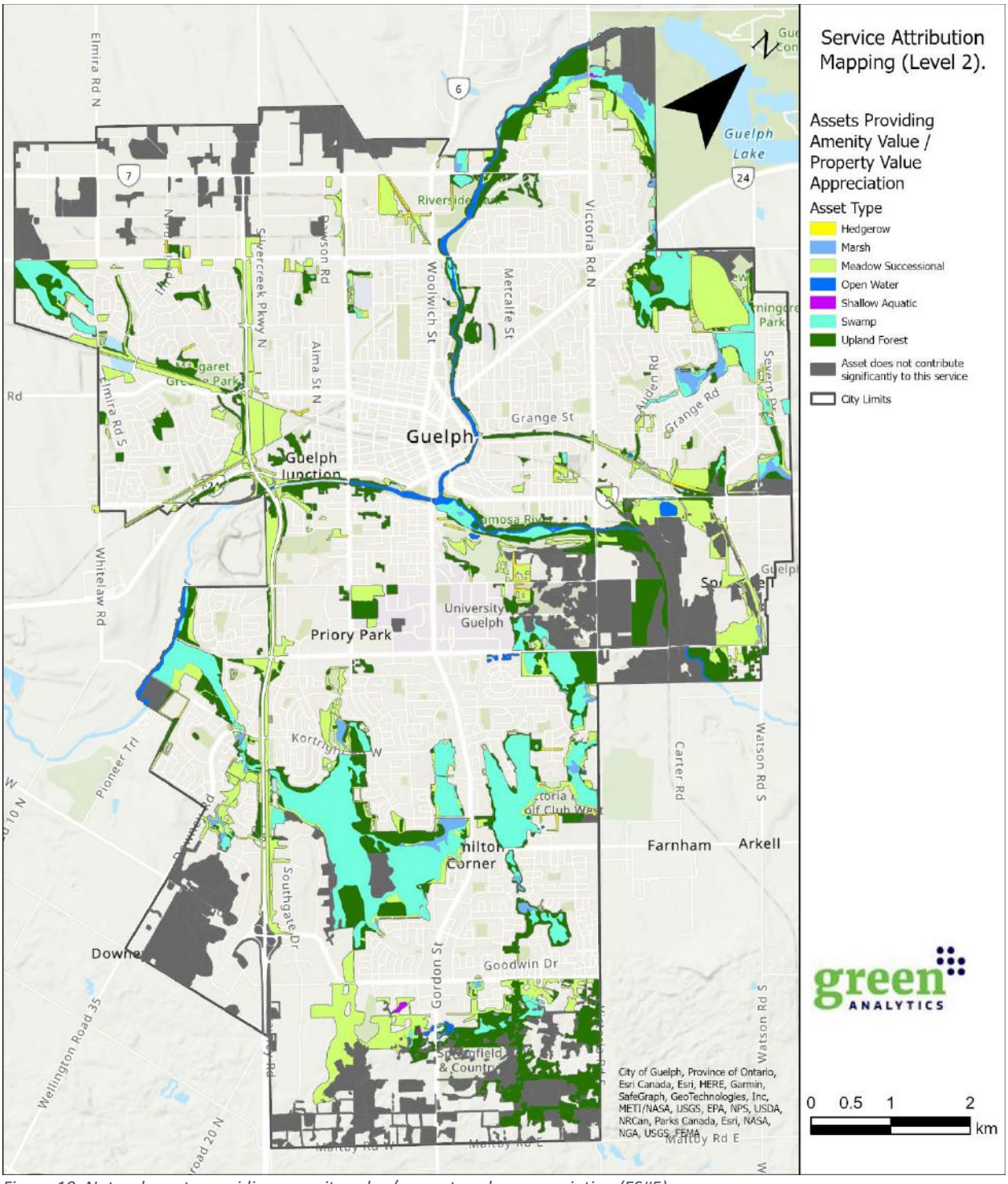

Figure 19. Natural assets providing amenity value/property value appreciation (ES#5).

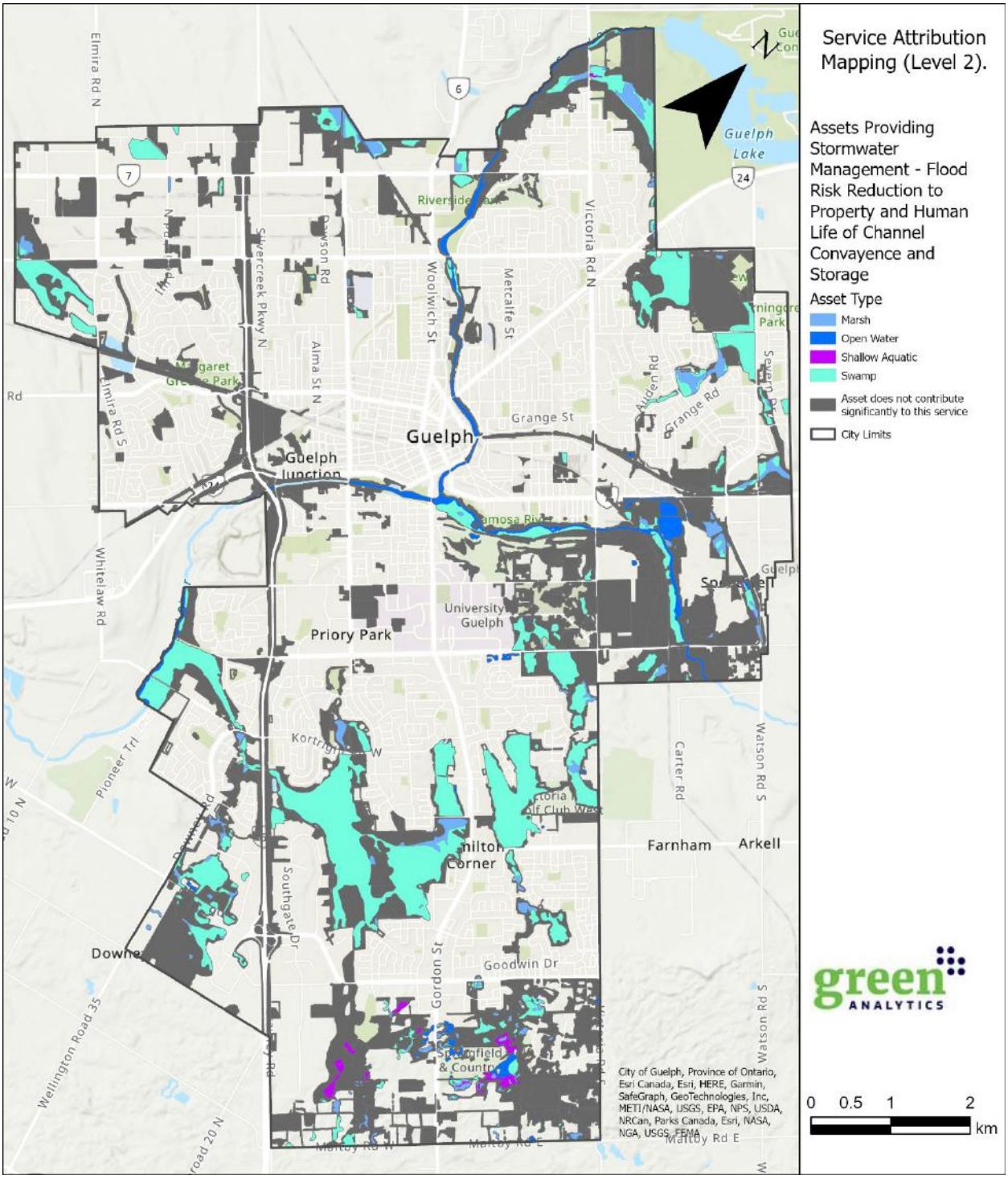

Figure 20. Natural assets providing stormwater management – flood risk reduction (ES#7).

