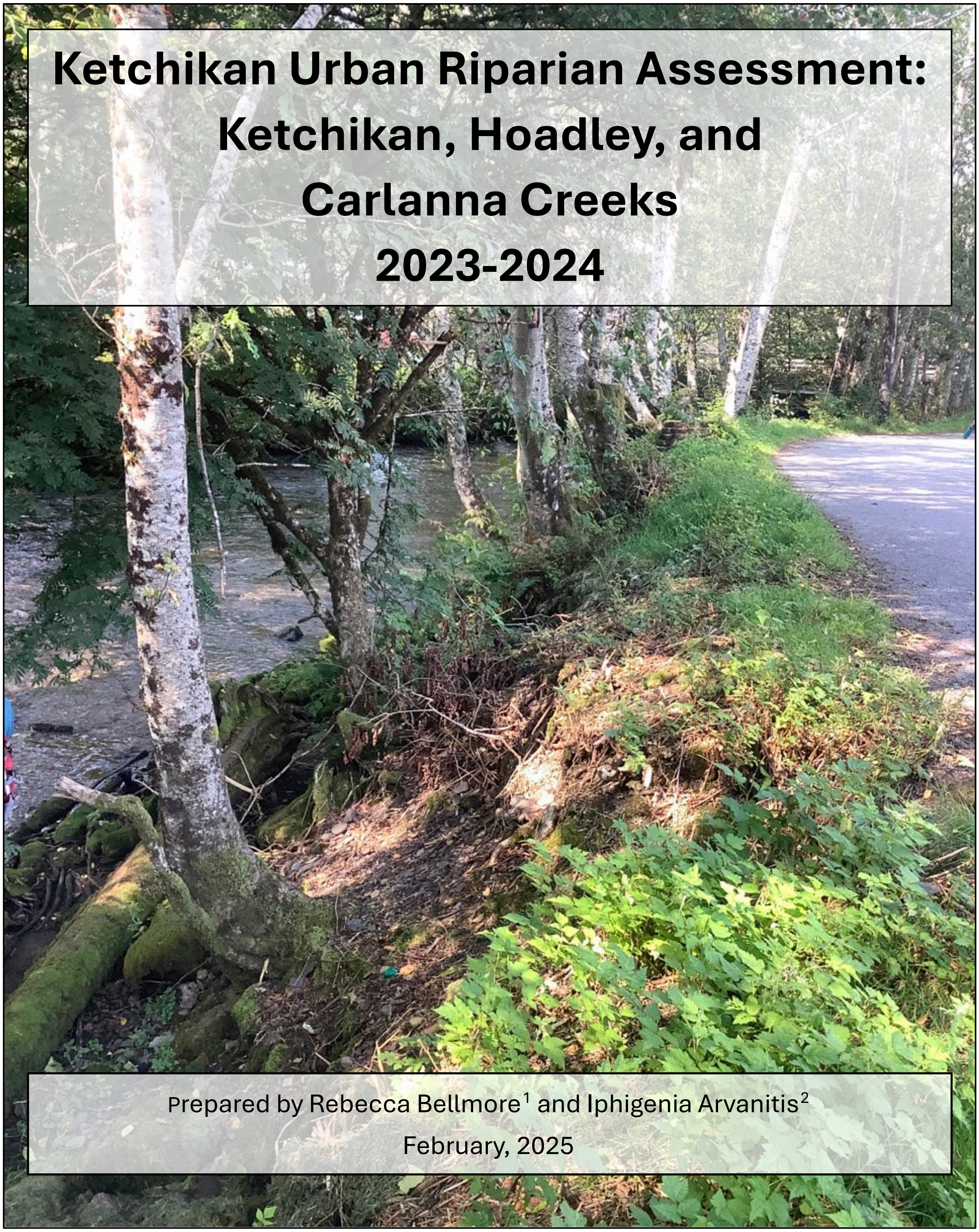
Ketchikan Urban Riparian Assessment: Ketchikan, Hoadley, and Carlanna Creeks 2023-2024



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Summary

Riparian zones are vegetated areas adjacent to streams that provide a range of ecological benefits and ecosystem services, including water quality treatment, stream temperature moderation, and fish and wildlife habitat. Urban development frequently encroaches on riparian buffers, impacting their functions and value. The riparian buffers of three urban streams, Ketchikan Creek, Hoadley Creek, and Carlanna Creek (Figure 1), were assessed to better understand their integrity, the impacts of development, and opportunities to improve their function and value for the community and ecosystem. Field assessments and desktop GIS analyses were combined to characterize cover type in the riparian buffers, map invasive species infestations, and identify places where development or other activities may be impairing riparian functions.

Ketchikan Creek's riparian buffer is the most densely developed of the three streams, and damage to remaining vegetation and soils is common due to easy access and heavy foot traffic. Hoadley Creek has active development, and land management on private property is impacting the riparian buffer throughout, with damaged native vegetation and drainage practices likely increasing erosion risk in many places. Carlanna Creek's riparian buffer is the least developed as a result of steep slopes that aren't conducive to building; however, the terrace is heavily developed on one side of the stream. Invasive plant infestations are a concern across the watersheds, and a more thorough assessment and a management plan are needed to address them, but many infestations are at a stage where eradication may still be feasible.

Location-specific recommendations are identified for each stream, but the highest priority recommendations to improve riparian health and function across the watersheds include:

- Restore existing riparian vegetation to reduce erosion, enhance treatment of current runoff, and promote fish and wildlife habitat.
- Invasive species assessment and management, especially knotweed, reed canarygrass, and European mountain ash.
- Outreach and education to landowners about the impacts of damaging riparian vegetation and dumping yard debris in riparian buffers.
- Assess the feasibility and potential efficacy of location-specific green stormwater infrastructure opportunities identified in the report.

Future actions could include:

- Establish a riparian setback for future (re)development.
- Detailed stormwater mapping.
- Implement green stormwater infrastructure projects.

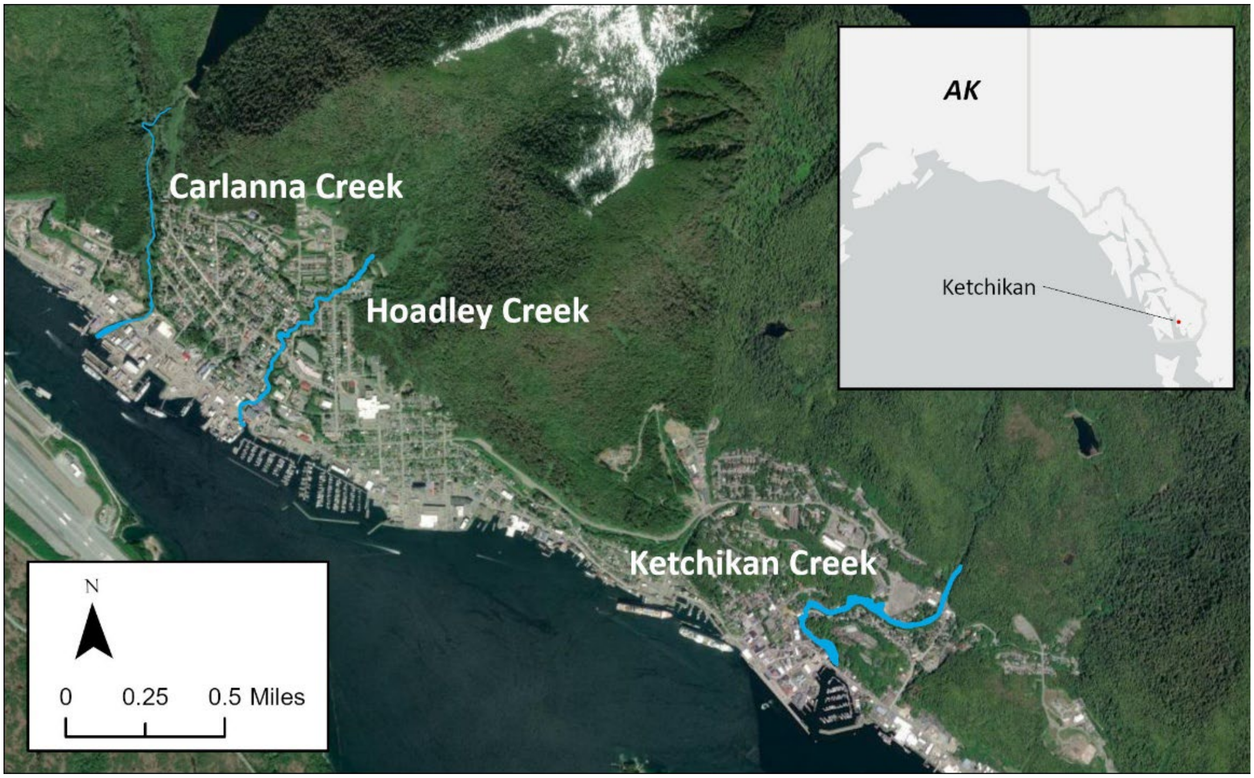

Figure 1. Overview of assessment areas, including Carlanna, Hoadley, and Ketchikan Creeks in Ketchikan, AK. The study focused on riparian areas of streams from the mouth upstream to the current extent of urban development.

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Study Purpose and Scope

Ketchikan is the second largest urban community in Southeast Alaska, with a population of approximately 14,000 residents. Previous water and sediment monitoring in Ketchikan's urban streams has identified concerns with pollutants that are often associated with urban development, including fecal bacteria and heavy metals, including zinc and copper. Additionally, 12 local beaches are listed as impaired water bodies due to fecal bacteria pollution, which human and pet waste contribute to.

Riparian zones – strips of vegetation along streams – support stream health and protect downstream water bodies by intercepting and treating pollutants, protecting soils from erosion, shading and cooling water, and providing fish and wildlife habitat. This study was undertaken to document the current status of Ketchikan's urban riparian areas and identify opportunities to improve riparian functioning and the health of adjacent streams and downstream water bodies.

The study focused on the riparian buffers of three streams that flow through the city of Ketchikan - including Ketchikan Creek, Hoadley Creek, and Carlanna Creek. The assessments were largely confined to within 50 feet of stream banks, from the mouth of the streams to the upstream end of current urban development, and focused on characterizing land cover, invasive species, drainage and erosion issues, and other land management impacts on native riparian vegetation to inform recommendations for restoring riparian health and functions. A cursory assessment of upland areas was conducted to identify opportunities for green stormwater infrastructure that can intercept and treat urban runoff before it reaches riparian areas and streams.

The Functions and Importance of Riparian Areas

Riparian zones are vegetated areas adjacent to streams, lakes and rivers. These dynamic areas intercept water draining from uplands, can be periodically flooded by surface water, and support unique vegetation and habitat. Vegetated riparian areas provide many benefits, including stabilizing streambanks and preventing erosion, protecting water quality by filtering and removing pollutants and sediment from runoff from upland areas, shading and cooling the stream, providing a corridor and habitat for wildlife, and contributing to high quality fish habitat. As development encroaches in riparian areas, these functions can be impaired. The loss of vegetation to impervious cover (e.g., rooftops, pavement), which reduces water infiltration into the soil, is particularly detrimental to riparian functions. Additionally, urban stormwater drainage systems often capture runoff and routes it directly into streams, bypassing the opportunity for riparian areas to treat urban stormwater runoff, which can carry sediment, heavy metals, excess nutrients, hydrocarbons, and bacteria.

Riparian buffer widths needed to support different functions have been investigated in many studies, and results can vary widely depending on the function of interest and site conditions (e.g., Wenger 1999, Mayer et al, 2005). Riparian vegetation and soils improve water quality by slowing water down and allowing sediments and associated pollutants to settle out and bind to vegetation and soils. As water infiltrates into soil, pollutants can be retained, processed and/or removed before reaching surface water. Steeper slopes, less surface roughness (e.g., vegetation), and certain types of soils allow water to move more quickly and minimize infiltration, reducing the effectiveness of riparian buffers as water treatment zones.

Ketchikan's urban streams and riparian areas provide habitat for five salmon species, cutthroat trout, steelhead, resident fish, deer, birds, and other wildlife, and they provide public green space and wild foods (Figure 2). However, Ketchikan currently lacks codified riparian buffer protections, and development has encroached on or replaced riparian areas in many places and may be impairing riparian functions. This assessment provides an overview of the status of riparian buffers along three of Ketchikan's urban streams – Ketchikan Creek, Hoadley Creek, and Carlanna Creek (Figure 1), and identifies opportunities for restoration and protection.

Figure 2. Top left: Sitka black-tailed deer feed on riparian vegetation. Top right: Blueberries provide forage for wildlife and people. Bottom left: Pink and chum salmon swim up Ketchikan Creek to their spawning grounds.

Methods

For the purposes of this study, 25- and 50-foot buffer widths were considered. While wider buffer widths may be preferred for some functions, a low-gradient, vegetated 50-foot buffer may provide relatively good protection (e.g. for fish habitat, sediment retention, nutrient removal). Additionally, from a practical standpoint, 50 feet is a common setback width in urban settings in Alaskan communities with setback regulations (e.g., Juneau, Kenai, Kodiak), and wider buffers may be especially difficult to mandate in areas with limited land available for development.

Desktop Analyses

Stream banks (bankfull) from the mouth to the upper extent of urban development were mapped using the following approach: City stormwater maps that included streamlines were georeferenced and stream outlines were converted to polygons. Bank edges were adjusted based on a DEM (OCM Partners, 2025) and derived slope data, and these were ground-truthed with bankfull width measurements at select locations in each stream. Horizontal buffers of 25 and 50 feet were delineated from mapped bank edges. There are likely many places where mapped streambank locations are not perfectly accurate, and mapped buffers should not be used for any regulatory purposes. However, this assessment is meant to provide an overview of riparian buffer status, and small inaccuracies will not impact the overall results.

Land cover types within the 25- and 50-foot buffers of the stream banks were categorized based on type of disturbance/development, including pavement, rooftop, semi-permeable developed; managed/damaged vegetation, and natural riparian (described below). High resolution aerial imagery (National Geodetic Survey, 2024) provided the basis for delineating cover types, which were ground-truthed during the field assessment where possible. Because much of the land along the riparian buffers is private, areas that weren't publicly visible could not be verified; however, aerial imagery was adequate in most places to delineate these coarse land cover categories. Maps with land ownership along the streams are provided in Appendix A.

<u>Cover Type Descriptions</u>

Paved: includes impervious asphalt/concrete streets, sidewalks, driveways, etc.

Paved areas have serious impacts on riparian function and stream ecosystems. There is a total loss of vegetation and water infiltration capacity, and pollution from vehicles, industrial activities, etc. on roads can degrade water quality in nearby streams, particularly when stormwater systems capture runoff and route it directly to the stream (e.g. Charters et al, 2021). Since rain and snowmelt cannot soak into soils and are rapidly transported to streams, peak flood flows can increase, and baseflows may decrease in areas with extensive pavement (Avellaneda and Jefferson, 2020).

Rooftop: includes the footprint of building roofs.

Like pavement, these areas also represent a total loss of riparian vegetation and water infiltration capacity. Atmospheric deposition of pollutants on rooftops and leachates from roof material can be a source of pollution from roofs (De Buyck et al, 2021). If gutters are directly connected to the storm drain system, rather than dispersing water onto a permeable surface, the impacts of rooftop area on stream hydrology and water quality are more severe (Taguchi et al., 2018).

Semi-permeable, developed: includes partially permeable, developed areas such as gravel, decks, and highly disturbed vegetated areas (e.g. vehicle parking).

