Vegetation and soil characteristics in relationship to green stormwater infrastructure on the High Line Canal

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Prepared by Denver Botanic Gardens for:

HIGH LINE CANAL CONSERVANCY

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Executive Summary

Parts of the High Line Canal are being formalized as green stormwater infrastructure (GSI) to slow, spread, and sink runoff from surrounding impervious surfaces. This is a unique endeavor, as the function of the newly implemented GSI will rely on naturally occurring vegetation and soil, not plantings or amended soils as is typical in other GSI settings.

This report illustrates key vegetation and soil factors that are expected to shape GSI function. We use pilot Reach 30 (from Wellshire Golf Course to I-25) as an example, and intend the concepts illustrated herein to provide guidance for future assessments in other GSI locations along the Canal. The factors we address include:

- The distribution of vegetation versus bare ground and litter along the Canal banks
- The identity (species), relative abundances, and distribution of plants expected to differentially shape GSI function based on their growth habits, longevity, and wetland affinity
- Soil health as indicated by soil organic matter, soil texture, bulk density, and salinity

The high-level findings of the assessment follow:

- There are areas along Reach 30 with high cover of litter and bare ground rather than vegetation. In these locations, the desired function of GSI may be compromised, and additional plantings might be beneficial.
- The Reach is dominated by four cool-season perennial grasses and one mid-sized shrub (buckthorn). There is also appreciable cover of several wetland species and ruderal introduced plants. We discuss how each group of plants might contribute to GSI function (or not), and describe how spatial variation in their distributions could mediate their effects.
- Soil health along the Reach is good according to all indicators assessed, with little evidence of degradation that could compromise GSI function.

Study Overview

Green Stormwater Infrastructure (GSI) on the High Line Canal

Constructed waterways, including irrigation canals and ditches, were foundational to the establishment of agriculture and early European settlement along Colorado's semi-arid Front Range. The High Line Canal, which runs 66 miles from the southwest of Denver at its inception in Waterton Canyon, to its northeastern extent near Green Valley Ranch, is an iconic example of the unique ecological and social benefits that are provided by human-made waterways in the West.

Now, as the Canal is being fully transitioned from its original use for irrigation to its current use as a recreational trail and greenway, its future is being reimagined. Less water will be moved through the Canal from its headgate on the South Platte River. This change poses a challenge for maintaining water in the Canal, and by extension, certain ecological services, including its significant tree cover and the habitat it provides for a diversity of plants and animals.

Figure 1. The High Line Canal provides wetland habitat for a diverse array of plants and animals. Since its construction in 1883, a unique urban-riparian plant community, much different from what would otherwise be shortgrass steppe, has developed.

Study Overview

Green Stormwater Infrastructure (GSI) on the High Line Canal

A new approach for keeping the Canal bed wet and its banks green relies on formalizing the Canal as green stormwater infrastructure (GSI). The current endeavor is somewhat unique, as few plantings or soil amendments are planned. Rather, the existing vegetation and soil will do the work of the GSI, which is to slow, spread, and sink incoming stormwater. Given this, we herein explore key vegetation and soil attributes along a one-mile stretch (Reach 30) of the Canal, which is the first pilot location at which GSI infrastructure (berms and forebays) has been installed (Figure 2).

Slow it, spread it, sink it.

Figure 2. Water pools near a newly installed berm on Reach 30 of the High Line Canal between Wellshire Golf Course and I-25.