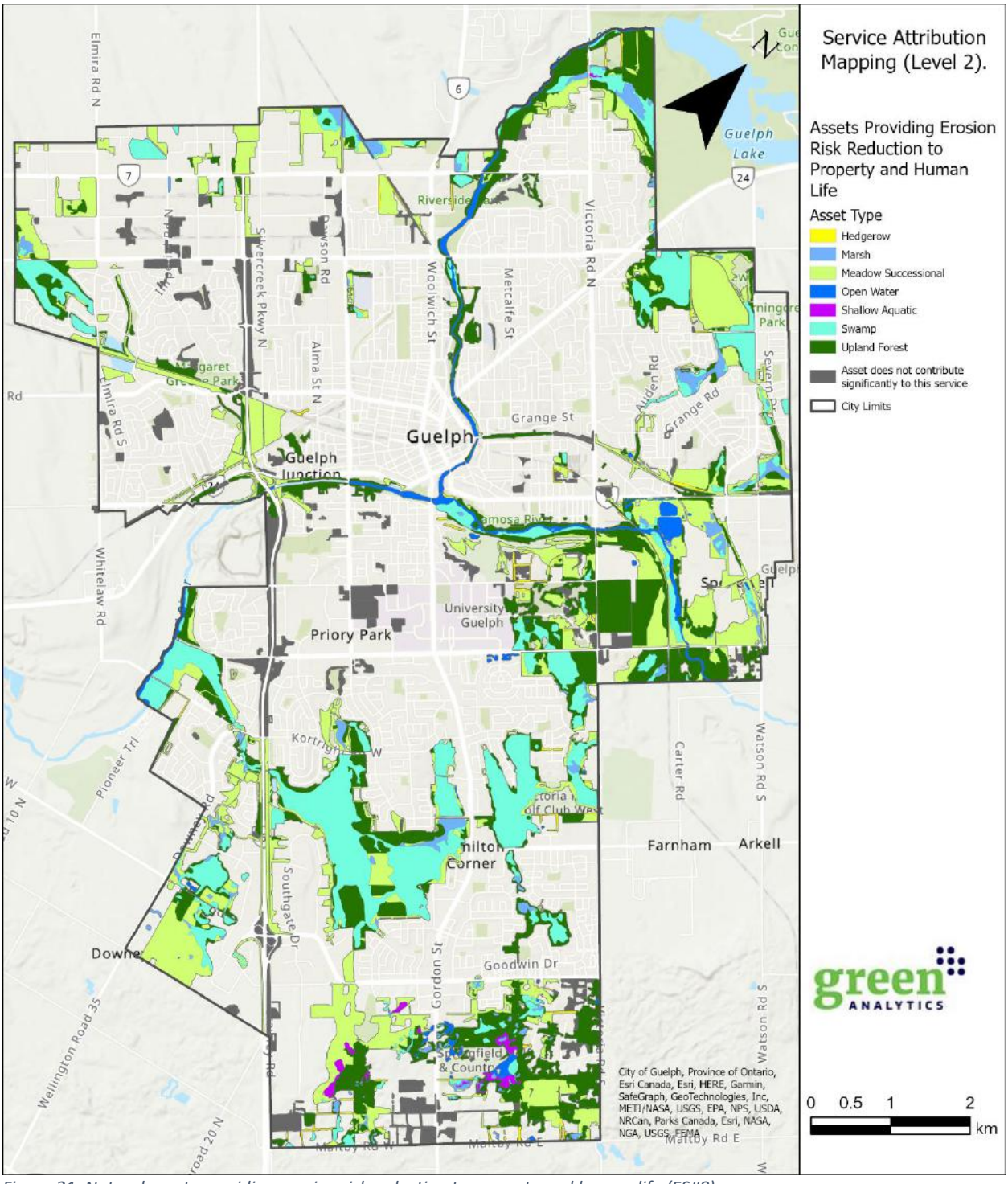

Figure 21. Natural assets providing erosion risk reduction to property and human life (ES#8).

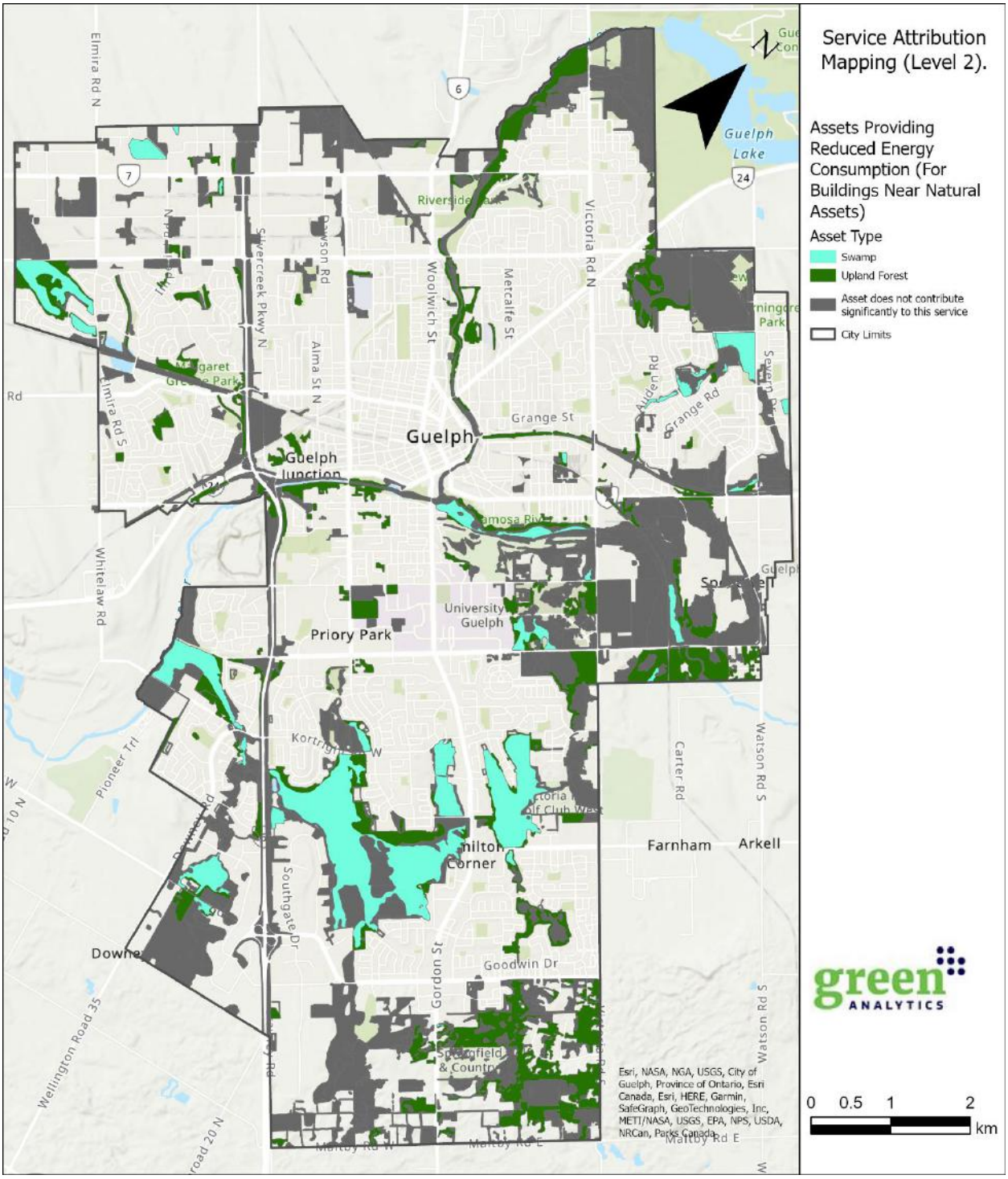

Figure 22. Natural assets providing reduced energy consumption (ES#10).