These areas represent a near or total loss of riparian vegetation and can be a source of sediment and other pollutants to streams. However, because some water can still infiltrate, impacts to flood flows may be less severe than impervious development, and some pollutants may be removed as water flows through the subsurface.

Managed/damaged vegetation: includes vegetated areas where the natural vegetation has been highly disturbed and is unlikely providing as much wildlife or water quality benefits as undisturbed riparian vegetation. This includes grass/lawns and riparian areas where trees and woody shrubs have been cut/removed.

Natural riparian: includes areas that retain undisturbed native riparian vegetation, trees, and/or woody shrubs. (Invasive species encroachments into these areas are noted in the study).

Field Assessment

Trained staff from the Southeast Alaska Watershed Coalition and Ketchikan Indian Community conducted a field assessment of the riparian areas around lower Ketchikan, Hoadley, and Carlanna Creeks in Ketchikan, AK (Figure 1) on August 21-25, 2023. Follow-up assessment work occurred on June 17, 2024 and October 21-22, 2024. The upper and lower extents of the assessment are shown in subsequent sections focusing on each creek's riparian area.

The assessment focused on areas within 50 feet of the stream banks, although relevant issues outside this buffer were noted. In addition to documenting ground cover types, stormwater outfalls and drains were mapped for comparison to previous mapping efforts, litter or other obvious pollution issues, areas of erosion, bank failure and other disturbances, and invasive species. Invasive species were not exhaustively documented, which was beyond the scope of this project, but highly invasive species like knotweed (*Reynoutria spp*), reed canary grass (*Phalaris arundinacea*), and European mountain ash (*Sorbus aucuparia*) were noted whenever they were observed. Data were collected in Field Maps, and photos were taken at most data collection points. In the findings below, the terms "river right" and "river left" refer to the side of the river when facing downstream.

During the field assessment a cursory assessment of existing stormwater management practices and infrastructure was conducted, and potential locations were identified where green stormwater infrastructure (GSI) could be implemented in the future to improve water quality and reduce flood risk. Potential projects that were identified for each watershed are described below but still need to be vetted for feasibility and potential effectiveness. An important first step would be to supplement existing storm water infrastructure maps with more detailed storm water mapping that clearly identifies where runoff travels over the land surface before reaching storm drains. This allows GSI to be properly sized and designed for the contributing area and potential pollutant types and loads. A summary of GSI types that may be appropriate for these watersheds are described in Appendix B.

Carlanna Creek

Watershed Context

Carlanna Creek drains a 2.5 square mile watershed (Figure 3). The upper watershed is forested and includes Carlanna Lake, which is dammed. The stream is listed for coho, chum, and pink presence from the outlet to just upstream of the confluence with Signal Creek, where there is a large waterfall (AWC Code 101-47-10180). Carlanna Creek flows through a steep and deep ravine with slopes averaging over 45 degrees (100%) from just below Carlanna Lake to approximately 0.1 miles above Tongass Avenue; in some places the terrace elevation is more than 150 feet above the stream. Urban development extends from the coastline to approximately 0.45 miles upstream of Tongass Avenue on the east side of the creek and 0.2 miles upstream on the west side of the creek. Upstream of Tongass Avenue, development extends to the edge of the terrace.

Riparian Assessment Results

The riparian buffer directly adjacent to Carlanna Creek is mostly intact, as its steepness precludes most development (Figure 4). Within the 50-foot riparian buffer, most development is in the most downstream portion (Figure 4). In total, 22% is developed, including just 9% impervious surfaces (pavement, rooftops) and 12% pervious cover (Figure 5).

However, because the stream banks are so steep, common target horizontal riparian buffer widths (e.g. 50 feet) are likely to be less effective at intercepting and treating stormwater, especially particulates and associated pollutants like heavy metals and polycyclic aromatic hydrocarbons (PAH) (Wegner, 1999). Therefore, the cover within 25 and 50 feet of the terrace edge, the last low-gradient area that would be efficient at retaining and removing pollutants from stormwater before it reaches the stream, was also assessed. Overall, 45% of the terrace buffer is developed, including 13% impervious cover (Figure 5). The terrace buffer is more highly modified and developed on the east side (river left); within 25 feet of the terrace edge, nearly 20 percent is paved, semi-permeable, or rooftop, and another third is managed or damaged vegetation (Figure 5). From 25 to 50 feet from the terrace edge, nearly half of the buffer is paved, semi-permeable, or rooftop, and nearly another third is managed or damaged vegetation, leaving just over 20% remaining as natural/unmanaged vegetation (Figure 5).

Despite limited development directly adjacent to the stream, knotweed, a highly invasive species that spreads vegetatively by rhizomes (pieces of root or stems) was documented in the riparian area (Figure 6). The most upstream mapped location of knotweed is a very large patch (at least 50 by 100 ft) that extends up the slope on river left and has established on river right as well (Figure 7). There are documented knotweed patches in the neighborhood on river left, and the infestations in the riparian area may have been spread by yard debris that was dumped or via stormwater carrying pieces of knotweed.

The steep stream banks are prone to erosion, particularly if native vegetation is removed or replaced with certain invasive species like knotweed (Matte et al., 2021). Damaged riparian vegetation was documented downslope of the residential development on the west side (river right) (Figure 8), and there were areas of erosion around stormwater outfalls on the east side (river left)

(Figure 8). Most of the stormwater runoff in the watersheds is collected by the stormwater drainage system and carried to the creek via three storm drain pipes that end not far below the top of the terrace (Figure 6), with outflows emptying onto the steep riparian buffer. At low flows, there may be some capacity for infiltration and stormwater treatment; however, at moderate to higher flows, stormwater runoff is likely flowing overland and quickly reaching the stream. Additionally, runoff from streamside properties that do not drain to the stormwater system will also flow down the steep banks with limited infiltration, especially where rivulets form on the steep slopes. Therefore, managing erosion, pollutant spills, and fertilizers on these properties is important for protecting water quality.

Recommendations

- Invasive plant survey and management; especially knotweed, including along the stream and in the neighborhood area on the east side of Carlanna creek.
- Restore damaged riparian vegetation in the downstream developed areas and on steep slopes to prevent erosion (Figure 9).
- Education and outreach about not dumping yard waste into the riparian area.
- Establish a setback from the terrace edge for any future development.
- Potential stormwater BMP project (requires additional vetting for feasibility and efficacy):
    - Explore stormwater BMP opportunities for parking lot runoff on the property NW of Tongass Ave., including enhancing the riparian area and/or the drainage ditch (Figure 9).

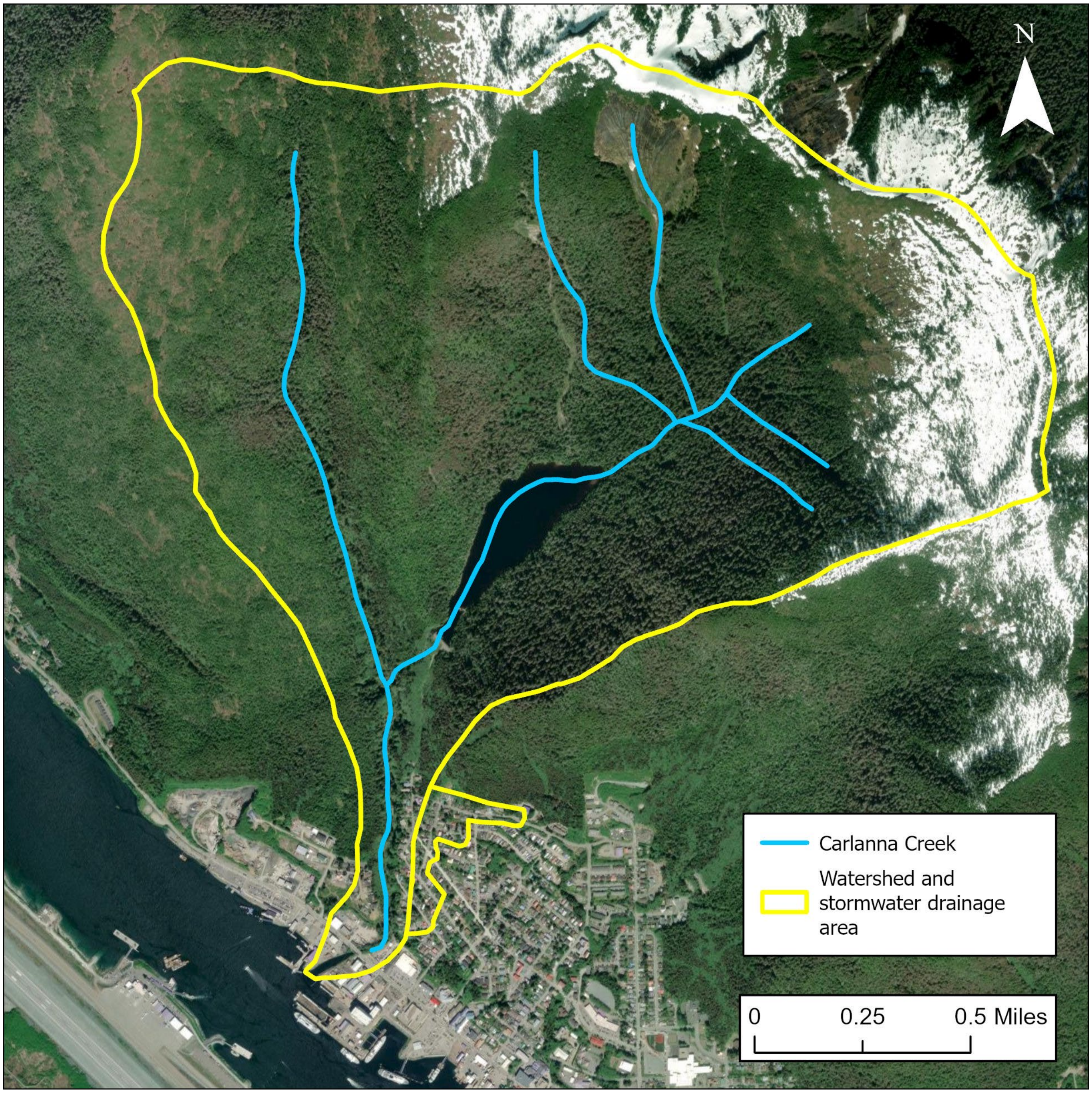


Figure 3. Map of Carlanna Creek watershed, including contributing areas to storm drains on the east side.

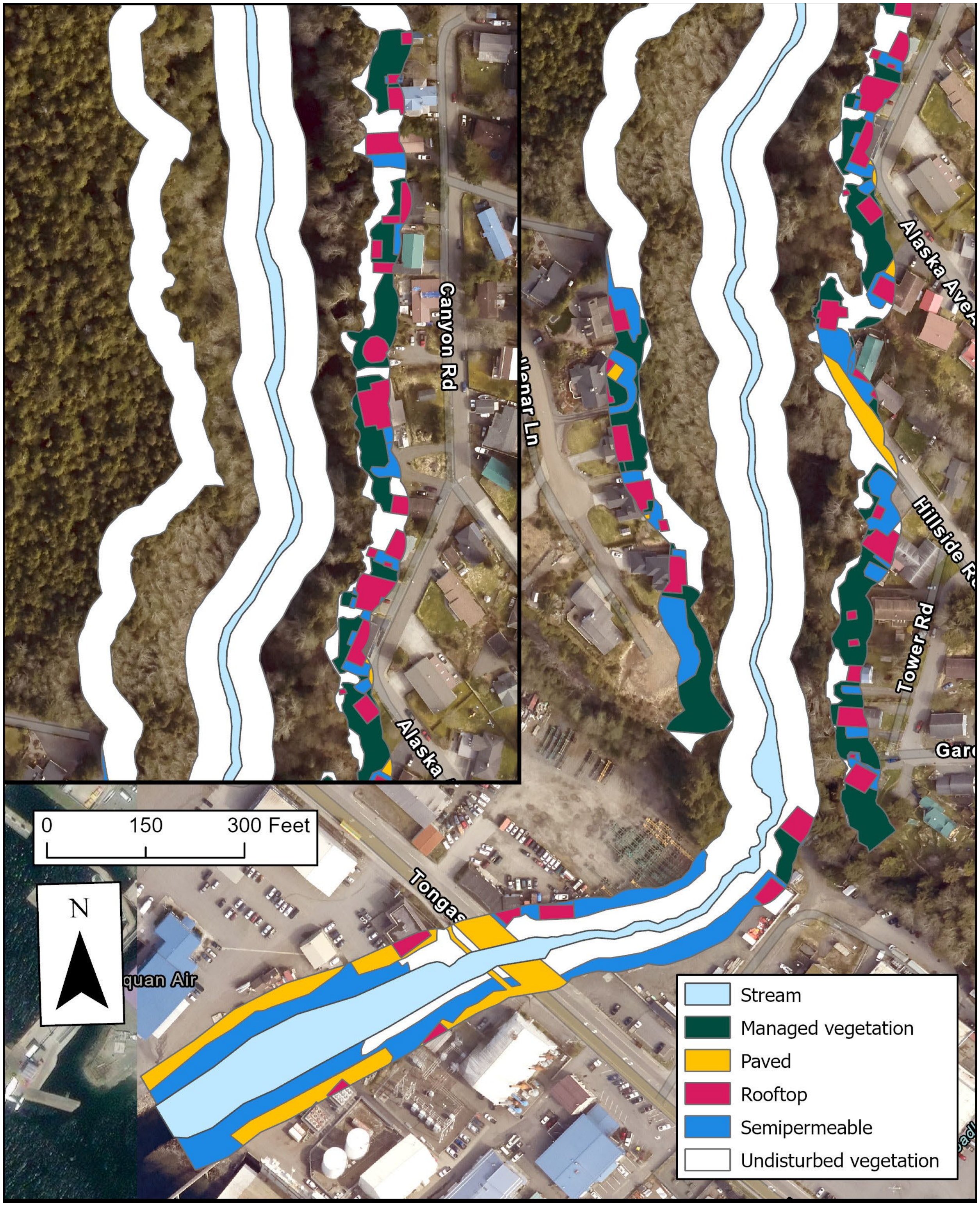
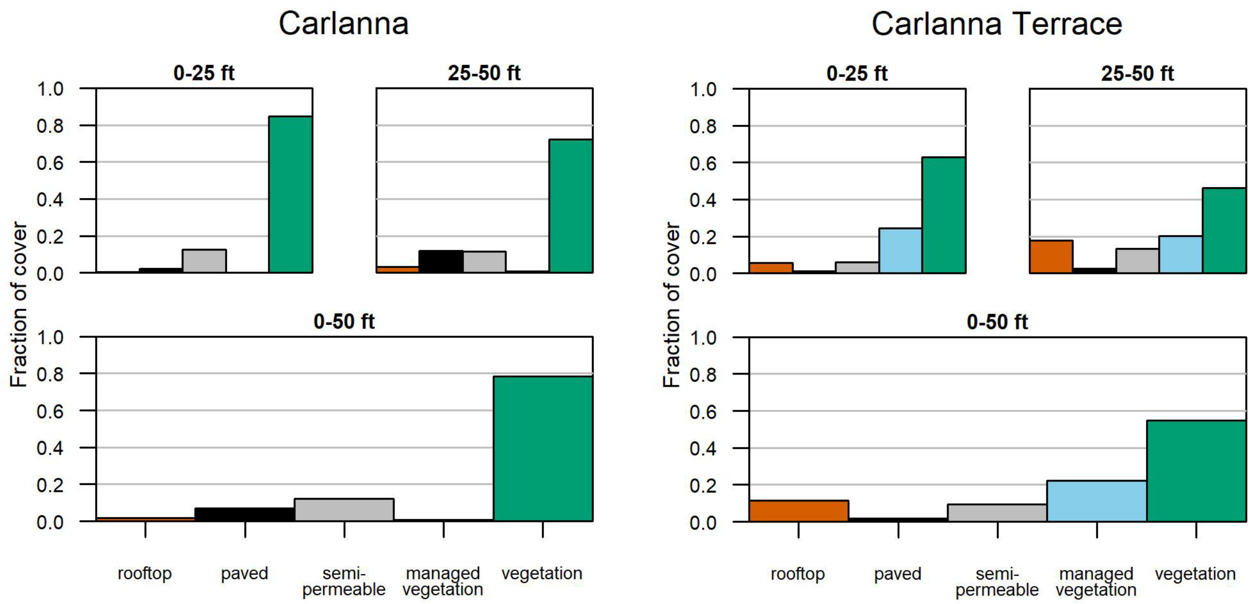


Figure 4. Land cover in the riparian buffer and terrace buffer of the lower and upper (inset) portions of Carlanna Creek. Buffers extend 50 feet from the stream bank or terrace edge.