Study Overview

The role of vegetation and soils in shaping GSI function

The desired functions of GSI on the Canal include promoting water infiltration into the Canal bed and banks, and allowing time (up to 72 hours) for plants to remove pollutants from incoming stormwater. These GSI functions will depend on key vegetation and soil characteristics (Figure 3), including:

- Distribution of vegetation versus bare ground and litter along the Canal banks
- Identity (species), relative abundances, and distribution of plants that differentially shape GSI function based on their traits (including the umbrella traits of functional group and wetland indicator status)
- Soil health as indicated by soil organic matter, soil texture, bulk density, and salinity (estimated with electrical conductivity)

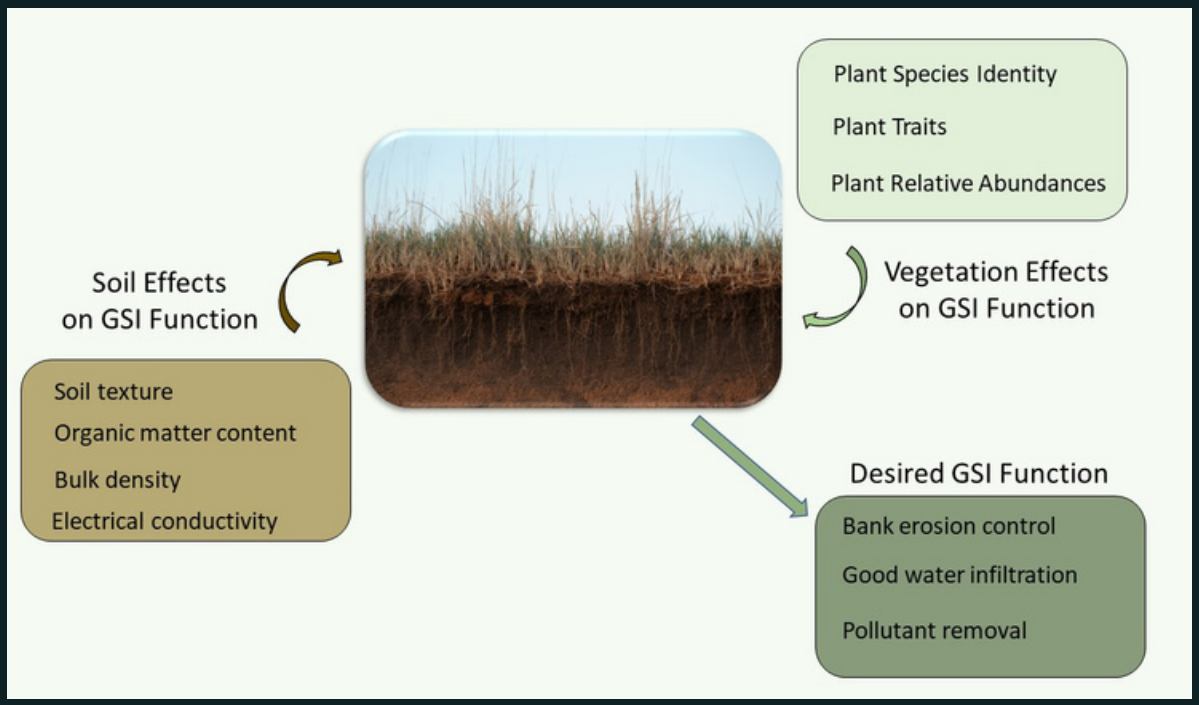


Figure 3. Schematic showing key plant and soil characteristics that shape GSI function and that are addressed in the current report.

Methods

Sampling design

Our sampling approach is based on the expectation that both the middle and lower banks along the one-mile stretch will experience periodic inundation during precipitation events. Assessing variation in vegetation and soil quality across the entire Reach (Figure 4), and from the top to bottom of the Canal banks, will indicate whether GSI function might vary spatially. To this end, we established nine 50-meter “baseline” transects parallel to the Canal bank (Figure 5). Each of these baselines in turn had five transects, located at ~10-meter intervals, running from the top to the bottom of the Canal bank (N = 45 transects; Figure 5). This design captured linear variation from west to east along the one-mile stretch, as well as vertical variation (zonation) from top to bottom of the Canal banks.