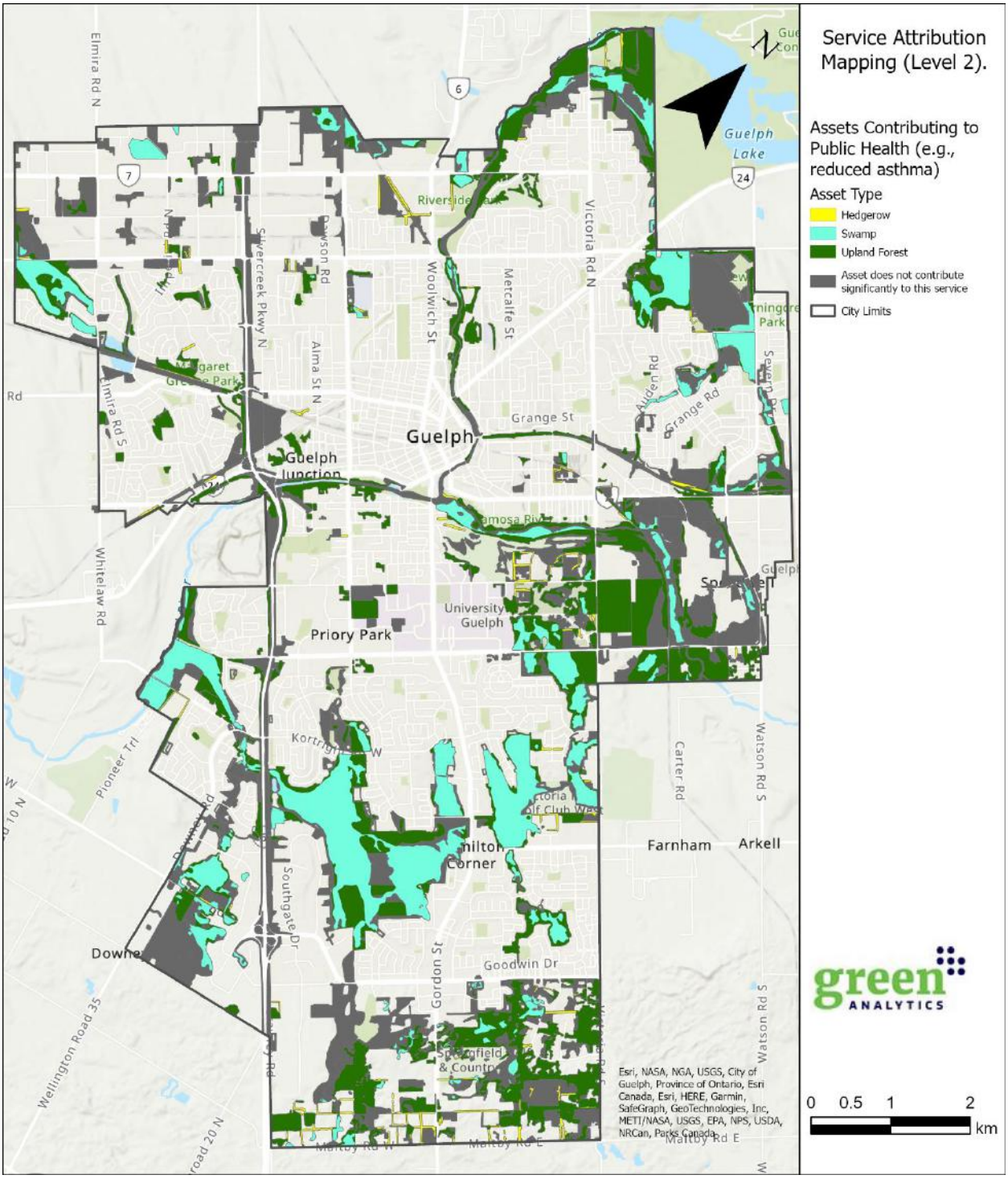

Figure 23. Natural assets contributing to public health via air quality improvements (ES#11).

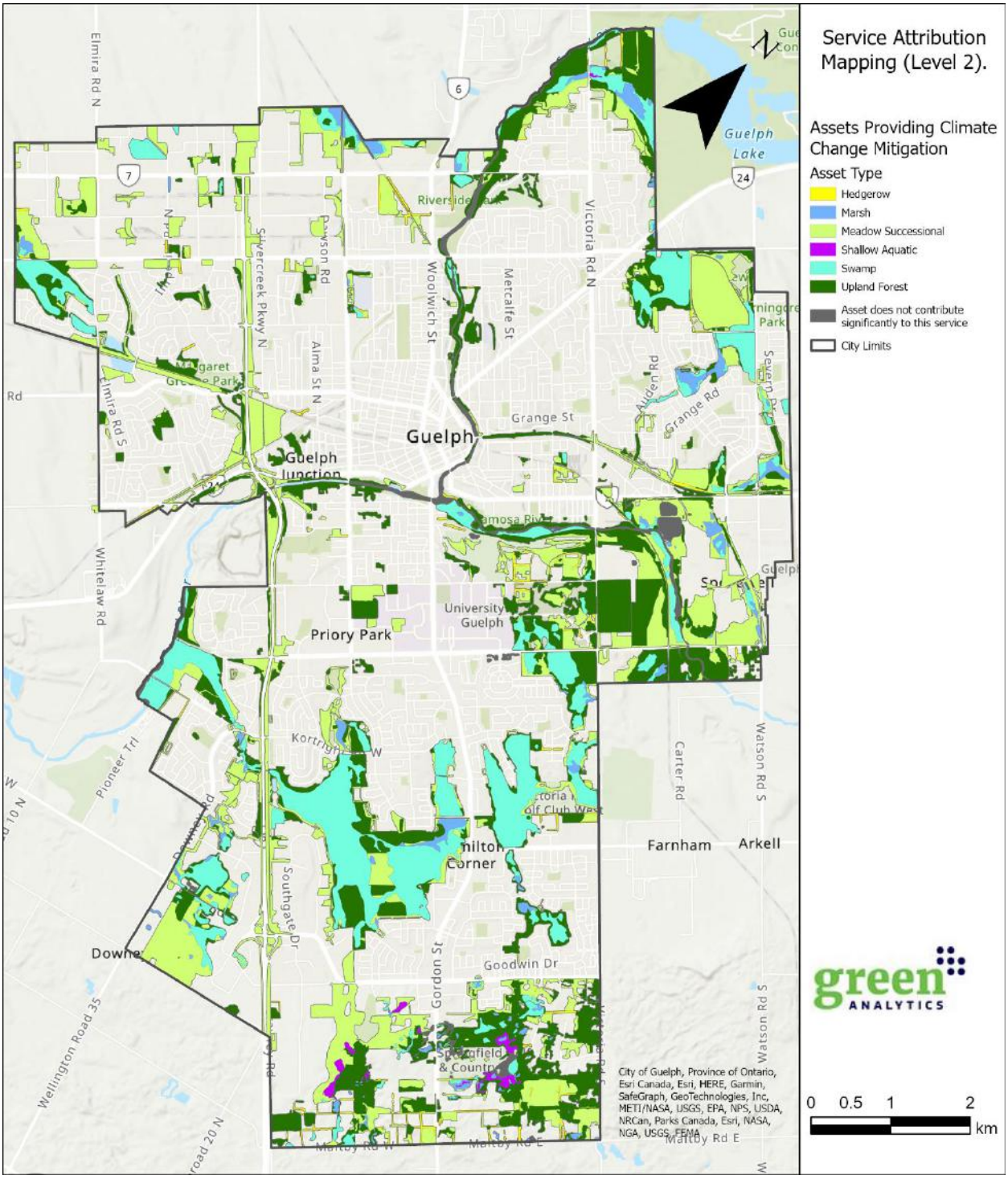

Figure 24. Natural assets providing climate change mitigation (carbon storage and sequestration) (ES#12).

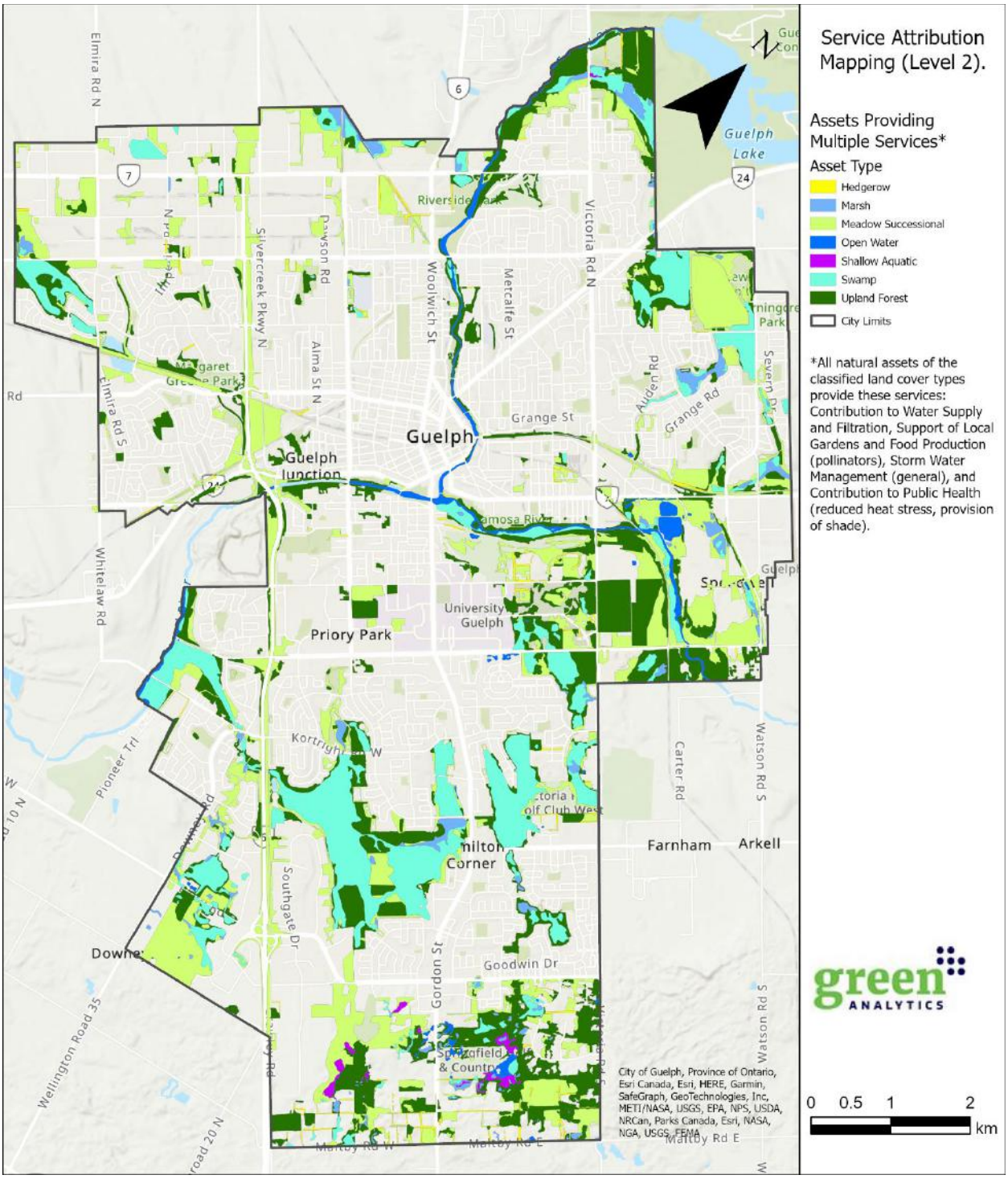

Figure 25. Natural assets providing water supply and filtration services (ES#1), support for local gardens and food supply (ES#4), stormwater management (water storage and management) (ES#6) and contribution to public health (reduced heat stress due to provision of shade) (ES#9).