Land Cover in Carlanna Creek Riparian Buffer



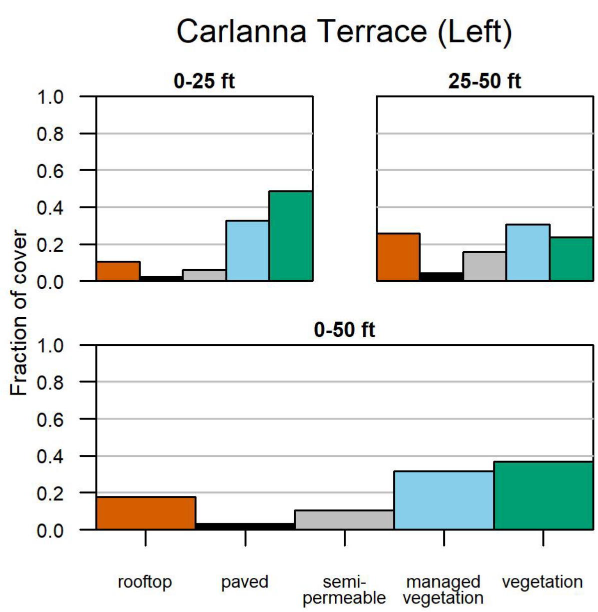


Figure 5. Land cover types within 50 feet of Carlanna Creek (top panels) and within 50 feet of the terrace edge (bottom panels). Panel titles indicate the buffer distance from the edge of the terrace: within a 25-foot buffer, 25-50 feet, or within 50 feet of the stream.

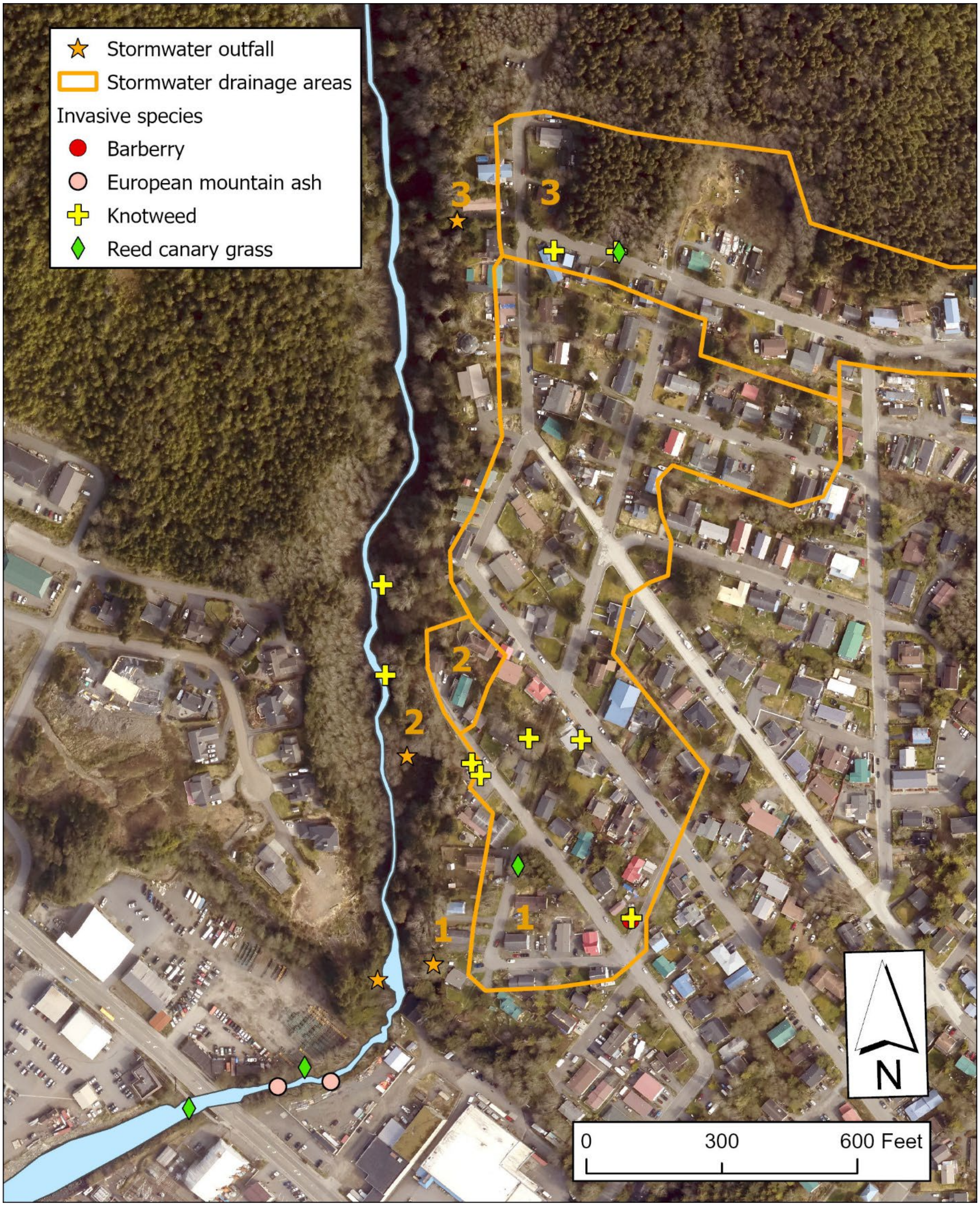


Figure 6. Locations of stormwater outfalls and approximate contributing areas (numbered), and locations of invasive species along Carlanna Creek and in the neighborhood to the east (neighborhood invasive species inventory was not comprehensive). The contributing area for the outfall on river right was not mapped.

Figure 7. Left: Large knotweed infestation (behind person), view from downstream. Right: Knotweed spreading on river left (lower left of image).

Figure 8. Gullies form on the steep slopes, rapidly transporting stormwater from developed areas on the terrace to the stream. The gully shown in the right photo is below a stormwater outfall.

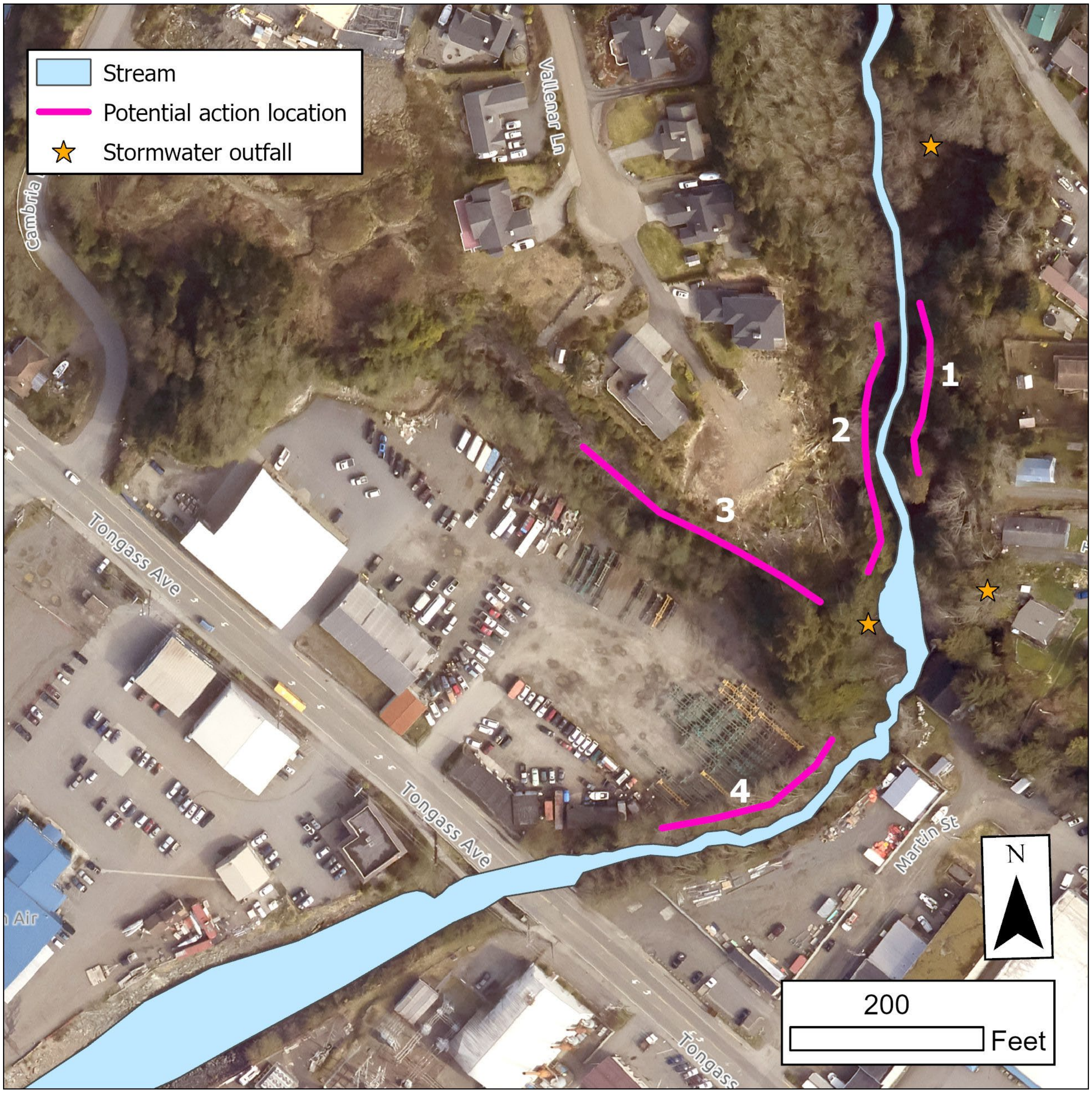


Figure 9. Potential locations for on the ground action, including: 1. and 2. Restore vegetation; 3. Install check dams and/or vegetate the gravel drainage ditch to create a bioswale; 4. Enhance interception and treatment of runoff in the riparian area by expanding the buffer, installing flow spreaders, and/or creating features like rain gardens.

Hoadley Creek

Watershed Context

Hoadley Creek drains a 0.8 square mile watershed (Figure 10). The upper watershed is forested, with the lower quarter developed to the shoreline. The stream is listed for coho presence and pink spawning from the mouth to Baranof Avenue, where a perched culvert presents a barrier (AWC Code 101-47-10200). The upper portions of development in Hoadley watershed are residential, with new and ongoing construction, while the lower watershed includes high traffic areas like the hospital and other medical offices, the elementary school, and several churches. Hoadley Creek flows in a deeply incised channel with steep banks in many areas, where the creek is not visible or easily accessible from the street level.

Riparian Assessment Results

The 50 foot riparian buffer in the lower commercial portion of Hoadley Creek is highly developed compared to upper portions through residential areas, although there are many homes and apartment buildings within the buffer (Figure 11). Overall, 34% of the 50 foot riparian buffer along the urban stretch of Hoadley Creek is developed (pavement, rooftop, semi-permeable, and managed vegetation like lawns), with 18% of that impervious surfaces (pavement + rooftop) (Figure 12). Several reaches of the creek are enclosed in large culverts, including over 250 feet beneath the hospital complex and 150 feet under Baranof Ave.

In addition to the impervious and semi-pervious development in the buffer, many locations where natural vegetation had been damaged by cutting, disposal of yard debris, and/or erosion associated with development were noted (Figure 13, Figure 14). These areas provide less functional habitat for wildlife and fish and make the banks more susceptible to erosion and should be a target for restoration. Additionally, many outfalls of local drains separate from the city stormwater system (e.g. French drains from private property) were documented along Hoadley Creek. Some outfalls empty onto bare soil, potentially contributing to erosion or increasing the risk of mass wasting events by saturating the soil, while other drains extended nearly to the creek, bypassing potential stormwater treatment in the riparian buffer (Figure 15). Outreach to landowners adjacent to the creek could improve storm drain outlet BMPs.

Invasive species were present along the stream throughout the urban area (Figure 16). There are many European mountain ash in the lower reach, and several knotweed patches were also documented downstream of Baranof Ave. that have the potential to spread rapidly in the riparian area (Figure 17). Invasive species should be targeted for control before they spread further into steeper, less accessible areas.

A few litter hotspots were documented, including up- and downstream of Baranof Ave. Illicit camping appeared to be a source, along with household waste (e.g. full garbage bags). Large woody vegetation in the area upstream of Baranof Ave was removed sometime between the summers of 2023 and 2024, possibly to address nuisance camping or loitering.

The watershed is steep and densely developed, leaving little room for green stormwater infrastructure. However, a few locations where parking lot and street runoff could be diverted to bioswales or infiltration basins before reaching the stormwater system were identified. These include the parking lot at 130 Carlanna Lake Rd. (Figure 19), near the parking area of Houghton Elementary (Figure 20), and along Baranof Ave near the creek crossing (Figure 21). The area around Jackson Heights and Jackson St. can also be assessed for additional BMP opportunities (Figure 22).

Recommendations

- Invasive species treatment, especially reed canarygrass and knotweed between Baranof Ave. and 1st Ave.
- Riparian vegetation restoration priority areas:
  - Hospital reach
  - Upstream of Baranof
  - Private landowners with impacts from recent construction
- Outreach and education about not dumping yard waste, protecting/restoring native vegetation, and erosion mitigation.
  - Impacts associated with new construction
  - Stormwater drain and private local/french drain outlet BMPs
- Litter prevention and control
  - Up- and downstream of Baranof Ave.
  - Tongass Ave. bridge area
- Potential stormwater BMP opportunities (all require additional vetting for feasibility and efficacy) (Figure 23):
  - Create an infiltration basin in the parking lot of professional building at 130 Carlanna Lake Rd. (area that is already non-functional for parking) (Figure 19)
  - Explore ways to re-route stormwater into gravel area between sidewalk and parking lot of Houghton Elementary along Baranof Ave. to create a retention basin/bioswale (Figure 20).
  - Create curb cuts and an infiltration basin along the downstream side of Baranof Ave to the east of Hoadley Creek (Figure 21).
  - Explore BMP options and potential efficacy at the NE corner of Jackson Heights and Jackson St. (Figure 22).