Figure 4. Satellite (top) and Open Street Map (bottom) views of the vegetation and soil sampling scheme along Reach 30 of the High Line Canal. We determined our Reach-level sampling locations (termed “baselines”) by first delimiting all areas along the Reach with safe accessibility. This generated 18 possible transects from which we haphazardly chose a subset of nine (labeled in pink) to provide good coverage along the Reach. Baseline 1 at Wellshire Golf Club was dropped due to bank inaccessibility.

Methods

Sampling design

We measured percent cover using the line-point intercept method, which involves dropping a pin flag at 0.25 m intervals along the transect and recording each species intercepted, plus what is present at the soil surface. Soil samples were taken during the first week of July 2020 using cores of five cm in diameter sunk to a depth of 5 cm. Cores were taken on a subset of 3 transects per baseline (9 baselines x 3 transects/baseline x 3 cores per transect = 81 total cores). Samples were sent to a soil quality testing laboratory at Colorado State University.

Figure 5. Example of transects (top) along which vegetation and soil data were taken. Nine “baseline” transects of 50 meters were run parallel to the Canal (left panel) and used to establish five perpendicular sampling transects (center and right panels) per baseline, spaced approximately 10 meters apart along the 50-meter stretch. There were 45 total transects. Soil samples pictured to the right.

Methods

Functional groups and wetland indicator status

Plant species functional groups can be used an indicator of their potential role in a GSI setting (Douthat 2022). In particular, plant longevity (annual, biennial, perennial) and growth habit (graminoid, forb, shrub) partly determine the role a particular species will serve in shaping water infiltration rates, bank stabilization, and potential removal of pollutants (Muerdter et al. 2018).

Further, wetland indicator status elucidates the ability of different plant species to withstand intermittent periods of inundation versus dry-down, as is typical in a GSI setting (Lichvar et al. 2016; Figure 6). Herein, plant longevity and growth habit were assigned using the USDA Plants Database and Ackerfield 2015. We used the National Wetland Plant List developed for the Great Plains Region (National Wetland Plant List 2020) to rank plant species along a continuum as follows:

Obligate Wetland (OBL):	Almost always a hydrophyte, rarely found in uplands
Facultative Wetland (FACW):	Usually a hydrophyte but occasionally found in uplands
Facultative (FAC):	Commonly occurs as a hydrophyte or non-hydrophyte
Facultative Upland (FACU):	Occasionally a hydrophyte, but usually in uplands
Upland (UPL):	Rarely a hydrophyte, almost always found in uplands

Figure 6. A newly installed berm with an example of vegetation zonation in the back-ground. Upland, highly managed grasses give way to trees and shrubs on the mid-bank. The lower banks and Canal bed are blanketed with *Carex emoryi*, an obligate wetland sedge (graminoid).

Results and Interpretation

Distribution of major cover types

Litter and bare ground will not slow, spread, and sink incoming stormwater with the same efficacy as live vegetation, which could inhibit GSI function in locations dominated by these less desirable cover types. An assessment of variation in cover from west to east across the one-mile Reach reveals that plant litter and bare soil together comprised a significant portion of cover at nearly all sampled locations (Figure 7). Cover of vegetation was never more than 50%, ranging from 0.26 ± SD 0.31 to 0.48 SD ± 0.41; plant litter had similar ranges of 0.24 ± SD 0.29 to 0.55 ± SD 0.35. And while bare soil was not overly prevalent (see B07, B15, B17, and B18 in Figure 7), it approached 25% cover in several locations (Figure 7).