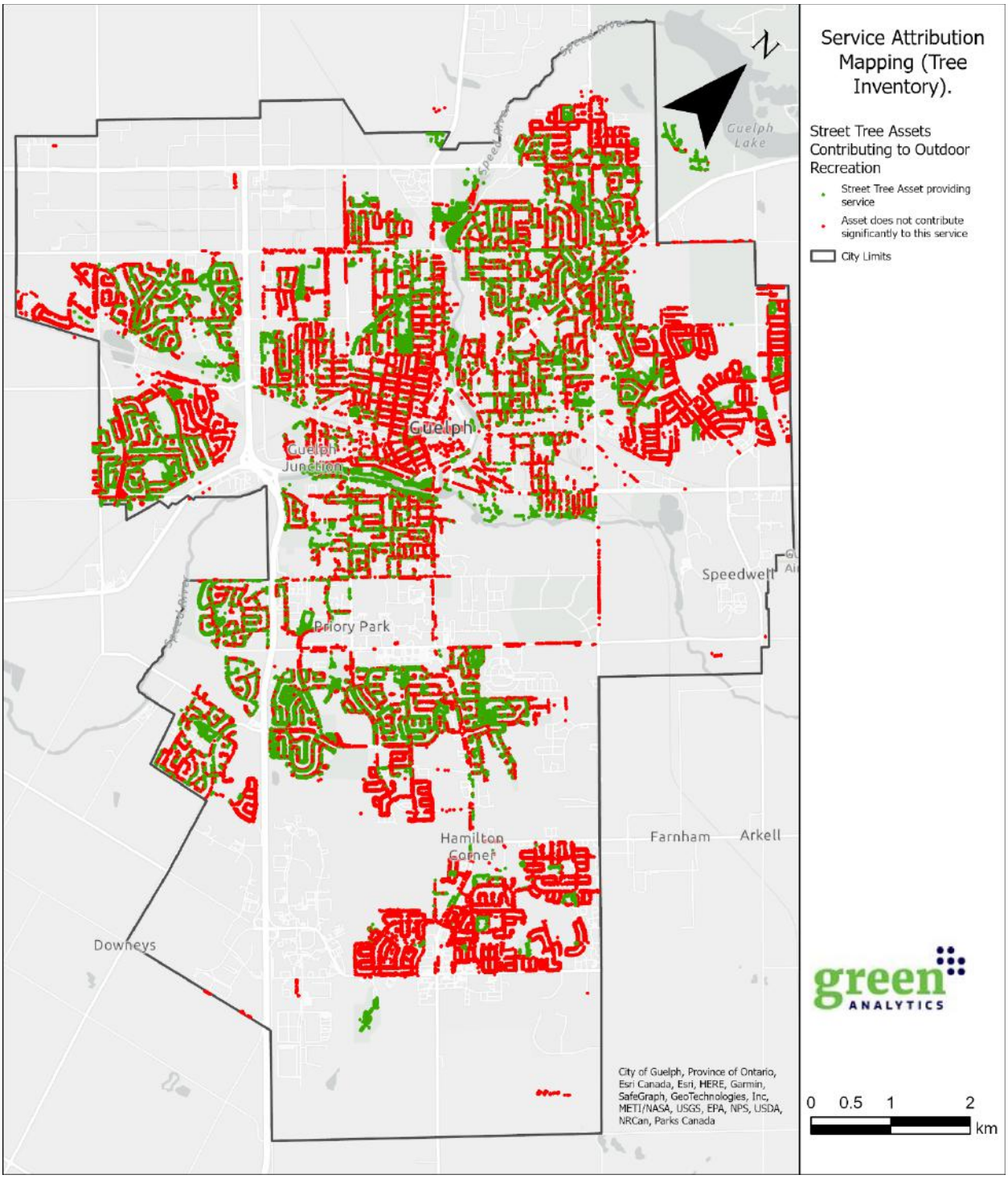

Figure 26. Street tree assets supporting outdoor recreation (ES#2).

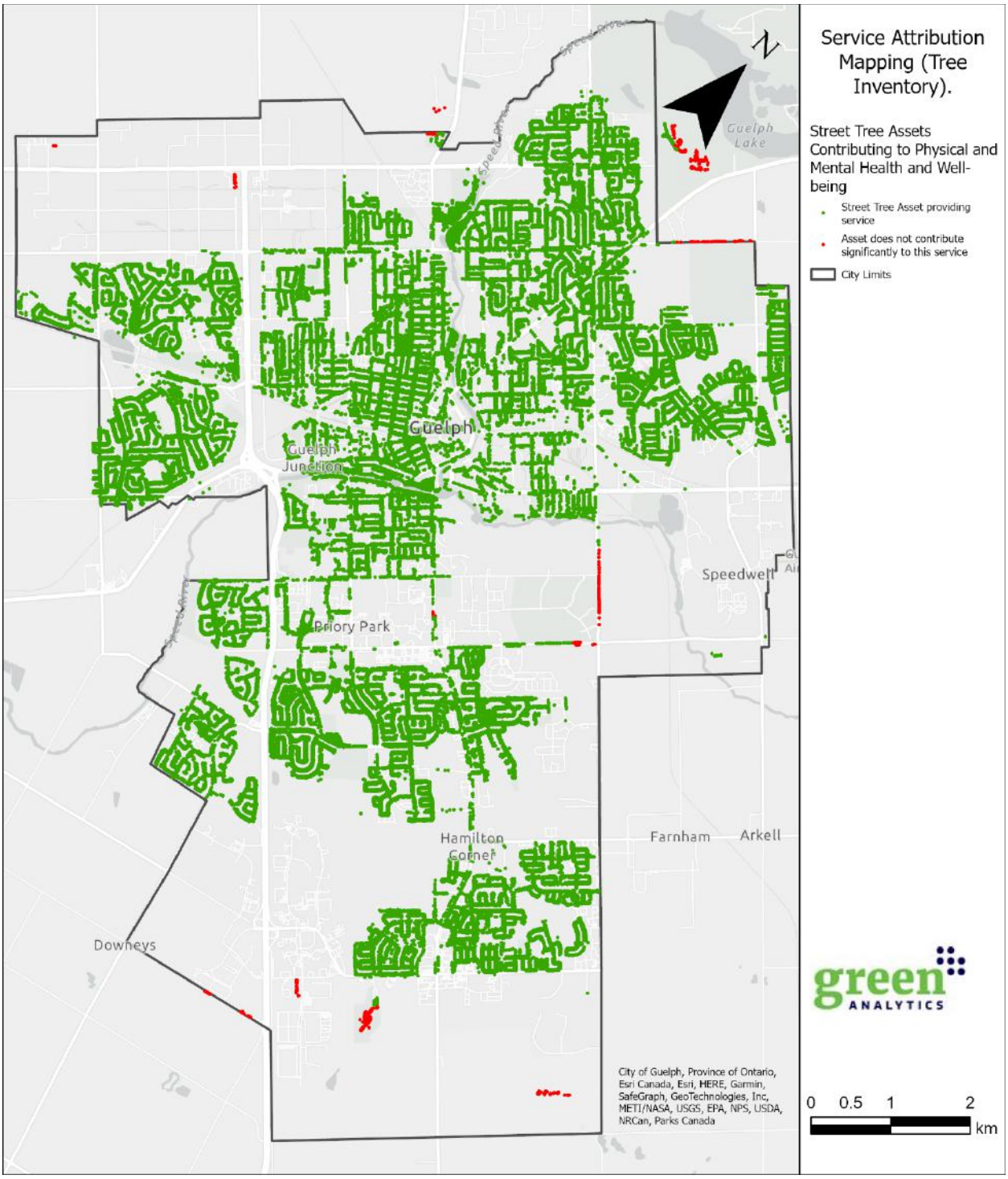

Figure 27. Street trees contributing to physical and mental health and well-being (from exercise in nature) (ES#3).