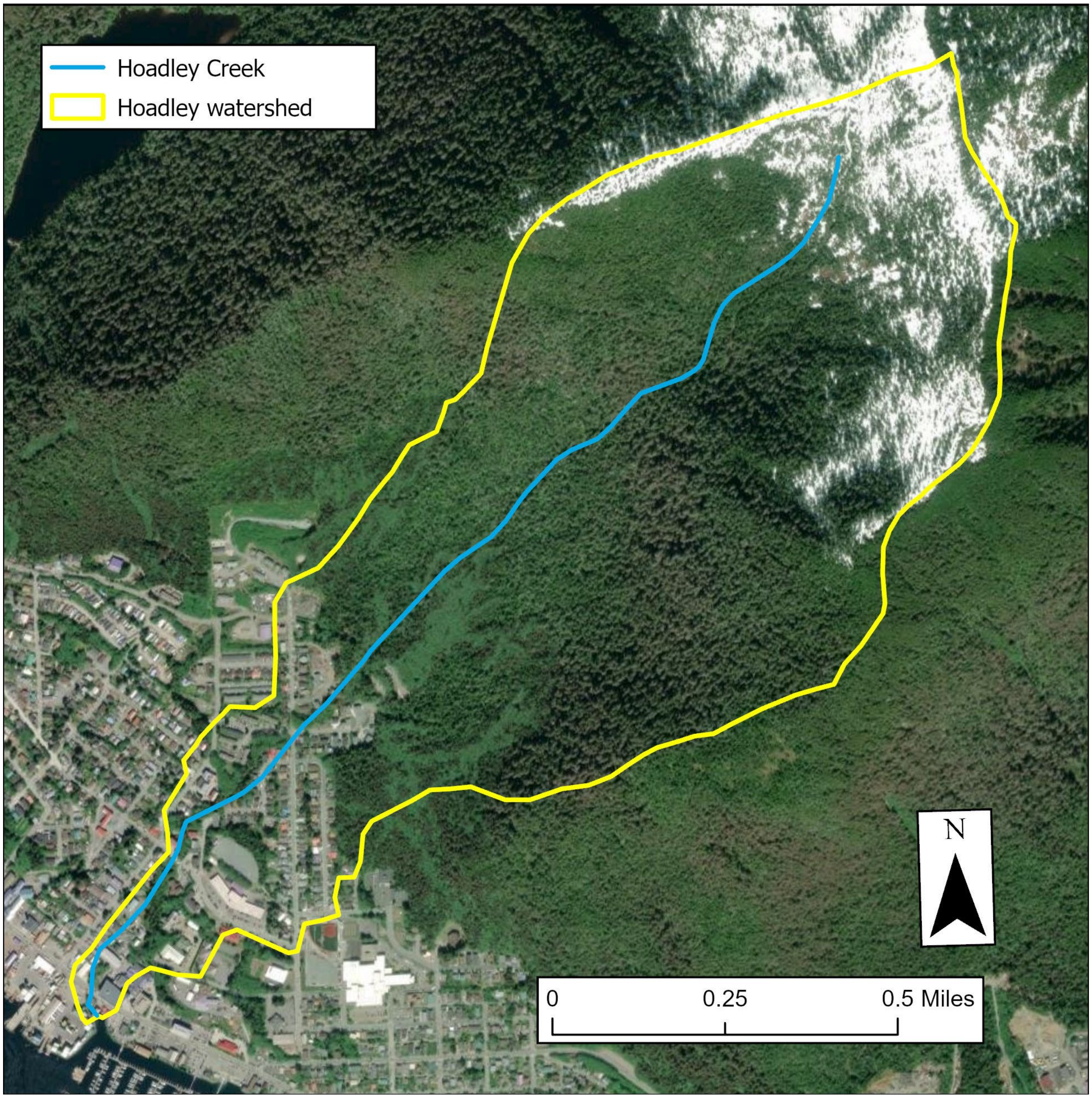


Figure 10. Overview of Hoadley Creek watershed.

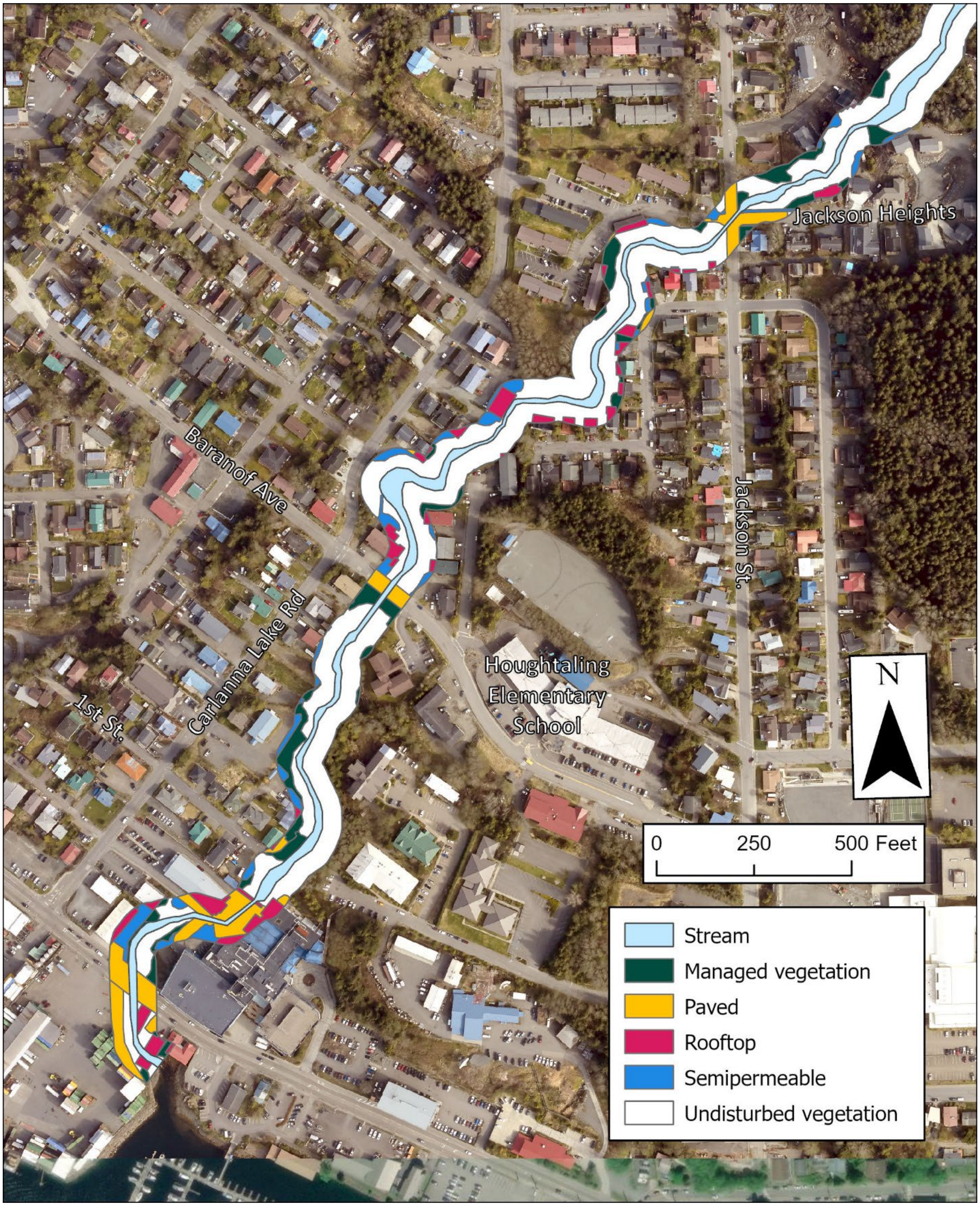


Figure 11. Land cover types within the 50-foot riparian buffer of Hoadley Creek.

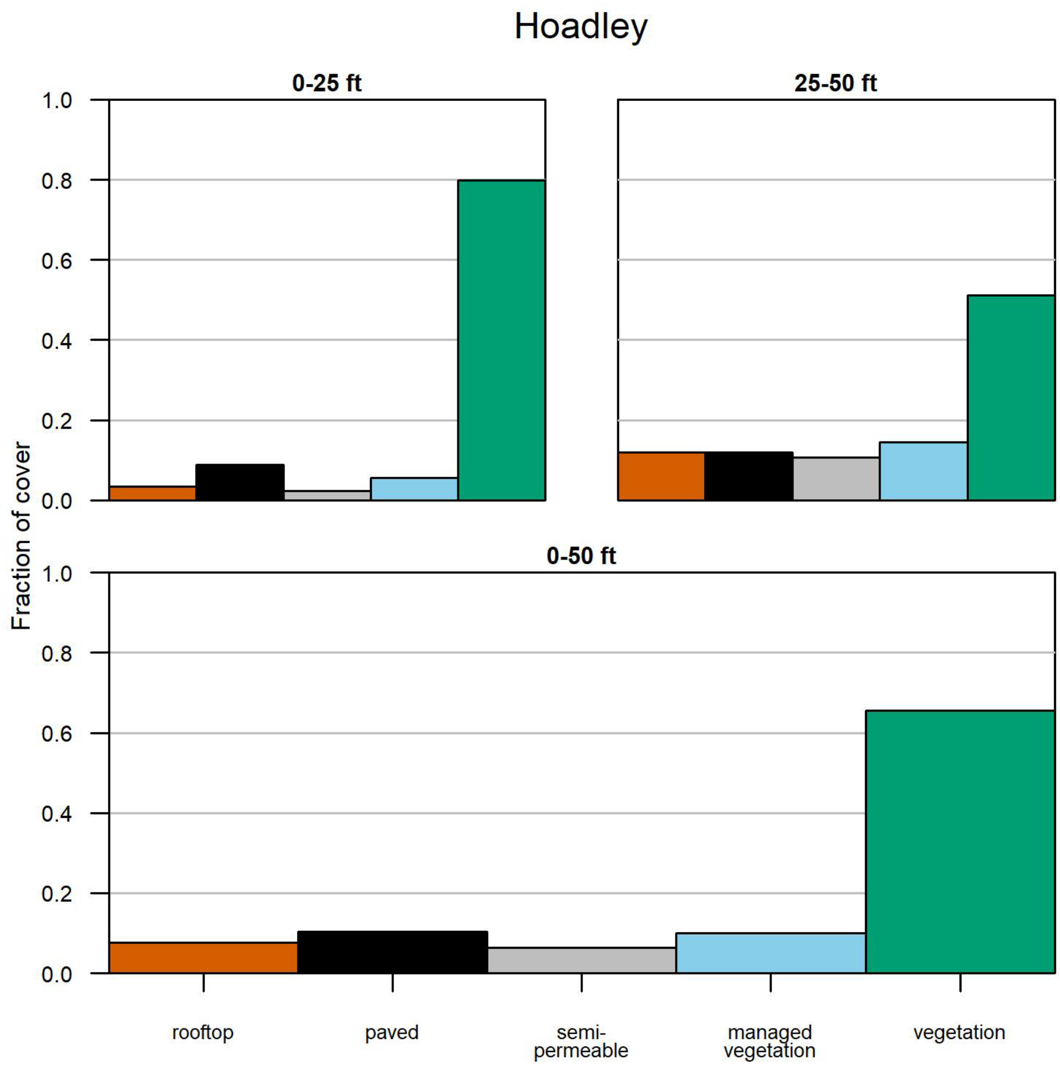


Figure 12. Land cover types within 50 feet of Hoadley Creek. Panel titles indicate the buffer distance from the edge of the terrace: within a 25-foot buffer, 25-50 feet from the stream, or within 50 feet of the stream.

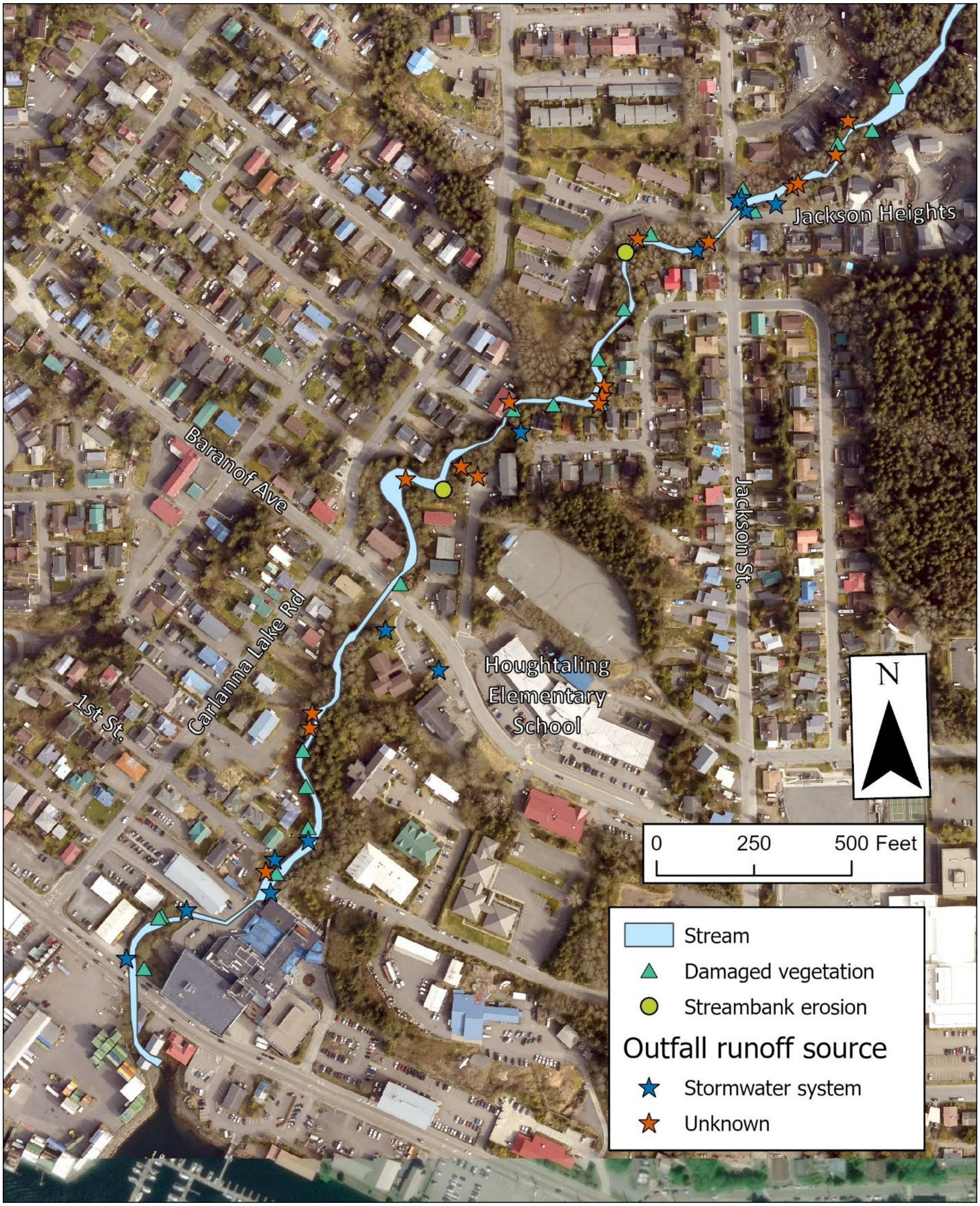


Figure 13. Locations where native riparian vegetation has been damaged and increased erosion risk, and other locations where the bank is being actively eroded and/or undercut. Additionally, locations of stormwater inputs with runoff source indicated ("Stormwater system" is indicated where outfall locations correspond to mapped outfalls on city stormwater maps).