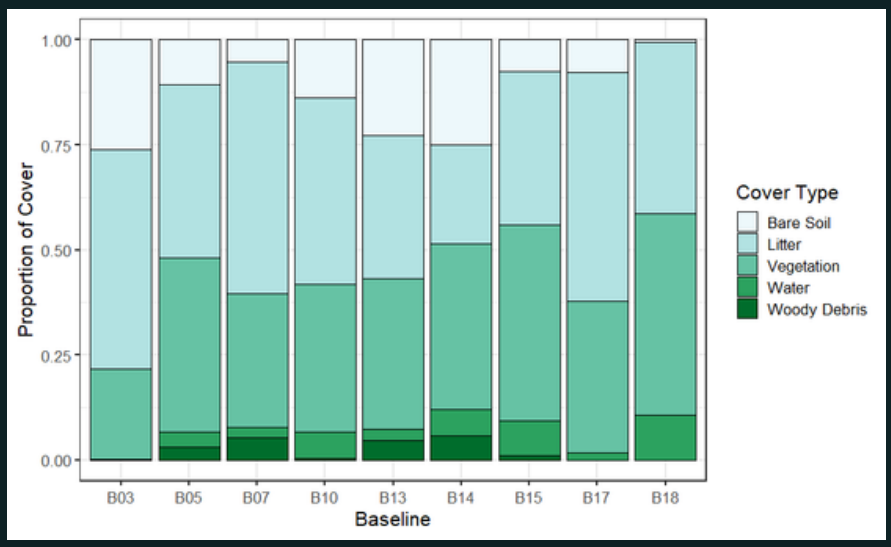


Figure 7. Top: Proportion of vegetated cover versus other types of cover at nine locations (baselines) along Reach 30 of the High Line Canal. Baselines are arranged on the x-axis from the westernmost extent (B03, near Wellshire Golf Course) to the easternmost extent (B18, near I-25). Proportion estimates are based on the means of N = 5 transects per baseline. Right, top: Example of litter/plant thatch covering the Canal banks. Right, bottom: Example of extensive bare ground on the far bank frame.

Results and Interpretation

Distribution of major cover types

When assessing cover types from the lower to upper banks of the Canal, some important patterns emerge. First, plant litter is the most common cover type along the lower banks (mean proportional cover of 0.36 ± SD 0.36; Figure 8), and bare soil is also prevalent in these locations, averaging 0.20 ± SD 0.32. Given the expectation that pollutant removal will happen as incoming stormwater is held in vegetated areas in the low-lying portions of the Canal, abundant litter and bare soil may reduce this desired function. There is, however, marked variation in each cover from baseline to baseline (see spread of black dots in Figure 8). A useful future endeavor may thus be to prioritize locations with low vegetation cover for plantings near the Canal bed. The same suggestion holds for the middle bank, which has similar cover patterns to the lower bank, and which could also be inundated during significant precipitation events.