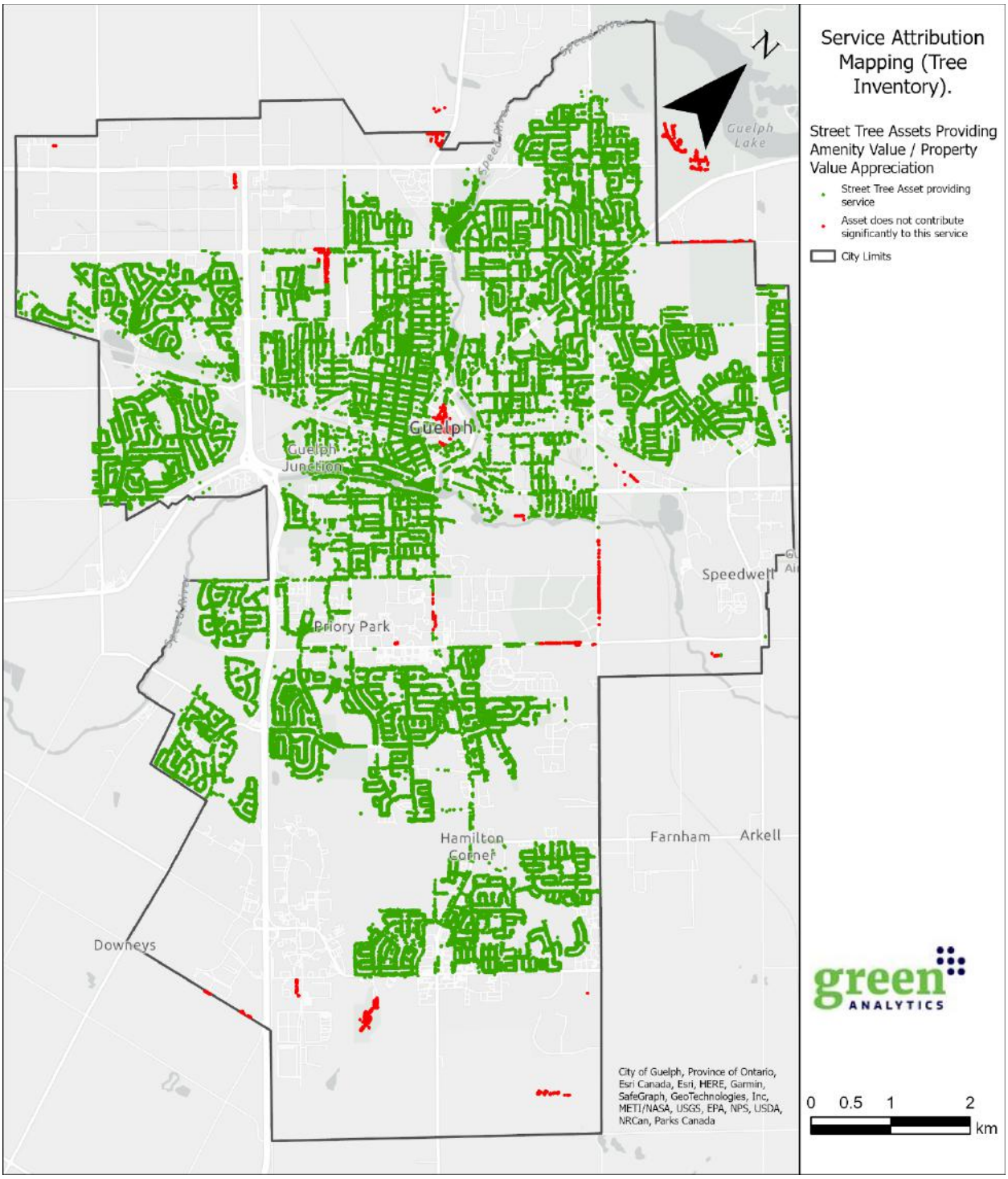

Figure 28. Street tree assets providing amenity value/property value appreciation (ES#5).

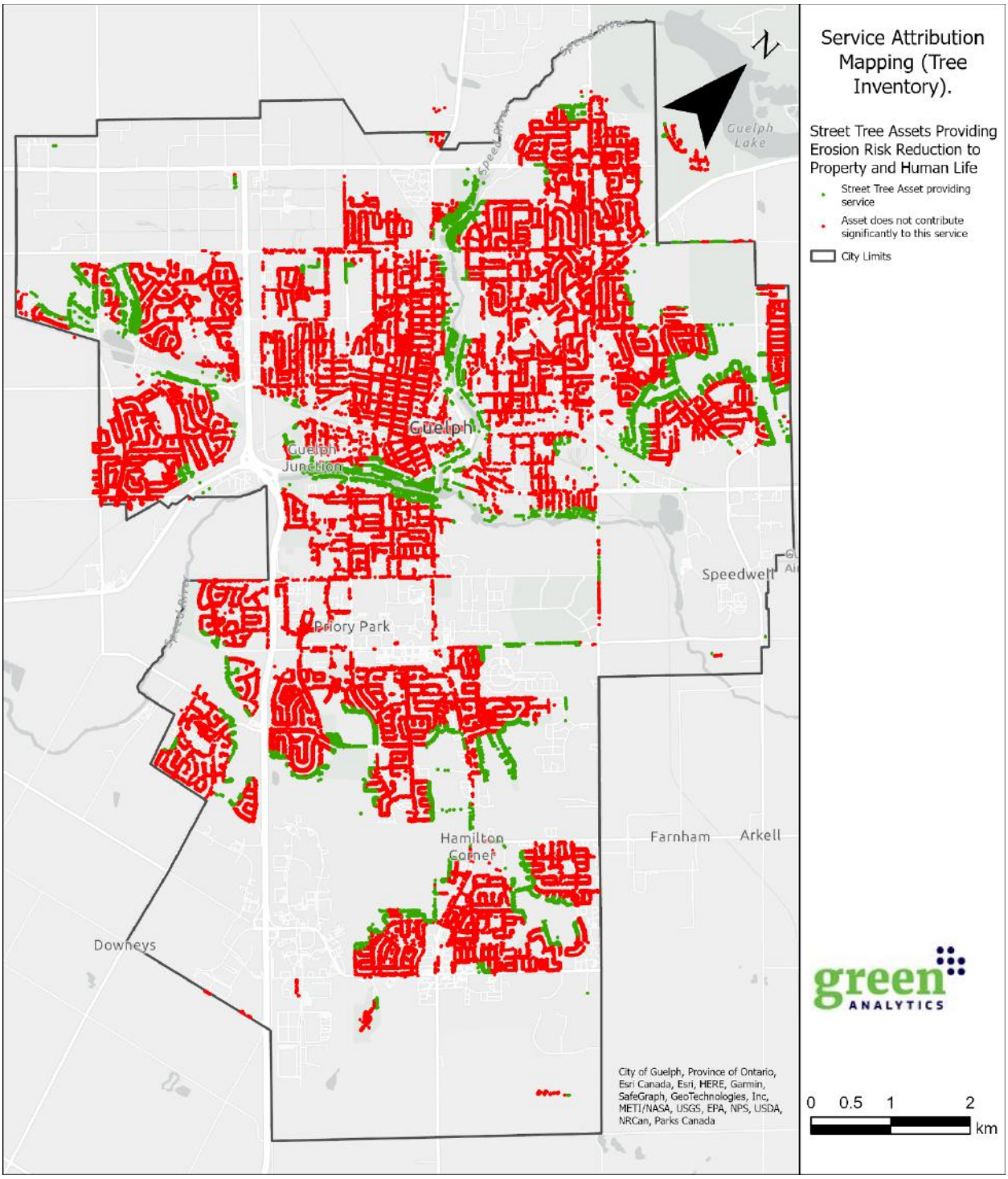

Figure 29. Street tree assets providing erosion risk reduction to property and human life (ES#8).