Figure 14. Damaged vegetation and erosion along Hoadley Creek. Top left: yard debris choking native vegetation. Top right: large rock and debris pushed over the terrace edge. Bottom left, Damaged vegetation and erosion below new construction. Bottom right: a displaced sediment filter sock and sediment-laden runoff below new construction.

Figure 15. Local drains empty onto bare soil (left) or right next to the creek (right).

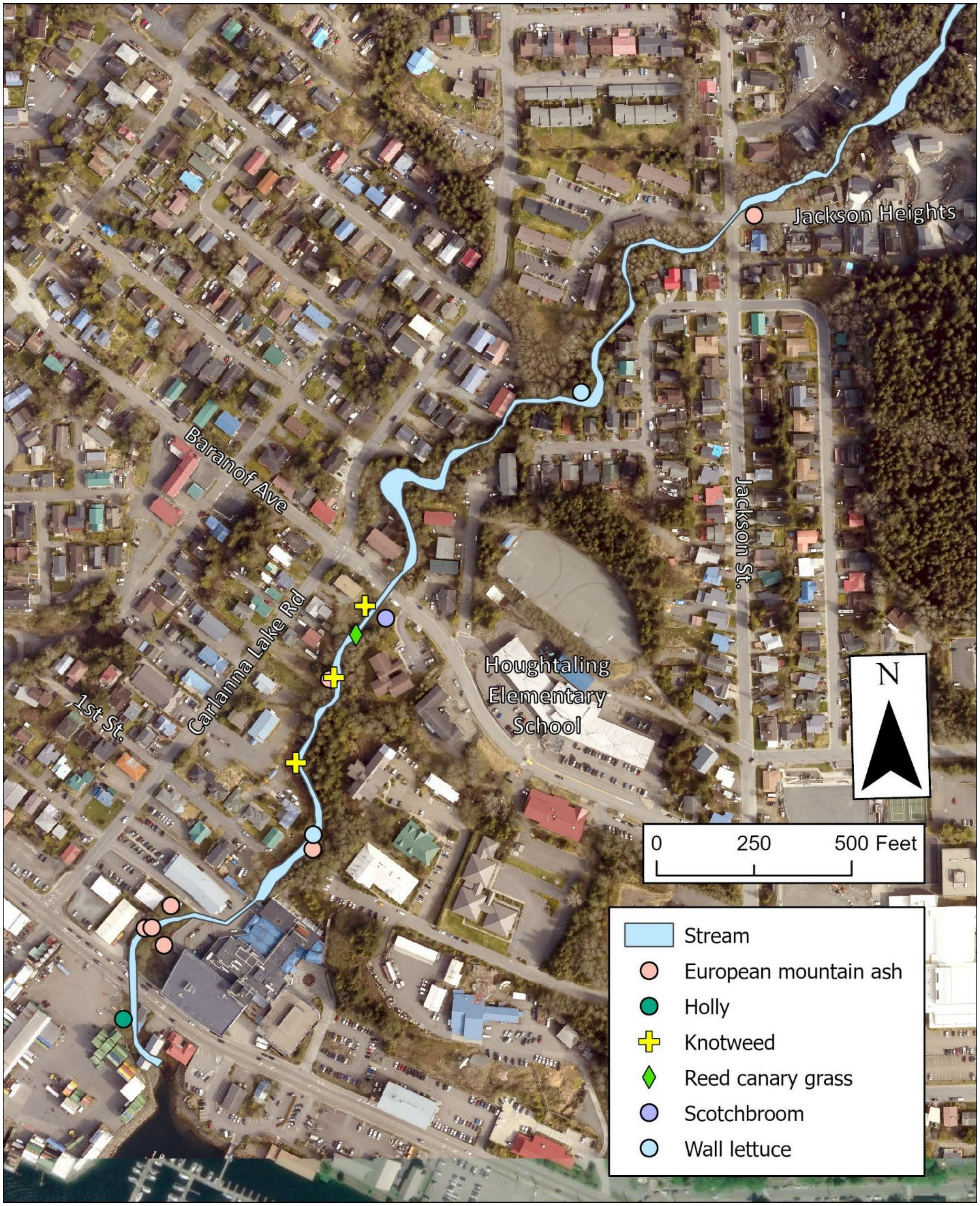


Figure 16. Locations of invasive species along Hoadley Creek.

Figure 17. Top: Large patch of knotweed between Baranof Ave. and 1st St. that extends from the creek up and over the bank. Bottom:: a patch of knotweed (center midground) just downstream of Baranof Ave only visible after the surrounding alder lost their leaves, with non-native invasive Scotchbroom in the foreground.

Figure 18. Litter spread through the vegetation just downstream of Baranof Ave.

Figure 19. An unused paved area at 130 Carlanna Lake Rd. that could be converted to an infiltration basin or bioswale and capture and treat stormwater runoff from the upper parking lot and/or part of the lower lot.

Figure 20. Existing gravel strip in front of Houghtaling Elementary Parking lot. The area could be modified to direct parking lot runoff to the gravel strip for infiltration and treatment before reaching the stormwater system.

Figure 21. An undeveloped strip of land along Baranof Ave. near Hoadley Creek Crossing that could be modified to accept street runoff before it reaches storm drains. For example, curb cuts and an infiltration basin could be installed.



Figure 22. Ketchikan Gateway Borough-owned land at the upstream corner of Jackson Heights and Jackson St. where riparian restoration would be beneficial, and stormwater BMP opportunities could be assessed.

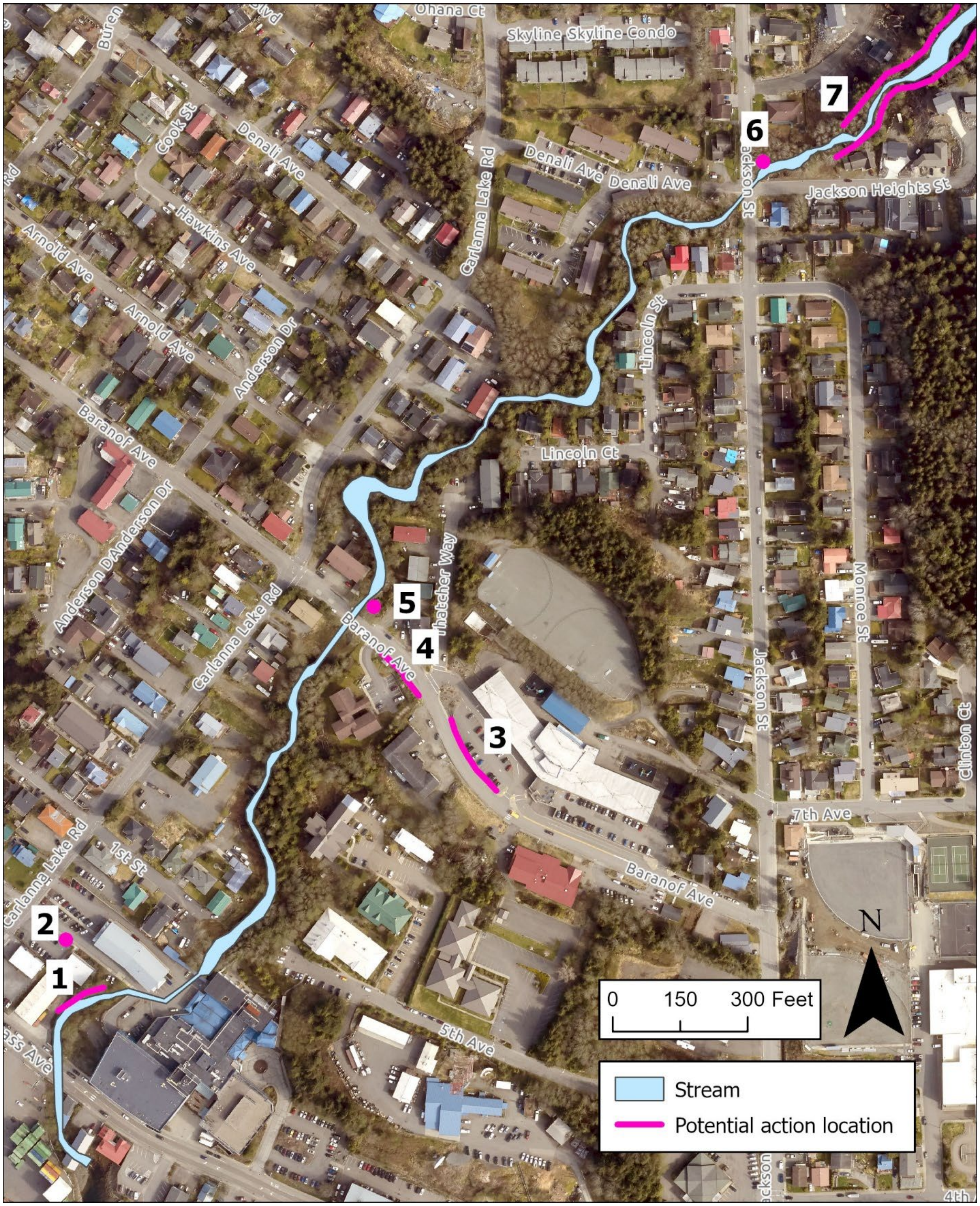


Figure 23. Potential locations for on-the-ground action, including 1. Restore vegetation; 2. Install an infiltration trench or biofiltration cell to capture runoff; 3. Convert existing gravel strip to infiltration trench or biofiltration swale that captures parking lot runoff; 4. Install curb cuts and infiltration GSI for road runoff; 5. Restore vegetation; 6. Explore potential GSI opportunities and restore vegetation; 7. Restore vegetation.

Ketchikan Creek

Watershed Context

Ketchikan Creek drains a 14.1 square mile watershed that includes Ketchikan Lake, the city's drinking water source (Figure 24). Ketchikan Creek is listed for coho, chum, pink, king, sockeye, cutthroat trout, and steelhead trout presence (AWC Code 101-47-10250) with anadromy ending downstream of Ketchikan Lake. Only the lowest 5% of the watershed is developed. The lower sections of the watershed include high density and high traffic commercial areas in the downtown core, residential areas, schools, and parks. Schoenbar Creek is the only significant tributary that drains urbanized portions of the watershed (~25% of the developed area); it enters Ketchikan Creek by Schoenbar Rd. and Park Ave. The riparian assessment focused on Ketchikan Creek, although lower Schoenbar Creek area was also assessed for stormwater management opportunities.

Riparian Assessment Results

An estimated 50% of the 50 foot riparian buffer along the urban stretch of Ketchikan Creek, from Stedmon St. to upstream of the Ketchikan Public Utilities facility north of Deermount St., is developed (pavement, rooftop, semi-permeable, and managed vegetation like lawns), with 33% impervious surfaces (pavement, rooftop) and 9% semi-permeable cover (Figure 25, Figure 26). Within the first 25 feet, 35% of the cover is developed, including 24% impervious surfaces (Figure 26). Some areas of the creek have development right up to the bank, especially in the lower reaches, while others have only narrow strips of vegetation remaining. The most intact areas include the natural area on the north side of the creek between the Harris St. bridge and Park Ave., and through City Park (Figure 25).

Except for a few areas, most of the vegetated riparian buffer is easily accessible to the many tourists and locals who enjoy Ketchikan Creek. Consequently, there are many social trails and areas with damaged vegetation, which has contributed to the formation of gullies and erosion (Figure 27). This is especially prevalent along Freeman St., Totem Dr. and the gravel trail upstream, Salmon Rd. and the gravel trail upstream, and by the skate park. Vegetation along these areas has also been damaged by mowing, cutting, and yard debris (Figure 28). Developing sanctioned trails with proper drainage that access popular spots and restoring the existing vegetated areas to reduce gully formation could help reduce erosion and increase the treatment of runoff that currently reaches the riparian buffer.

Within vegetated areas, many invasive species, including knotweed, reed canary grass, European mountain ash, and holly were identified (Figure 29). Several knotweed infestations observed along the creek, including just upstream of the Park Ave. bridge and at Freeman St., are noticeably growing over time and need to be controlled (Figure 30). There are additional infestations along Schoenbar Creek downstream of Valley Forge and at the entrance of the Borough Parks and Recreation facility that should also be addressed to prevent downstream spread. European mountain ash was prevalent along and upstream of Totem Way, where holly was also interspersed (Figure 31).

The steep watershed and dense development promote erosion and pollutant runoff while limiting opportunities for GSI in Ketchikan Creek watershed. However, several potential projects that could help treat stormwater before it enters the storm drain system and stream were identified. Existing gravel drainage ditches along Venetia Way (Figure 32) and Schoenbar Road, from approximately Fairly Chasm Road to Valley Forge (Figure 33) could have check dams installed and additional vegetation planted to promote infiltration and treatment before runoff reaches storm drains. The south side of Schoenbar Rd., just downstream of the Schoenbar Creek crossing, has a flat vegetated buffer area that could accept and treat street runoff via curb cuts before it reaches a storm drain by the bus stop (Figure 33). Elevated planters along Dock St. could be replaced with bioretention planters that receive road and/or parking lot runoff (Figure 35). Finally, the parking area and turn-around by the Totem Heritage Center could be re-graded to route more runoff to the existing vegetated area at the center of the turnaround (Figure 36).

These projects (Figure 37) still need to be vetted for feasibility and potential effectiveness. An important first step would be to supplement existing storm water infrastructure maps with more detailed storm drain mapping that identifies clearly where runoff travels over the land surface before reach storm drains. This allows contributing areas to be quantified and infrastructure to be properly sized and designed for the contributing area and potential pollutant types and loads.

Recommendations

- Restore riparian vegetation and reduce the impacts of social trails along
    - Freeman St.
    - Totem Dr. and gravel path upstream.
    - Salmon Rd. and gravel path upstream.
    - Skate Park area.
- Invasive species management, especially knotweed, reed canary grass, and European mountain ash.
- Outreach and education about not dumping yard waste, protecting/restoring native vegetation, and erosion mitigation.
- Setback ordinance for (re)development.
- Map stormwater drainage, including surface runoff, to inform GSI project development.
- Potential GSI opportunities (all require additional vetting for feasibility and efficacy):
    - Install check dams and vegetate the ditch along Venetia Way to promote infiltration and treatment. Curb cuts may also be installed to direct more water to the ditch.
    - Convert raised planters along Dock St. to bioretention planters that accept runoff from the parking lot and/or street.
    - Re-grade the parking area and roundabout to direct more runoff to the existing vegetated area by the Totem Heritage Center. The vegetated area may better infiltrate and treat stormwater with more porous substrate and/or different grading.

  Schoenbar Creek

    - Install check dams and vegetate the gravel ditch area along Schoenbar Rd. in front of the charter school and ball field.

- Create a bioswale or other GSI feature and install curb cuts along Schoenbar road between the charter school and middle school to allow street runoff to enter the vegetated riparian area instead of the storm drain system.'
- Reclaim/revegetate or create a green stormwater feature on the uphill entrance to the middle school.