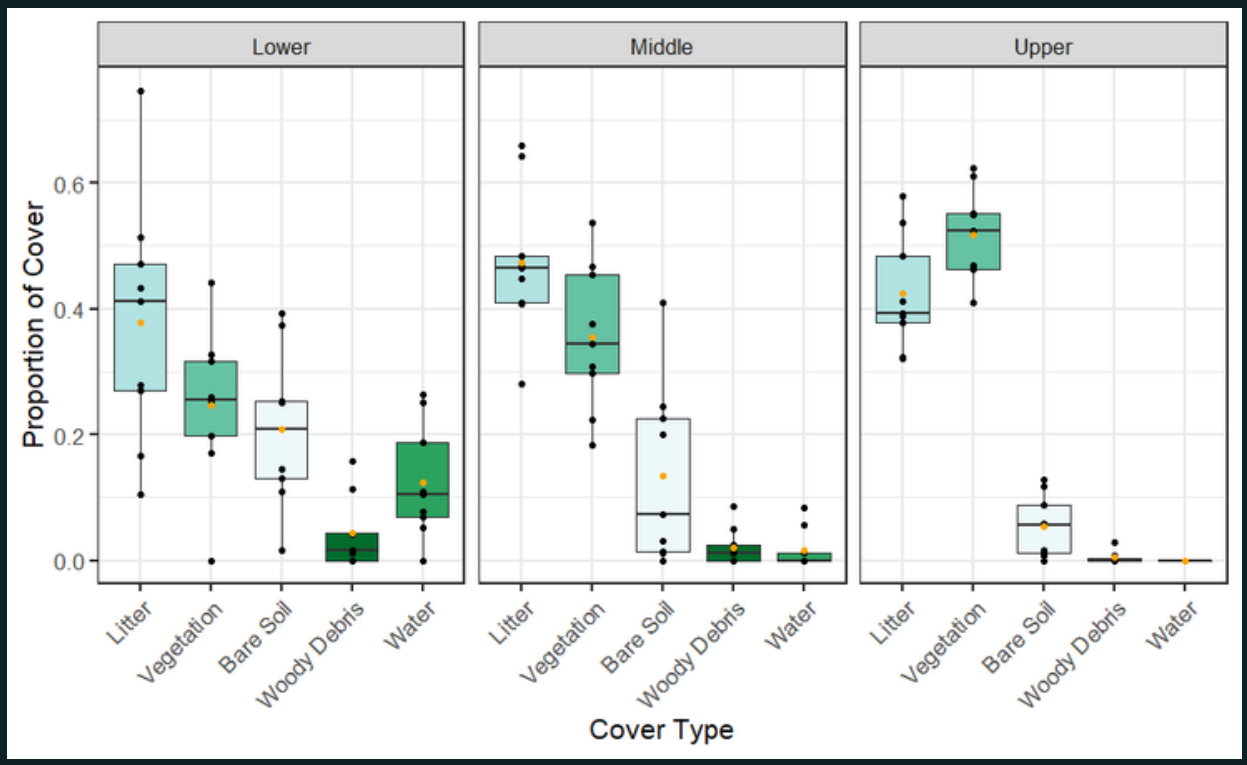


Figure 8. Boxplots of proportion cover by general cover types showing grand means (orange circles, based on means of nine baselines) and baseline means (black dots, based on means of 5 transects per baseline). Median is denoted by the horizontal black bar. Whiskers extend to 1.5x the inter-quartile range. Black dots beyond the whiskers (if present) are outliers.

Results and Interpretation

Most abundant plant species

It is typical for plant communities to be dominated by a few abundant species, with these species largely shaping ecosystem function. It is therefore useful to consider which species are most abundant along Reach 30, as they will shape GSI function depending on their associated traits. Four of the five most abundant species are cool-season perennial grasses and one is a shrub (Figures 9, 10; Table 1). An expected function of the abundant grasses is their ability to bind soil and reduce erosion via their extensive root systems; to facilitate water infiltration via the creation of macropore space and maintenance of soil structure; and, for reed canary grass (*Phalaris arundincea*) in particular, to filter pollutants from stormwater.