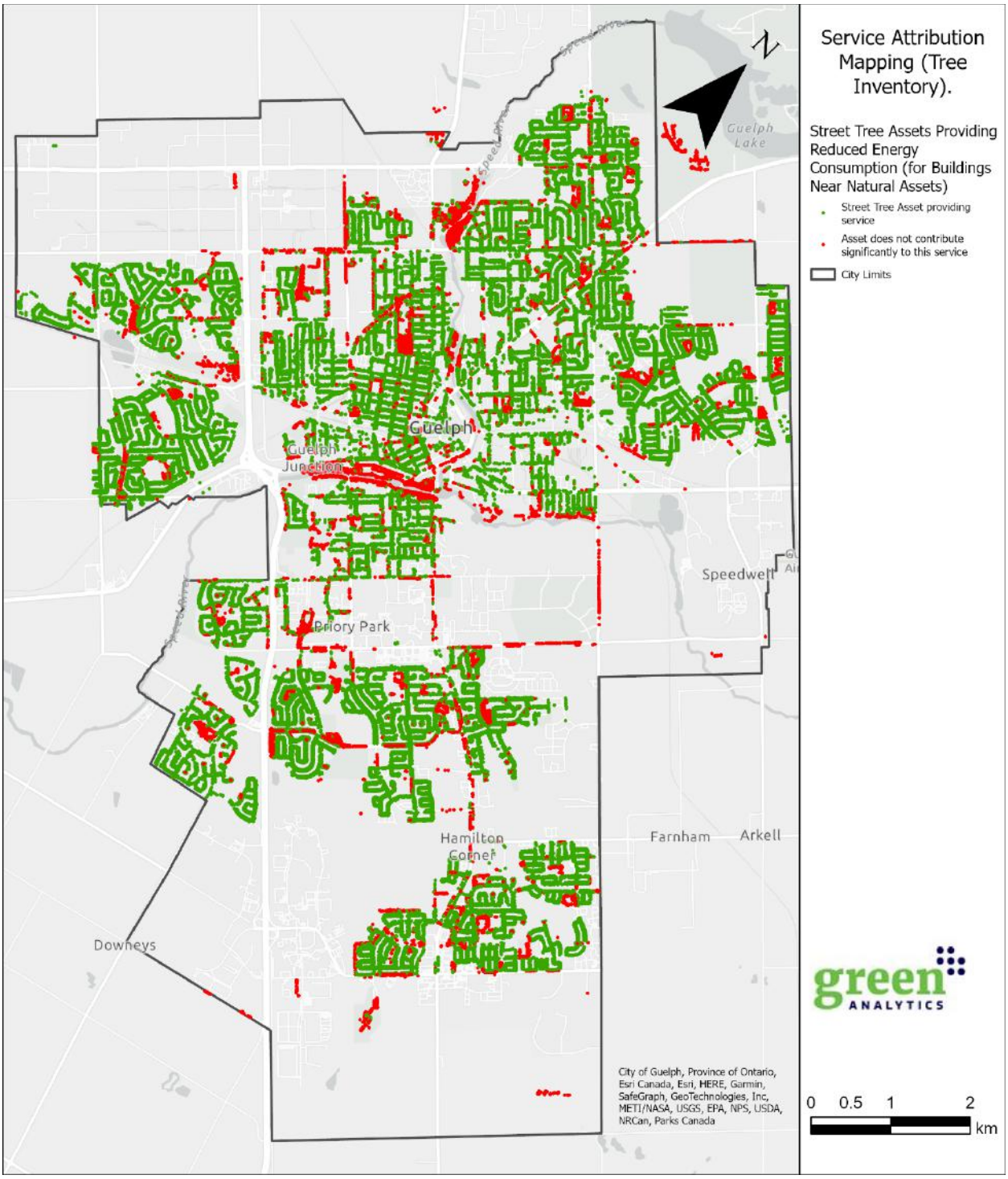

Figure 30. Street tree assets providing reduced energy consumption (ES#10).

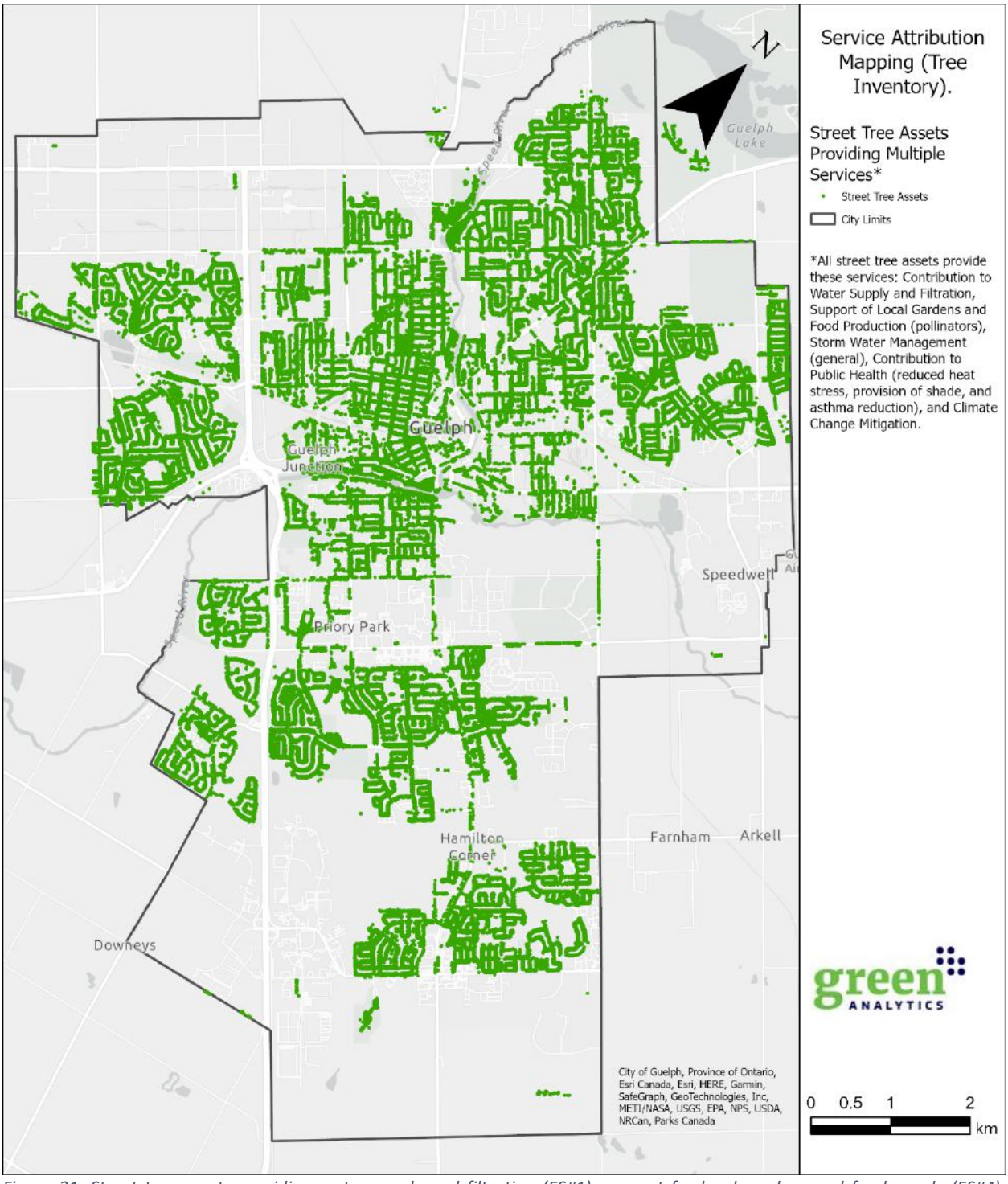

Figure 31. Street tree assets providing water supply and filtration (ES#1), support for local gardens and food supply (ES#4), stormwater management (water storage and management) (ES#6), public health (from reduced heat stress due to provision of shade and reduced asthma from air quality improvements) (ES#9, ES#11), and climate mitigation (due to carbon storage and sequestration) (ES#12).