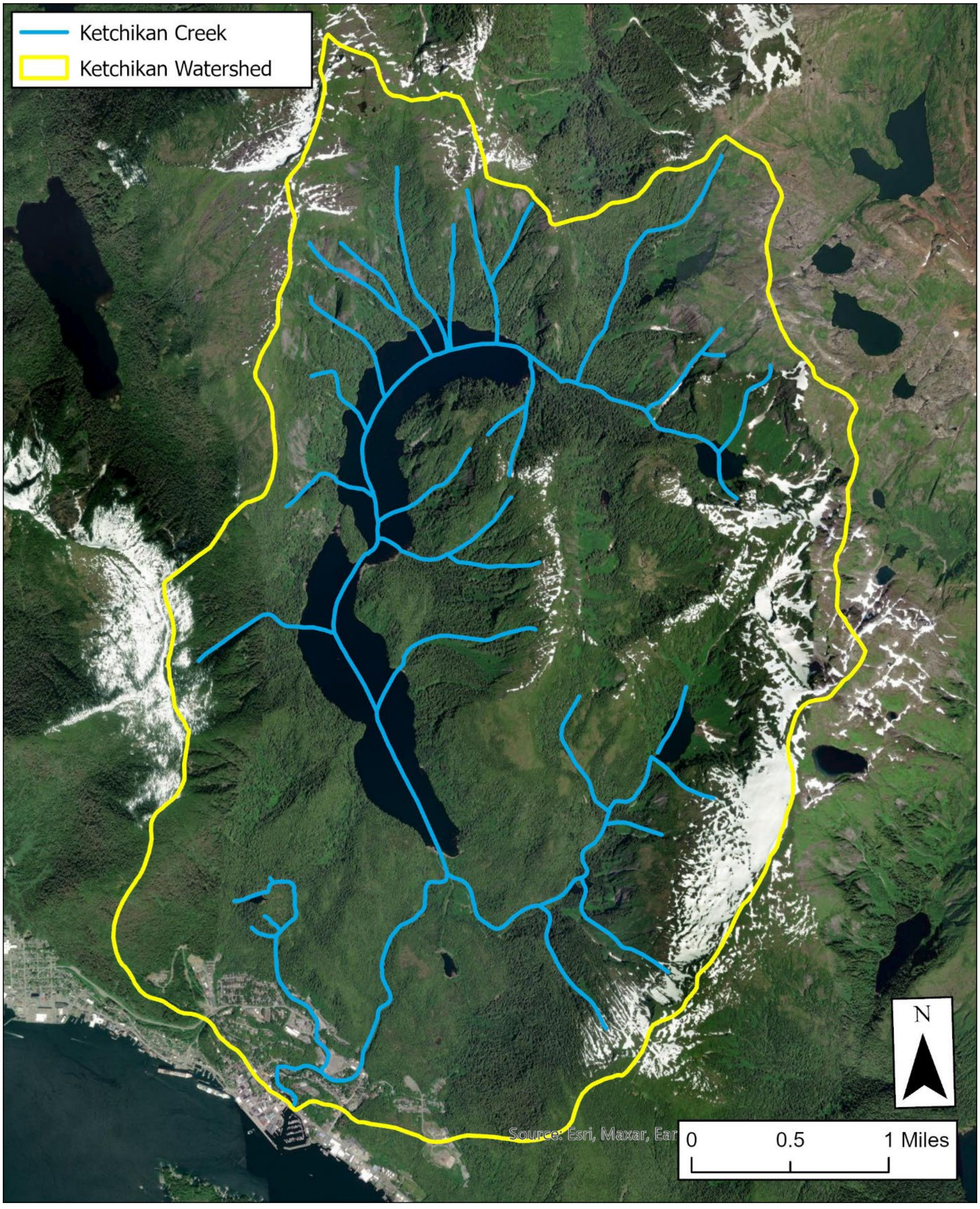


Figure 24. Overview of Ketchikan Creek watershed. The southernmost tributary is Schoenbar Creek.

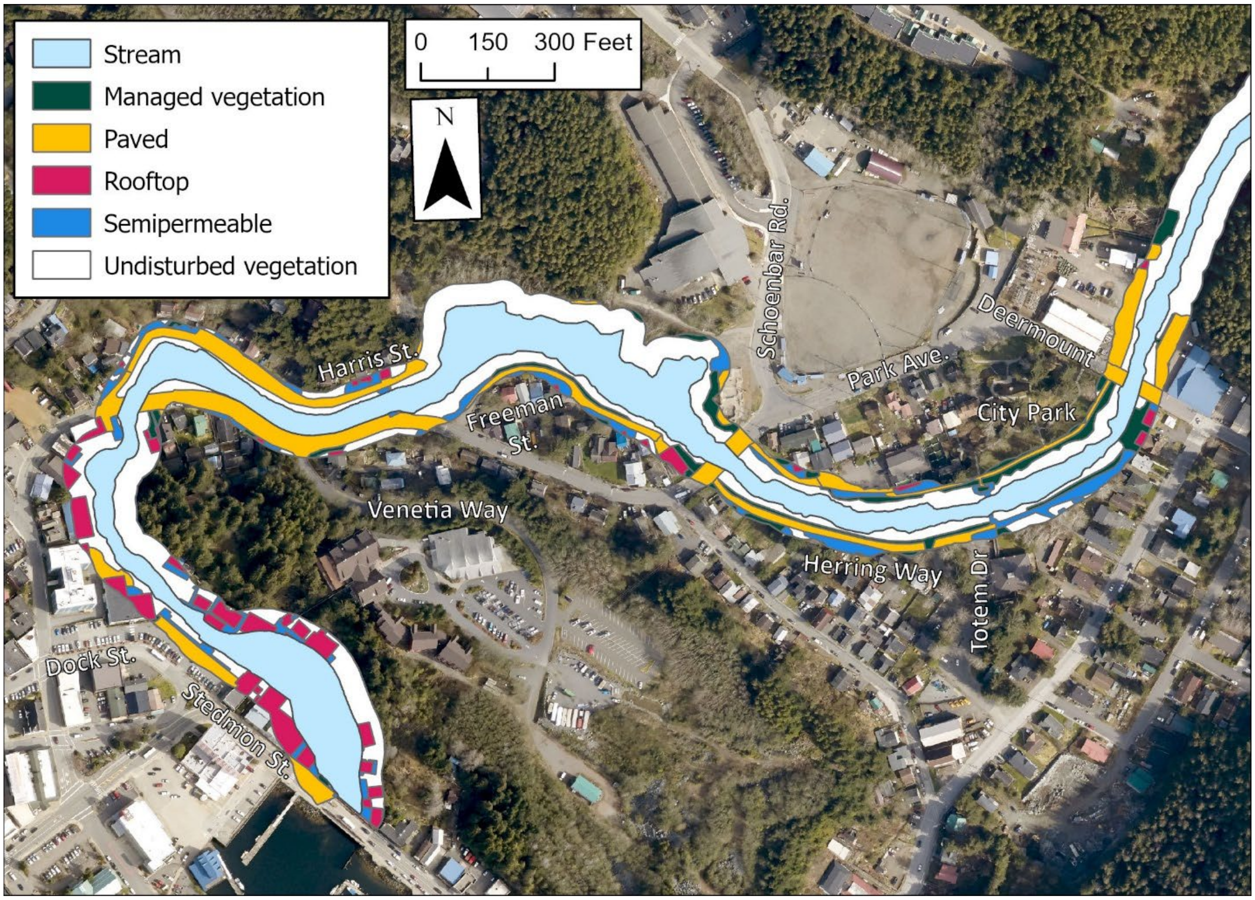


Figure 25. Land cover in the 50-foot riparian buffer of Ketchikan Creek.

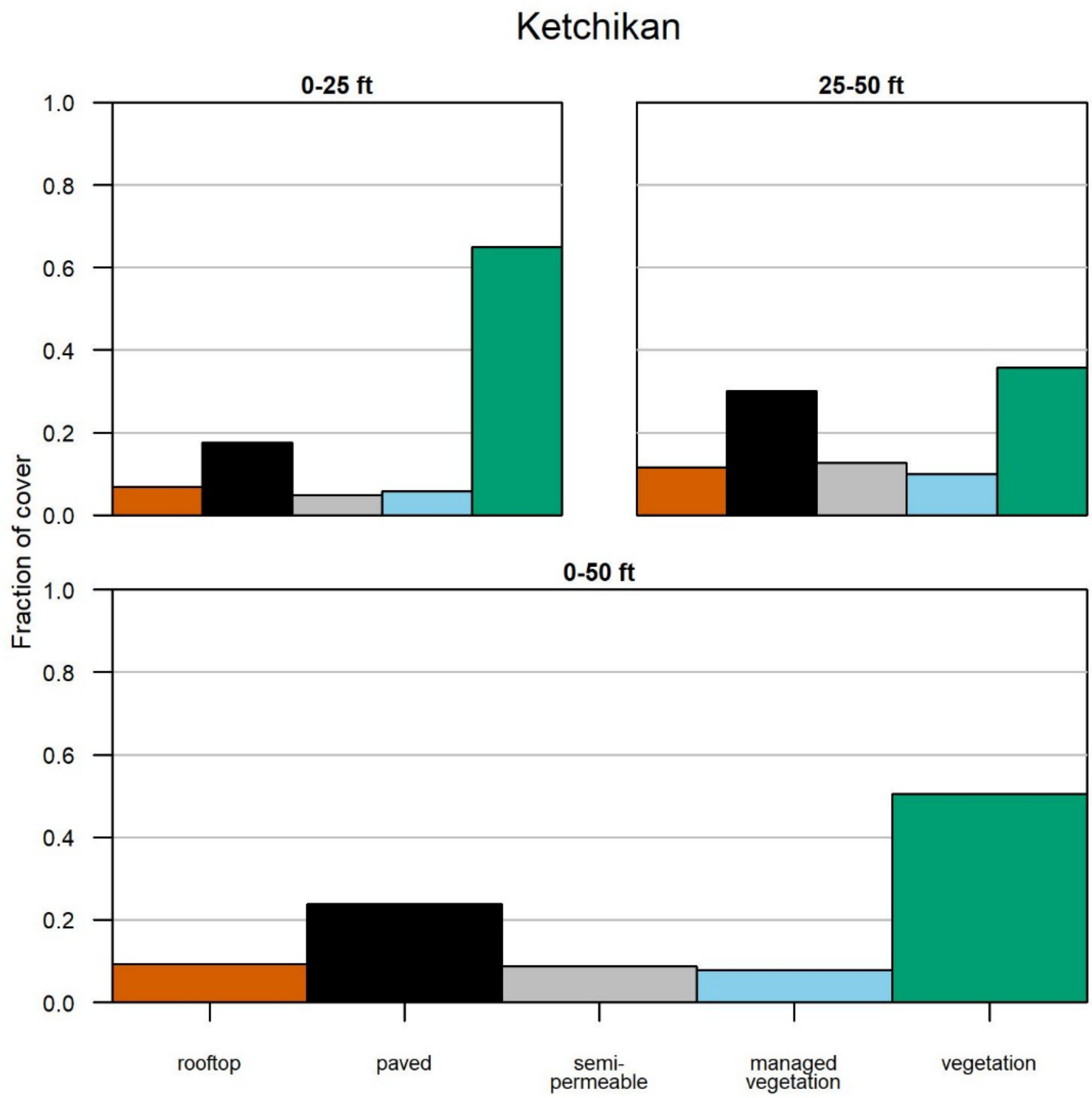


Figure 26. Land cover types within 50 feet of Ketchikan Creek. Panel titles indicate the buffer distance from the edge of the terrace: within a 25-foot buffer, 25-50 feet from the stream, or within 50 feet of the stream.

Figure 27. Examples of social trails along Herring Way (left) and Freeman St. (right) that damage vegetation, increase the risk of bank erosion and promote the formation of gullies that concentrate runoff and reduce infiltration and treatment potential.

Figure 28. Yard clippings dumped in a narrow riparian buffer strip (left), and a long, narrow buffer strip with mowed/damaged understory (right) along Herring Way.

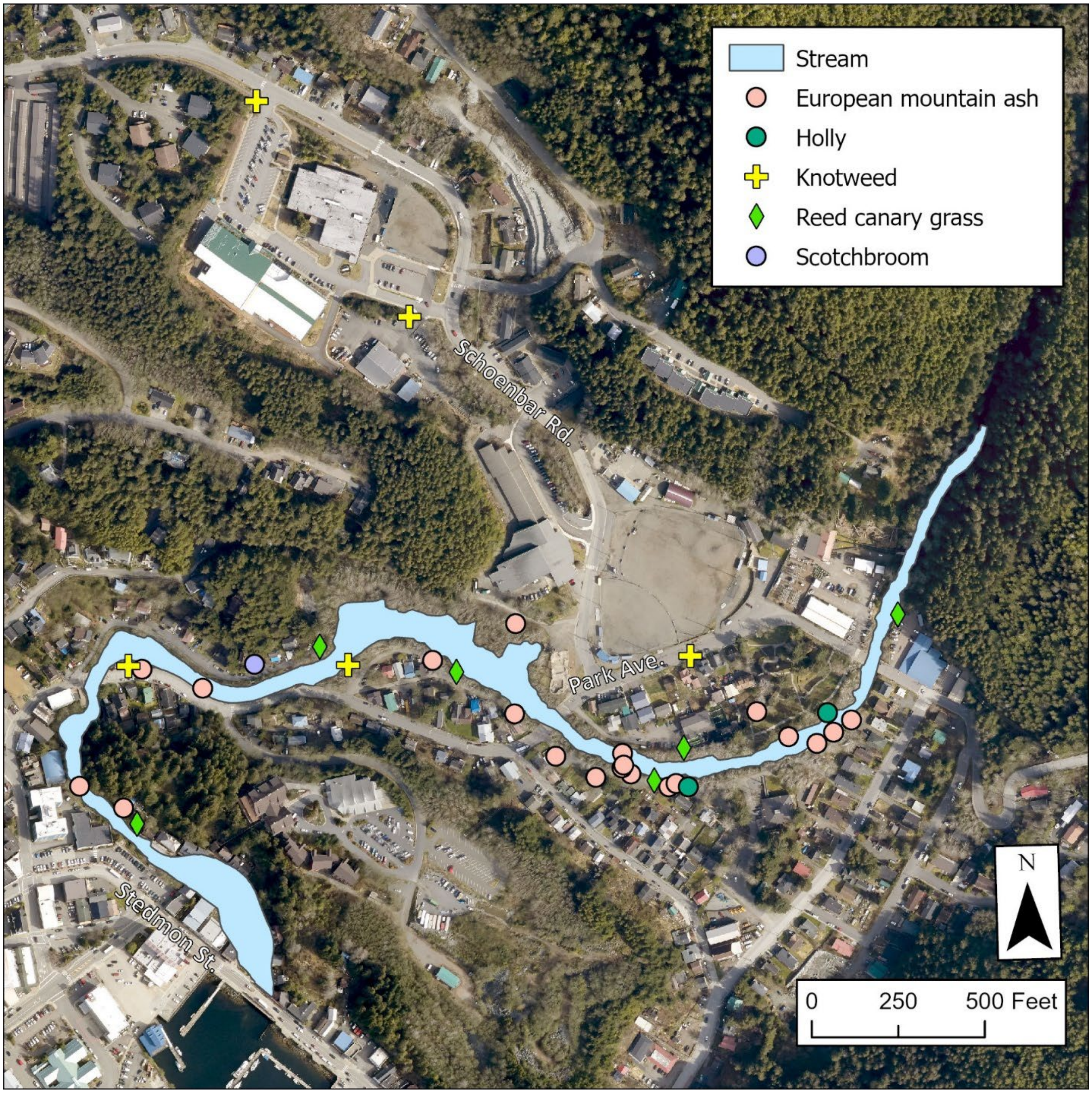


Figure 29. Invasive species documented along Ketchikan Creek

Figure 30. Knotweed on Ketchikan Creek by Freeman St (left). The patch was cut back but is regrowing (left). All cuttings must be bagged and disposed of to prevent the spread of vegetative propagules.