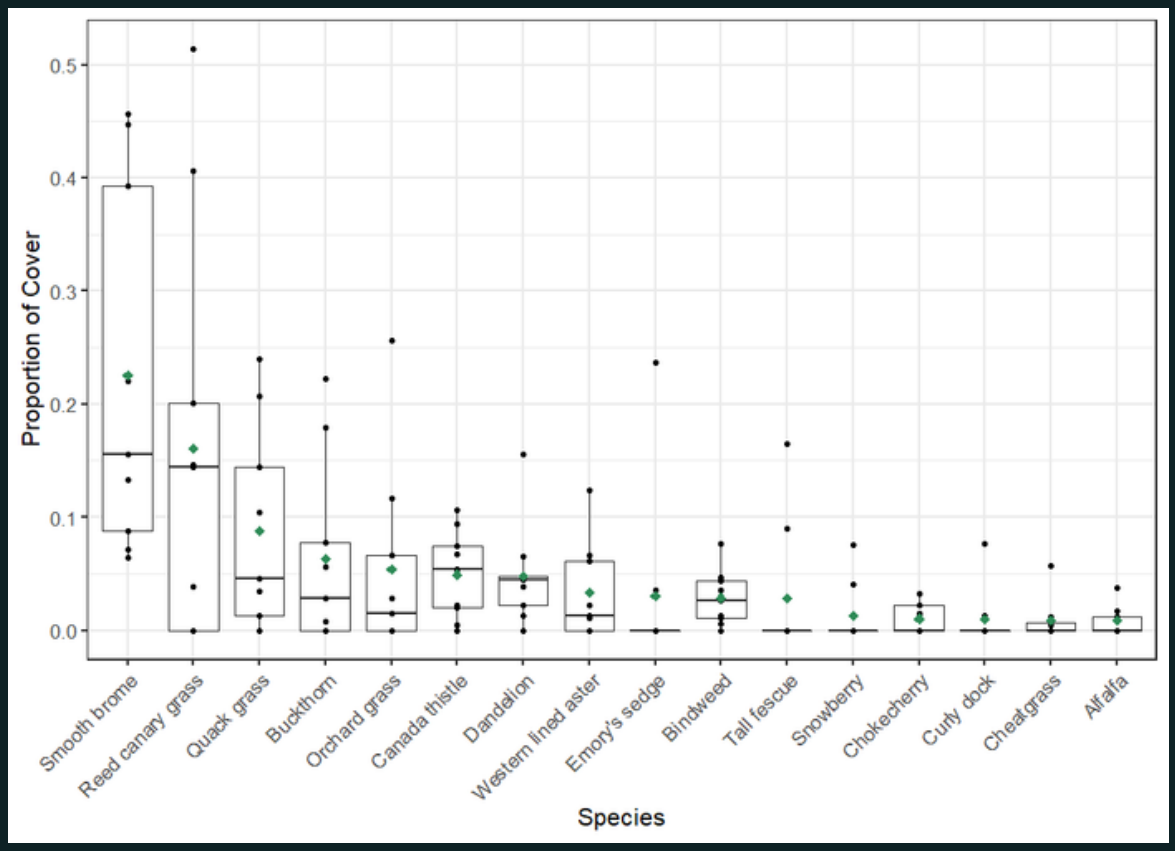


Figure 9. Boxplots of proportion cover by species showing grand means (green diamonds, based on means of nine baselines) and baseline means (black dots, based on means of 5 transects per baseline). Median is denoted by the horizontal black bar. Whiskers extend to 1.5x the inter-quartile range. Black dots beyond the whiskers (if present) are outliers.

Results and Interpretation

Most abundant plant species

Species	Traits	Proportion of cover by bank location	Potential mediation of GSI function
Smooth brome (*Bromus inermis*)	Sod-forming perennial grass Rhizomatous Cool season Wide ecological niche breadth Upland	Upper: 0.43 ± SD 0.39 Middle: 0.19 ± SD 0.34 Lower: 0.05 ± SD 0.17	May bind soil and reduce erosion; hardy and resistant to saline soils and drought; can crowd out other species and reduce diversity
Reed canary grass (*Phalaris arundinacea*)	Sod-forming perennial grass Rhizomatous Cool season Flood tolerant Facultative wetland	Upper: 0.014 ± SD 0.06 Middle: 0.13 ± SD 0.3 Lower: 0.33 ± 0.45	Used for erosion control, shoreline stabilization, pollutant filtration; tolerates periodic flooding; can crowd out other species and reduce biodiversity.
Quack grass (*Elymus repens*)	Sod-forming perennial grass Rhizomatous Cool season Invades disturbed, moist areas Facultative upland	Upper: 0.15 ± SD 0.22 Middle: 0.07 ± SD 0.2 Lower: 0.03 ± SD 0.17	May bind soil and reduce erosion; Significant cover on the mid-bank, where it might not tolerate increased inundation.
Buckthorn (*Rhamnus cathartica*)	Shrub Vigorous recruitment from seed Can root up to several feet depth Cold- and drought-hardy Facultative upland	Upper: 0.04 ± SD 0.14 Middle: 0.08 ± SD 0.26 Lower: 0.07 ± SD 0.25	Deep roots may increase soil porosity and water infiltration into deep soil layers.
Orchard grass (*Dactylis glomerata*)	Perennial grass Non-rhizomatous Cool season Mostly shallow roots (8 cm deep) Shade-tolerant Facultative upland	Upper: 0.06 ± SD 0.15 Middle: 0.07 ± SD 0.23 Lower: 0.03 ± SD 0.16	Roots may create pore space in shallower soil layers than occupied by the other dominant grasses

Table 1. The five most abundant species on Reach 30 of the High Line Canal, including traits that may shape their function in a GSI setting and their percent cover across the upper, middle, and lower banks.