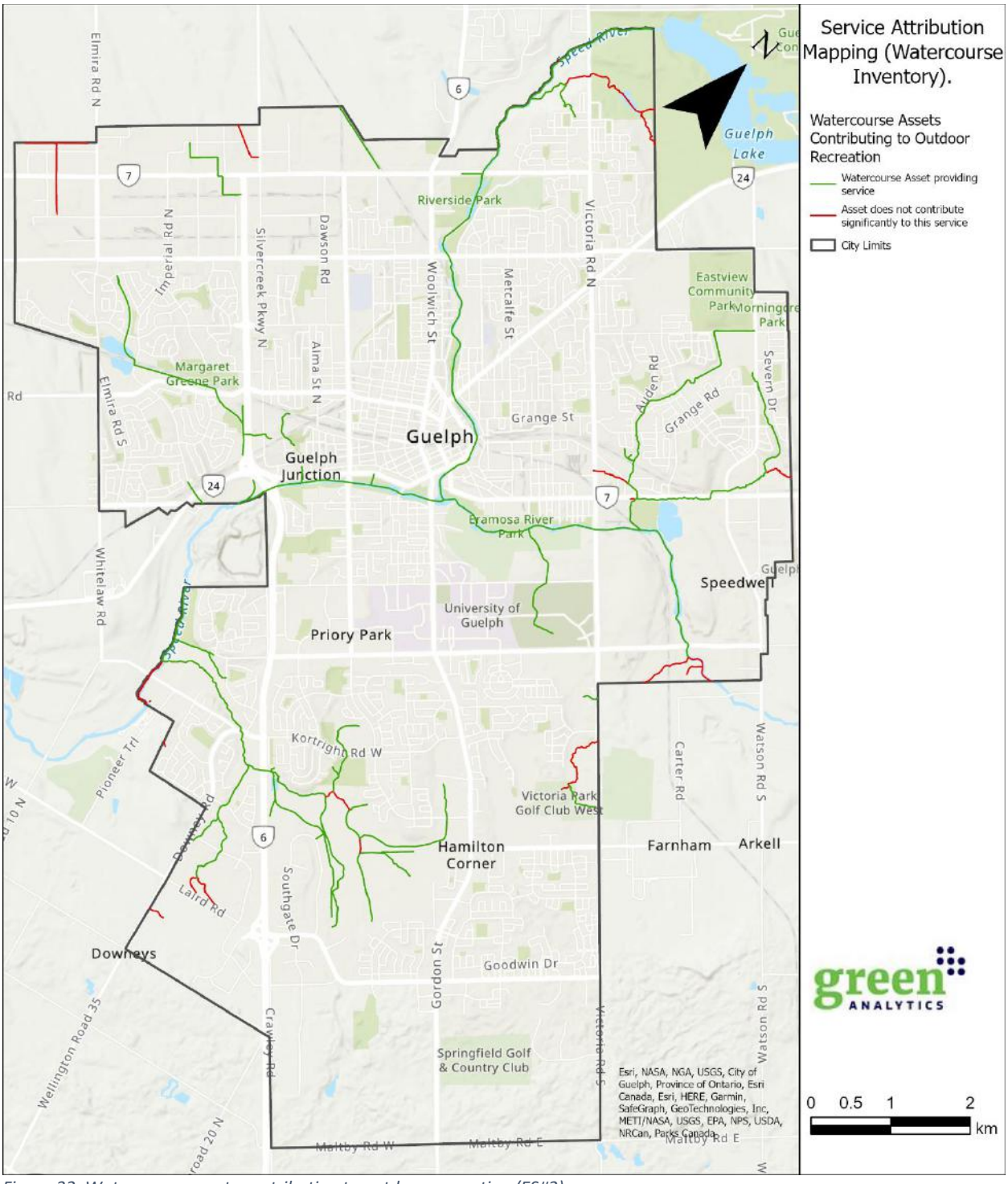

Figure 32. Watercourse assets contributing to outdoor recreation (ES#2).

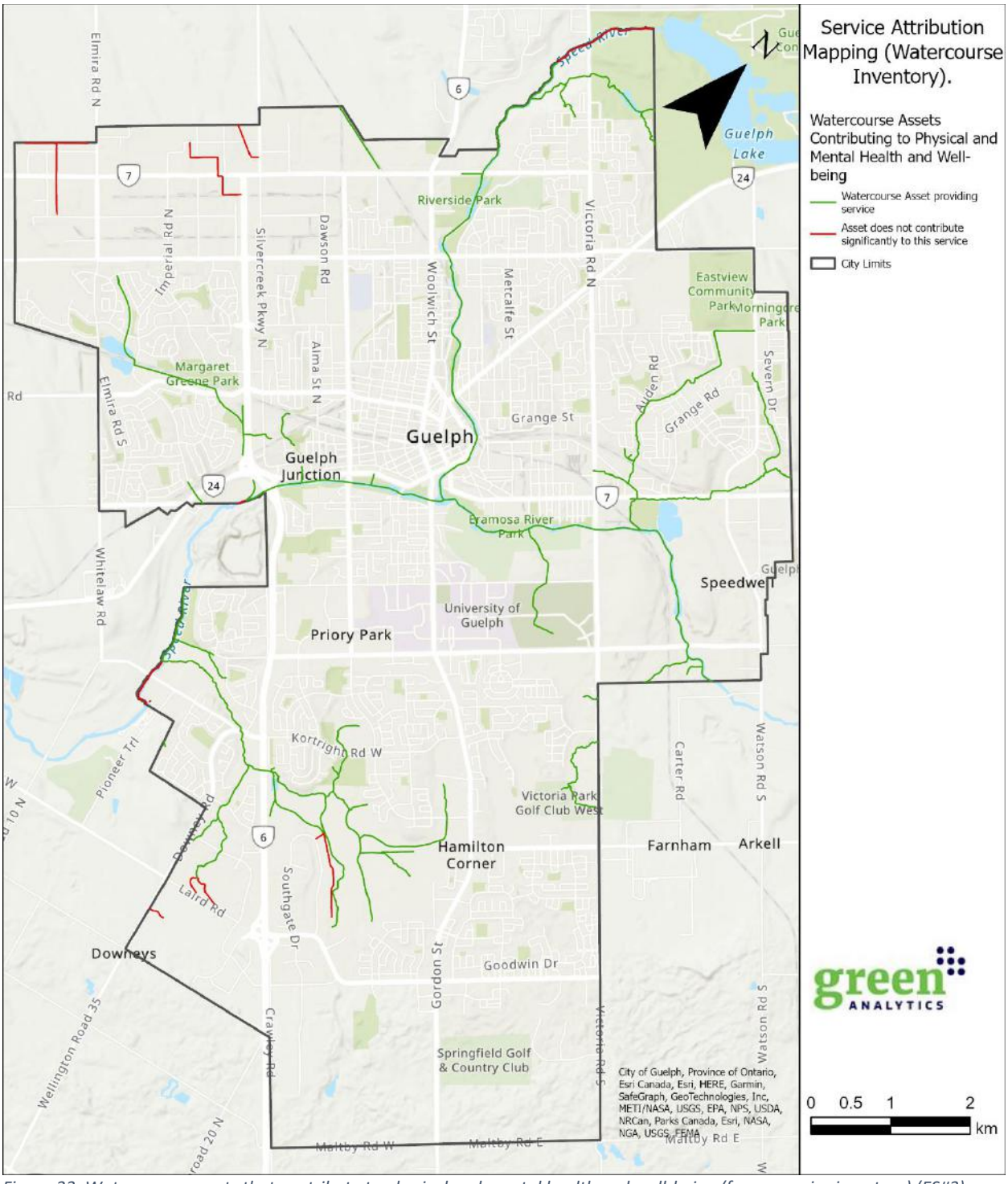

Figure 33. Watercourse assets that contribute to physical and mental health and well-being (from exercise in nature) (ES#3).