Figure 31. Large and small European mountain ash line Totem Dr. and the path upstream (left). Reed canary grass in a disturbed strip of vegetation along Totem Way.

Figure 32. Storm drain at a low point of the Cape Fox Lodge parking lot and the top of a drainage ditch that extends downhill to Park Ave that could be enhanced as a biofiltration swale with check dams and vegetation to promote infiltration and water treatment. Curb cuts could be added to direct more street runoff to the ditch.

Figure 33. Unvegetated gravel ditch along the south side of Schoenbar road that could be upgraded with check dams, vegetation, and curb cuts to intercept, infiltrate and treat stormwater runoff (biofiltration swale).

Figure 34. Vegetated buffer on the south side of Schoenbar Rd. that could accept and treat street runoff via curb cuts before it reaches the storm water system. Stormwater treatment capacity of the area could be upgraded with a bioswale or filtration trench.

Figure 35. Raised planters on Dock St. that could be converted to bioretention planters that receive and treat runoff from the parking lot and/or street.

Figure 36. Existing vegetated area in front of the Totem Heritage Center. The existing drainage system passes through the area, and the road and parking lot could be regraded to direct more water into the area. The vegetated area could be upgraded to a biofiltration swale with more porous substrate and/or alternative grading to promote infiltration and treatment before water leaves through a drain and enters the stream a few meters away.

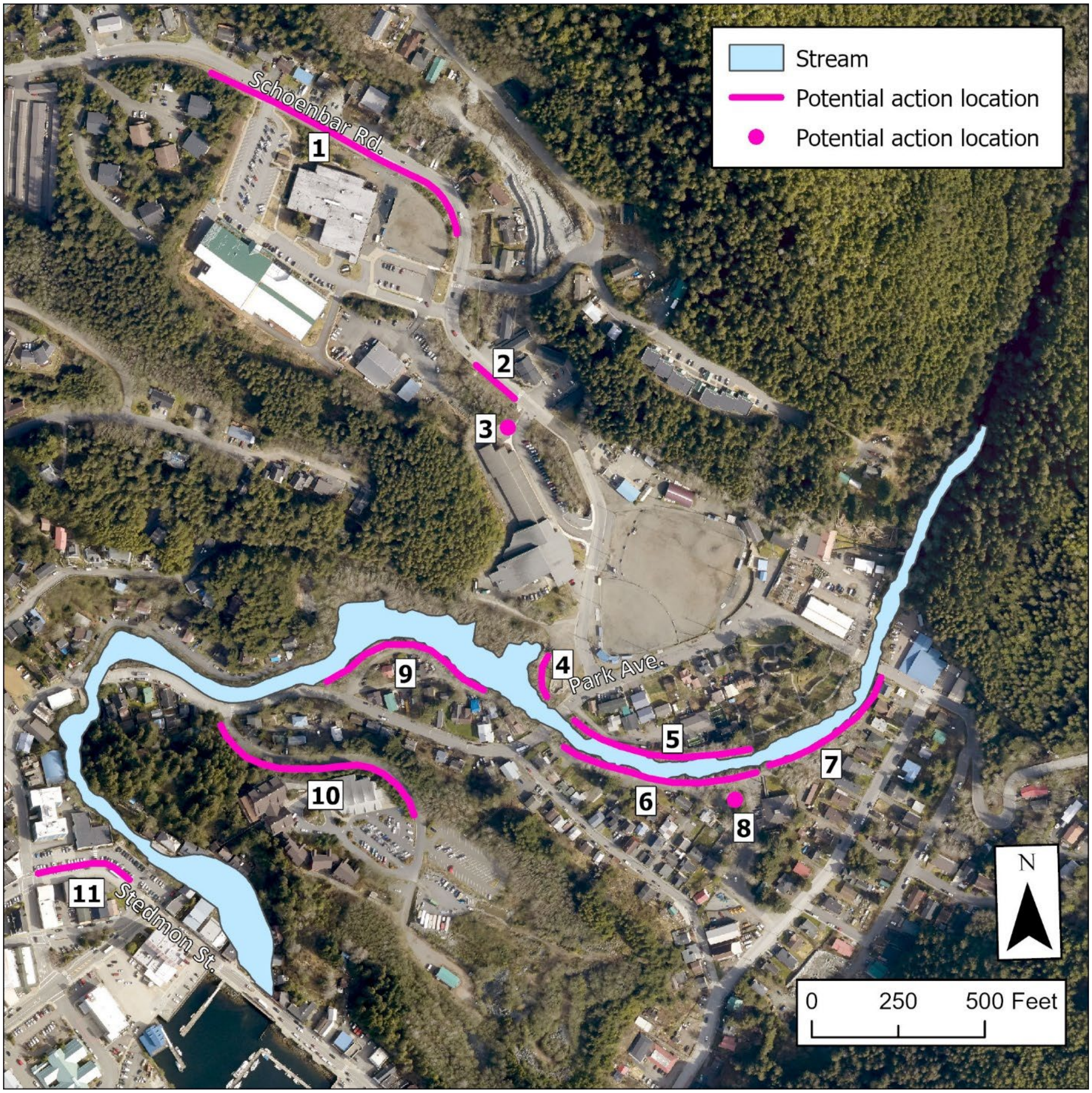


Figure 37. Locations of potential riparian restoration and GSI projects along Ketchikan and Schoenbar Creeks. 1. Create a biofiltration swale with a series of check dams, vegetation, and curb cuts/slot drains to enhance runoff filtration in the existing gravel conveyance ditch. 2. Convert the existing vegetated area between the sidewalk and creek to a biofiltration swale or infiltration trench and install slot drains to direct runoff into the swale. 3. Re-vegetate unused paved/gravel area or install an infiltration feature or biofiltration cell. 4. Restore damaged vegetation, and improve social trails to reduce runoff and erosion to the stream. 5., 6., 7. 9. Restore native riparian vegetation, install flow spreaders, and create sanctioned trails to limit gully formation and erosion. 8. Regrade surrounding pavement to direct runoff into the existing vegetated area, which could be regraded and vegetated to increase water detention and filtration before entering the stream (e.g. biofiltration swale). 10. Create a biofiltration swale with a series of check dams, vegetation, and curb cuts to enhance runoff filtration in the existing gravel ditch. 11. Convert elevated planters to bioretention plants and install curb cuts/slot drains to direct runoff from the street and/or parking lot into them.

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Appendix A. Land ownership maps

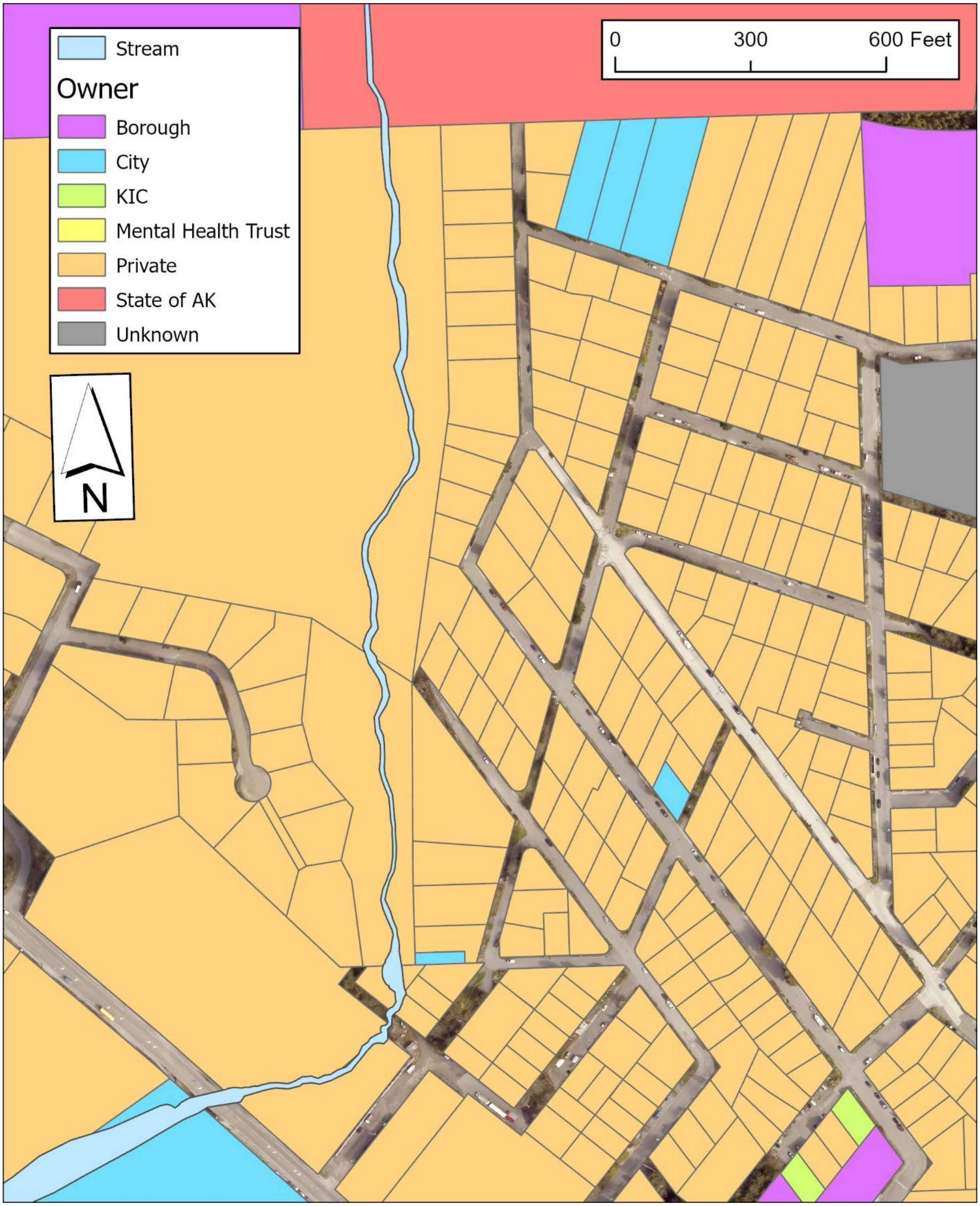

Figure A.1. Land ownership surrounding Carlanna Creek.

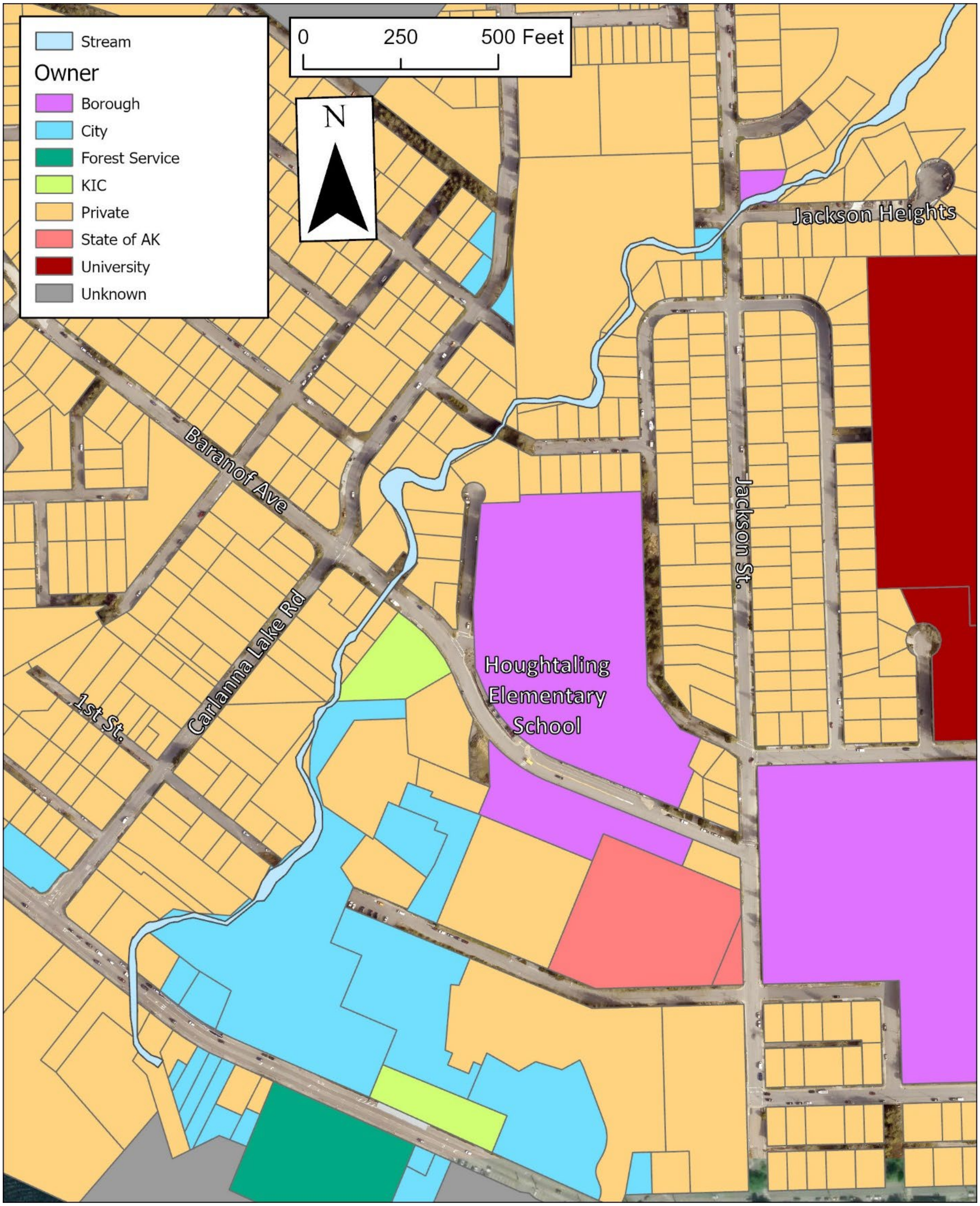

Figure A.2. Land ownership surrounding Hoadley Creek.