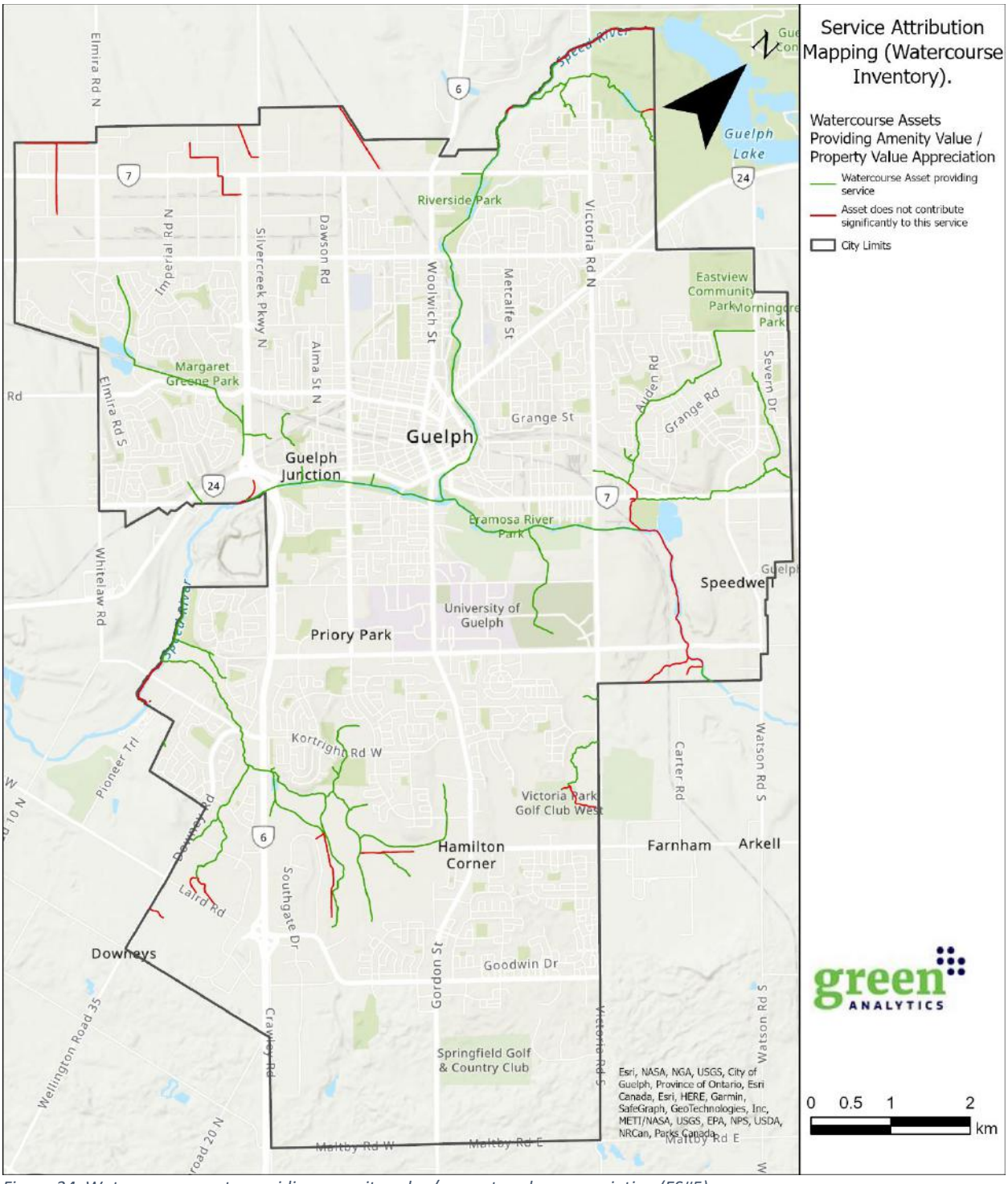

Figure 34. Watercourse assets providing amenity value/property value appreciation (ES#5).

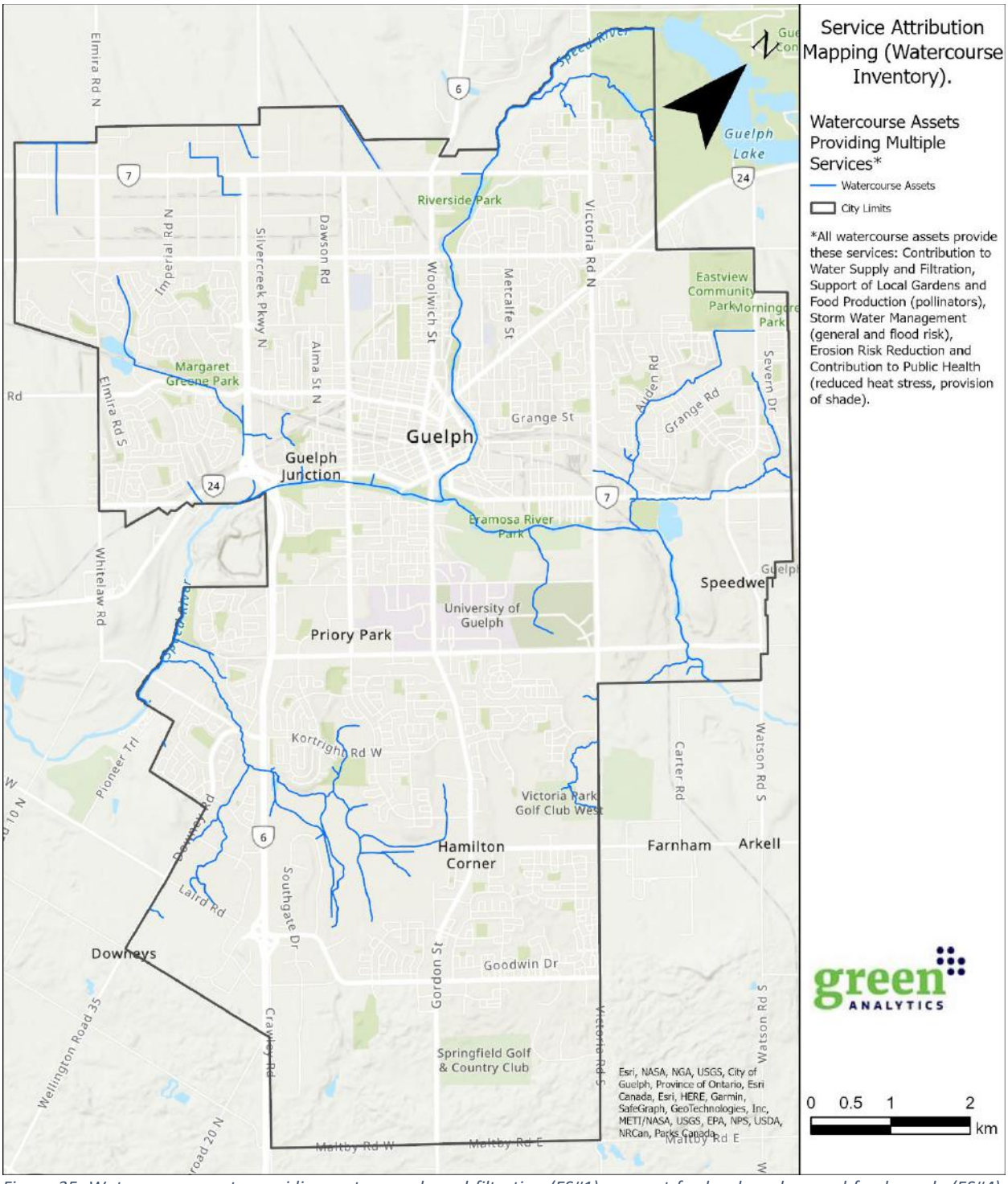

Figure 35. Watercourse assets providing water supply and filtration (ES#1), support for local gardens and food supply (ES#4), stormwater management (water storage and management) (ES#6), stormwater management flood risk reduction to property and human life (ES#7), Contribution to Public health (reduced heat stress, provision of shade) (ES#9), erosion risk reduction (ES#8) and contribution to human health due to reduced heat stress from the provision of shade (ES#11).

6 Concluding Remarks

This document provides an overview of the NAI framework and mapping results (based on the current data) for publicly-owned street trees, watercourses, and terrestrial natural features that are both publicly and privately owned in the City of Guelph. Although privately owned natural assets have been included in the terrestrial natural features inventory, they will only be considered through the City's natural asset planning as part of high level planning and to provide context but will not be considered for municipal maintenance and management planning and / or investment.

As noted in Section 1, the mapping and condition of these assets, as well as the ownership of the assets, can, and should, be updated on a regular basis as new information becomes available to optimize the value of the natural asset dashboard as a planning and management tool for the City of Guelph. For example, many of the terrestrial natural features currently in private ownership in the City's south end (i.e., south of Clair Road) are expected to come into public ownership through the planning process as the implementation of the Clair Maltby Secondary Plan proceeds.

As part of this first natural asset framework and assessment completed for Guelph, the GIS dashboard and database provided to the City, as described and illustrated in this report, includes:

- A City-wide inventory whereby the natural assets are depicted spatially demonstrating their type, location, distribution and extent (Section 2);
- A condition assessment that depicts the state of the assets according to seven metrics identified and confirmed in consultation with City of Guelph representatives (Section 3);
- A risk assessment which illustrates the relative risk to the assets according to a rating system that is in keeping with that used for built assets by City asset managers (Section 4); and
- Identification of key ecological services applicable in the City, and attribution of these services to the City's asset types.

The services provided by natural assets are of the utmost importance yet estimates of their value are frequently absent from decision-making processes. This includes, for example, the value of stormwater management, carbon sequestration and storage, air quality regulation, urban heat reduction, recreation opportunities and aesthetic appreciation.

By conceptualizing nature as an asset, asset managers are able to codify, measure, and track the ways in which citizens and municipalities depend on it, and assess the condition of assets, and the risks they are prone to, as an avenue for informing decisions about how to manage those assets. This parallels the approach taken for built municipal assets and is essential to ensuring the value of municipal natural assets and their ability to deliver services does not diminish over time.

Taking this approach can also reduce the need for costly investments in built infrastructure as in many cases, natural assets are able to provide comparable, if not superior, services to built assets (e.g., stormwater management services). This is clearly illustrated in the *Natural Assets Inventory Review and Valuation: Hanlon Creek Subwatershed* (EA 2022) developed as a pilot study for the City as part of this project and submitted under separate cover.

The approach used for the natural asset inventory and assessment described in this report is in keeping with the requirements of the *Asset Management Planning for Municipal Infrastructure Regulation* (O. Reg. 588/17) introduced by the Province of Ontario, and helps ensure that the City is in compliance with

this regulation, which requires municipalities to include green infrastructure in their asset management processes as part of comprehensive asset management plans by July 1, 2025.

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