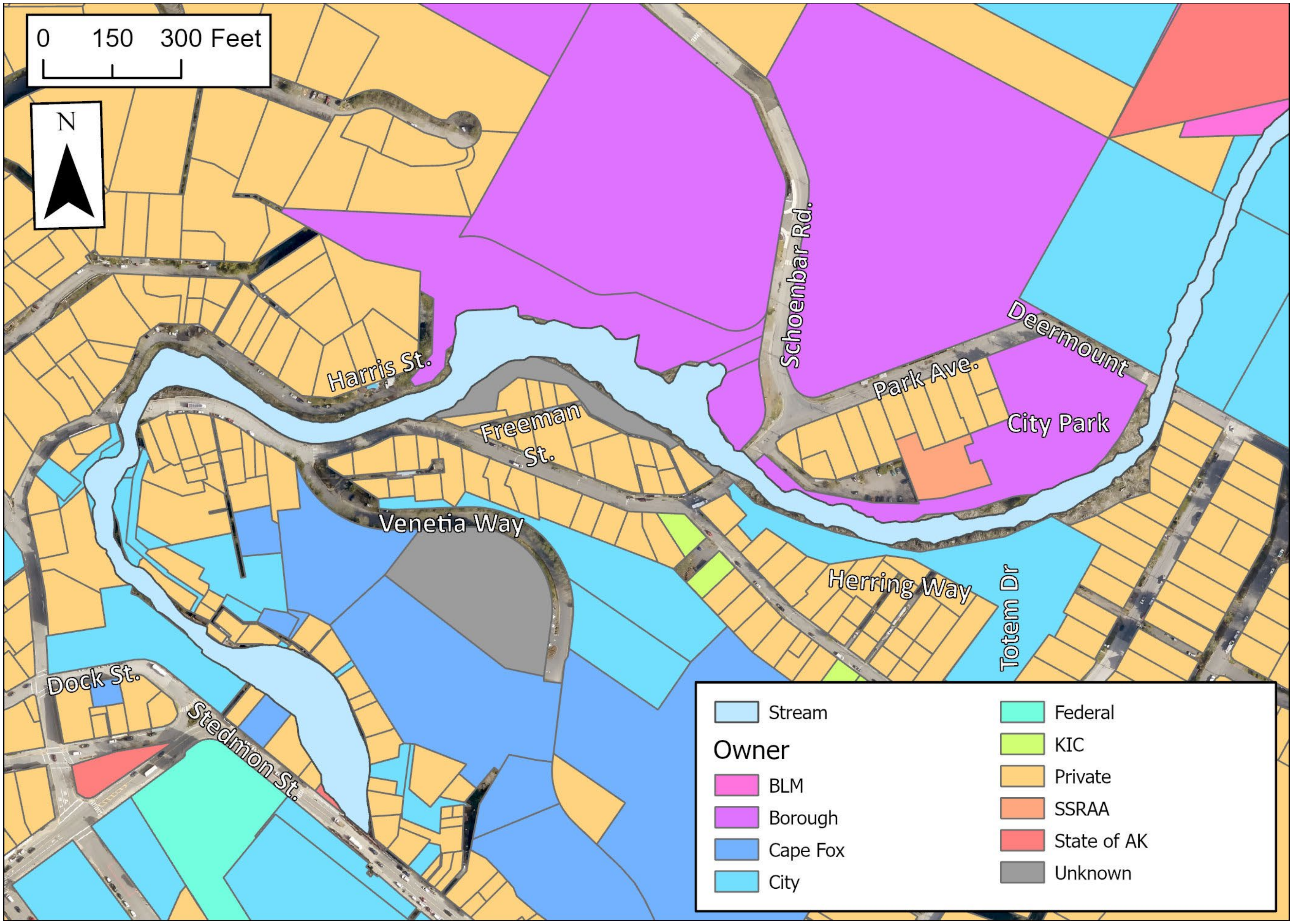

Figure A.3. Land ownership surrounding Ketchikan Creek.

Appendix B. Green Stormwater Infrastructure Examples

The green stormwater infrastructure (GSI) examples provided below may be useful in Ketchikan's dense urban area to intercept and treat stormwater runoff before it reaches the storm drain system and streams, where pollutants can impact aquatic life in receiving and downstream water bodies (e.g. estuaries, beaches). This Appendix provides only a brief overview of a few different types of GSI; more comprehensive, relevant sources of information are listed at the end.

GSI is typically designed to provide one or both of the following functions: flow control (slowing the movement of water to reduce peak stream flow), and/or runoff treatment (removing pollutants from runoff before it reaches surface water). In addition to these functions, GSI provides beautification benefits to the community and can integrate into existing gray infrastructure (e.g. Figures B.2., B.3., B.5. B.6.)

"Infiltration" GSI designs promote downward flow of runoff to groundwater, which slows its travel time to surface water. With appropriate vegetation and soil mixes that have high infiltration rates, sorption capacity and microbial activity, infiltration GSI can also provide runoff treatment, as pollutants are retained, transformed, or adsorbed. In contrast, "biofiltration" GSI designs promote horizontal flow of runoff through vegetation and surface soils/material that provide runoff treatment primarily through settling, filtration, and plant uptake.

GSI designs can incorporate various pre-treatment components, such as oil-water separators, settling basins, and forebays to remove some pollutants and sediments before runoff enters downslope portions of the structure (Figure B.1.). Pre-treatment facilities can increase the lifespan of the infrastructure (for example, by slowing the rate of fine particles filling the voids of gravels and soils) and confining areas that need to be maintained more frequently. They are particularly important for areas that receive runoff with high suspended solids, debris, and hydrocarbons.

GSI designs can also integrate with the traditional storm drain system to ensure that if infiltration or storage capacity is overwhelmed, excess runoff can enter the gray stormwater system and not cause localized flooding (Figure B.2.). Overflow drains and underdrains are options to route water from GSI to gray infrastructure when local capacity is overwhelmed. Curb cuts and slot drains shunt drainage from pavement to adjacent GSI, diverting runoff from gray stormwater infrastructure while allowing excess runoff to reach storm drains under extreme flow conditions. Flow spreaders create sheetflow into GIS features, which dissipates flow energy and promotes more even infiltration.

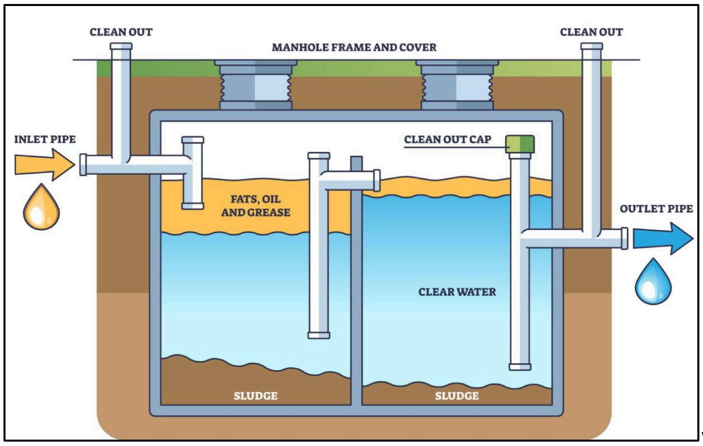

Figure B.1. Examples of pre-treatment facilities: Left: Basic design for an oil-water separator that removes solids and oils (Anderson Waste). Right: A forebay to remove sediment before it enters a retention basin (Massachusetts Clean Water Toolkit).



Figure B.2. Top left: Slot drains in Juneau divert road runoff into an infiltration GSI. Top right: Curb cuts in Seattle divert pavement runoff into an infiltration basin before it reaches stormwater drains. Bottom left: A curb cut directs flow from a parking lot into a strip with a flow spreader that ensures even distribution of water into the vegetated infiltration trench.

GSI options for Ketchikan

1. **Biofiltration swale:** Biofiltration swales are vegetated strips designed to remove some suspended sediments and pollutants via sedimentation, filtration, infiltration, and plant uptake as water moves mostly horizontally through the structure. Swales can be designed with check dams that slow water conveyance and promote infiltration and water treatment and overflow drains for times when capacity is exceeded. If the swale is along a road or parking lot, including curb cuts or slot drains can divert additional runoff into the swale for treatment. Wet biofiltration swales are similar to biofiltration swales but have plants that can tolerate frequently saturated conditions that are a result of near-continuous water inputs and/or poorly drained soils.

   May be appropriate for:

   - Existing long sloped gravel trenches that currently function primarily as runoff conveyance structures, such as along Venetia Way and Schoenbar Rd (Figure B.3.).
   - Existing vegetated areas that already or could receive stormwater runoff, such as the vegetated stormwater ditch in the Totem Heritage Center parking lot, and between Schoenbar Way and Schoenbar Creek in front of the charter and middle schools.

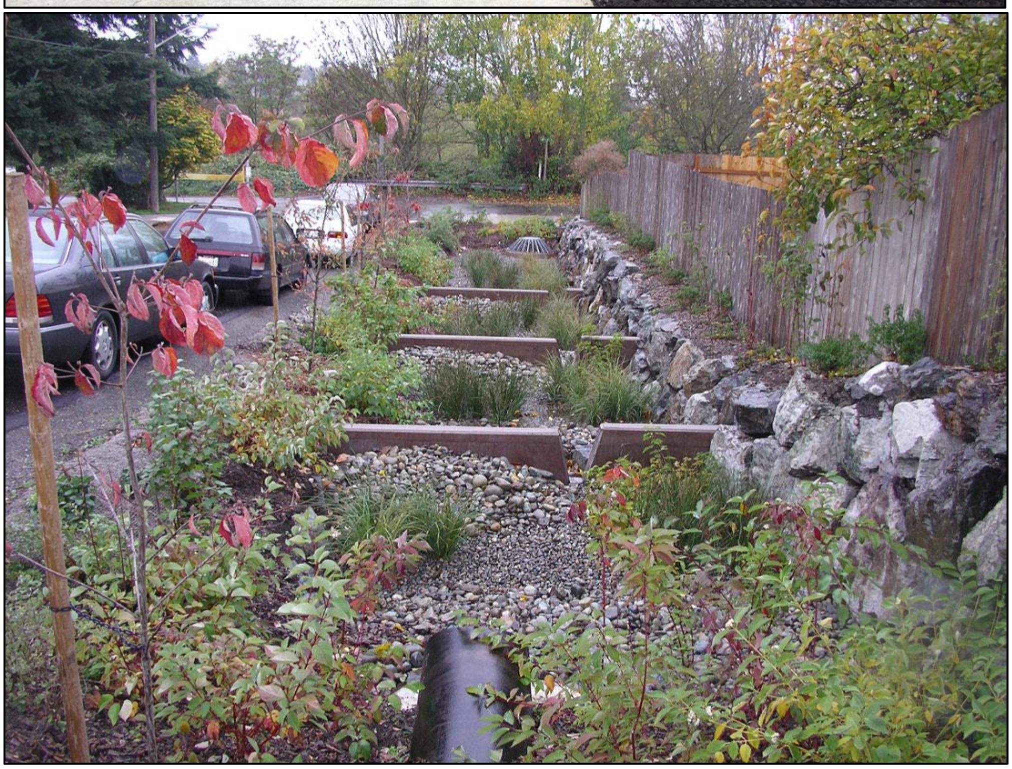

Figure B.3. Top: Unvegetated gravel ditch along the south side of Schoenbar road that could be upgraded with check dams, vegetation, and curb cuts to intercept, infiltrate and treat stormwater runoff. Bottom: Example of a biofiltration swale equipped with check dams to slow water movement from one cell to the next that could replace the gravel conveyance ditch picture above. An elevated overflow drain at the bottom of the feature (upper middle) prevents localized flooding if inflows exceed infiltration capacity.

2. **Vegetated filter strip:** Vegetated filter strips are flat vegetated areas next to pavement that receive sheet flow runoff, which is treated via filtration, uptake by plants, and infiltration into the soil. Flow spreaders can ensure runoff is spread evenly across the strip.

   May be appropriate for:

   - Existing riparian/vegetated areas directly adjacent to roads or parking lots, including Herring Way, Freeman St. alley, and the parking lot NW of Tongass Ave and Carlanna Creek. Some of these areas suffer from erosion due to gully formation and social trails, and flow spreaders could help ensure runoff is more uniformly distributed into the riparian vegetation and reduce erosion.

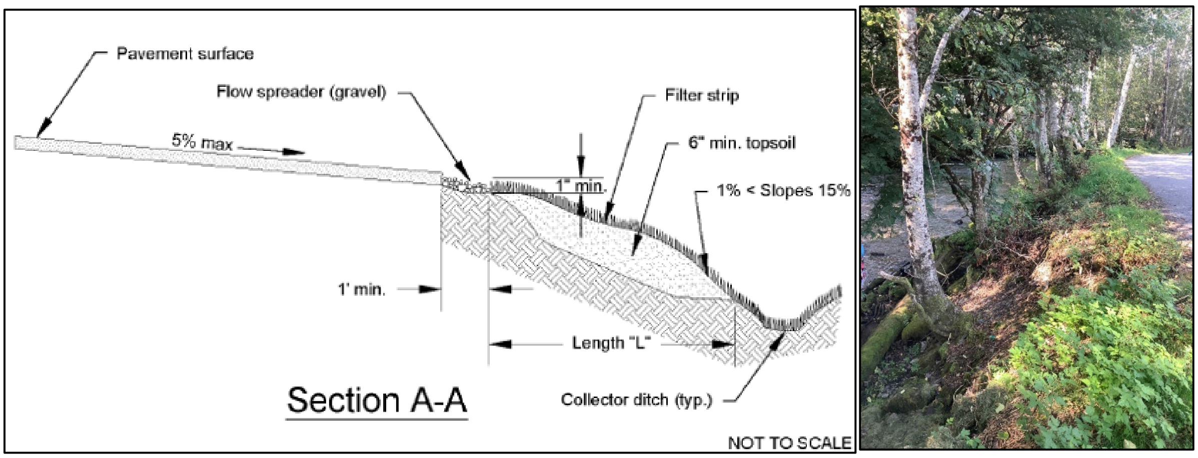

Figure B.4. Left: Side view of a vegetated filter strip design, with flow spreader between pavement and vegetation (SWMMWW). Right: Riparian strip along Herring Way where runoff treatment could be protected/enhanced and erosion reduced by including a flow spreader and restoring native vegetation.

3. **Infiltration Basin:** Infiltration basins detain water in earthen impoundments, where pollutants can be removed in the soil and by plants as water infiltrates vertically. A pretreatment structure like a forebay or oil-water separator may be especially helpful to remove sediment and decrease maintenance requirements over time.

4. **Infiltration Trench:** An infiltration trench has a shallow strip of coarse sediment surrounded by soil. Runoff distributes through the highly porous coarse sediment strip and then permeates surrounding soils. As with infiltration basins, pre-treatment structure should be considered.

5. **Bioretention cell/swale:** Bioretention features are infiltration structures designed to maximize water quality treatment by incorporating specially selected plants and soil mixes. Bioretention cells are depressions that collect and store stormwater runoff to promote infiltration and pollutant removal. A bioretention swale is a series of connected cells that accept overflow from the upstream cell.

   Taking into account shape and size, infiltration basins or trenches or bioretention cells/swales may be appropriate for:

- Existing relatively large flat, unused gravel/paved areas along parking lots and roads, including in front of Houghtaling Elementary School, and130 Carlanna Lake Rd office complex parking lot (Figure B.5.).
- Existing relatively flat vegetated areas that could accept stormwater runoff, such as downslope side of Baranof Ave by Hoadley Creek.

Figure B.5. Left: Unused paved area in office complex parking lot on Carlanna Lake Rd. that could be converted to an infiltration basin or bioswale to capture and treat stormwater runoff from the upper parking lot and/or part of the lower lot. Top right: Example of an infiltration basin that accepts parking lot runoff via curb cuts. Bottom right: Example of a bioretention cell (SWMM LID Controls).

6. **Bioretention planters:** Bioretention planters are small, contained areas that accept stormwater runoff and promote infiltration and pollutant removal. Planters typically have open bottoms that allow runoff to infiltrate into groundwater, but they can also be closed and equipped with underdrains that connect to gray stormwater infrastructure (bioretention planter boxes).

   May be appropriate for:

   Small areas that could be dedicated to GSI instead of pavement or sidewalk, including existing elevated planters like those along Dock St (Figure B.6).

Figure B.6. Top left: Existing raised planter boxes along Dock Street that could be replaced with bioretention planters. Top right: An unobtrusive bioretention planter with a single tree that receives runoff through a slot drain. Bottom left: A larger bioretention planter that accepts street runoff through slot drains.

<u>Additional Green Stormwater References</u>

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