Results and Interpretation

Most abundant plant species

From a GSI perspective, the high prevalence of buckthorn (often growing on the mid- to lower banks; Table 1) introduces structure to the vegetation, including a taller canopy that directly intercepts precipitation, and deeply ramifying roots, which can move water to deeper soil layers. Buckthorn's native counterpart, chokecherry (*Prunus virginiana*), was also relatively common (Figure 9) along the Canal's mid-banks. While there may be some overlap in function of buckthorn and chokecherry, the growth habits of these species are different. First, buckthorn forms dense thickets that develop bare soil underneath (Alba, personal observation), creating conditions that are undesirable in a GSI setting. Second, buckthorn was growing in appreciable numbers along the lower bank, while chokecherry was restricted to the mid-bank (data not shown). In built GSI settings, shrubs on not planted in low-lying areas where they can interrupt sheet flow within herbaceous vegetation (Stormwater Enterprise 2022). As such, it may be that buckthorn will in some ways inhibits GSI function, although still providing the service of deep water infiltration.

Figure 10. Several of the most abundant species occurring along Reach 30 of the Canal. Abundant species will serve a central role in shaping GSI function. From left to right: smooth brome, reed canary grass, quackgrass, buckthorn, orchard grass, western lined aster, Emory's sedge. Photos by Max Licher and Tony Frates.

Results and Interpretation

Most abundant plant species

Another important highlight is that two native wetland species, western lined aster (*Symphyotrichum lanceoatum* ssp. *hesperium*) and Emory's sedge (*Carex emoryi*), are present in appreciable numbers along the Reach. Emory's sedge in particular may have high function in cleaning pollutants from stormwater, as *Carex* species are often chosen for this feature in GSI planting palettes. Given this potential function, it is important to note that Emory's sedge distribution is extremely patchy along the one-mile stretch, with only two stands (Figure 9) largely contributing to its abundance (discussed further on page 16). The sedge's presence could represent an opportunity to outplant it more evenly along the one-mile Reach.

Plant Functional groups

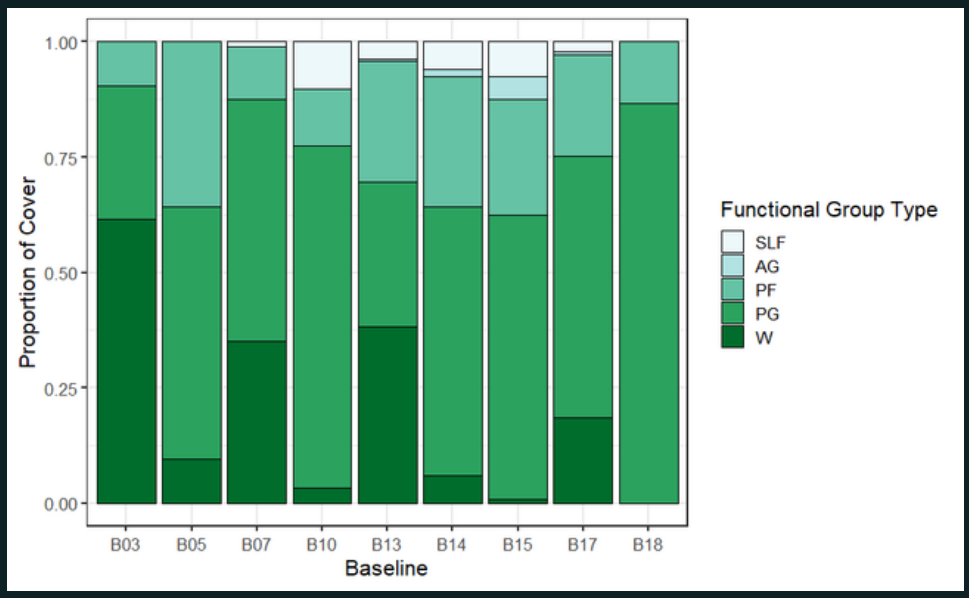
There was a total of 66 species identified along the one-mile Reach, which together comprise the local plant community and overall natural palette that will shape GSI. The aggregate function of all species in the community can be partly understood by considering their distribution among functional groups and wetland indicator status. While the "jobs" performed by different functional groups will likely overlap, some expectations are that:

- Short-lived grasses and forbs will contribute less to desired GSI function given their lack of robust roots and quick turnover in the system
- Perennial graminoids with their dense, fibrous roots will support bank stabilization, generation of macropores that facilitate water infiltration, and removal of stormwater pollutants via sediment filtration or uptake of nutrients and toxins
- Woody plants with deeper roots can facilitate water infiltration to greater depths
- Generally, varied plant architecture (e.g., an herbaceous understory with shrub mid-story and some larger trees) supports multi-functional GSI (please note that the vegetation sampling method reported here did not capture trees)

Results and Interpretation

Plant functional groups

Figure 11. Proportion of total plant cover at 9 sampled locations (baselines) broken out by functional group. SLF = short-lived forb (annuals plus biennials); AG = annual grass; PF = perennial forb; PG = perennial grass; W = woody (includes shrubs only).



Short-lived forbs and grasses are not prevalent along the one-mile stretch, contributing a maximum of 15% cover at a single location (Figure 11, see B15). Nearly all the short-lived species were introduced, disturbance-loving ruderals that had sparse occurrences in upland locations near the Canal path. Their low abundance, paired with their locations on the upper banks, suggest they are unlikely to inhibit GSI function. Examples (Figure 12) include cheatgrass (*Bromus tectorum*), horseweed (*Conyza canadensis*), blue mustard (*Chorispora tenella*), and sow thistle (*Sonchus oleraceus*).

Figure 12. Examples of short-lived species growing in upland locations on Reach 30 of the High Line Canal. From left to right: cheatgrass, horseweed, blue mustard, and sow thistle.

Results and Interpretation

Plant functional groups

Perennial graminoids are the most abundant functional group along the one-mile reach, ranging from 32% to 75% cover (Figure 11). When combined with co-occurring long-lived forbs, most sampled locations have vegetation that is dominated by long-lived herbaceous cover. Such coverage bodes well for desired GSI function. In several locations (e.g., B03, B07, B13, B17, Figure 11), appreciable cover of woody (shrub) plants create structural diversity that can achieve multi-functional GSI outcomes, for example by maximizing water infiltration in both the shallow and deeper soil layers.

In terms of differences in functional group coverage from the upper to lower banks of the Canal, the main difference occurs on the mid-bank, where woody species have their highest cover (mid-bank mean ± SD = 0.27 ± 0.37 versus upper bank = 0.08 ± 0.17 and lower bank = 0.15 ± 0.33). Correspondingly, perennial graminoids have lower cover on the middle banks (0.46 ± 0.35) than the upper (0.66 ± 0.25) or lower (0.62 ± 0.39) banks. Given this higher ratio of shrubs to perennial graminoids on the mid-banks, GSI function may differ in this zone, for example, if multi-functionality arises via water infiltration into both the shallow and deep soil layers.

Figure 13. Example of *Euonymus* shrub and perennial grasses that together create vegetation structure with the potential to serve complementary GSI functions.

Results and Interpretation

Wetland indicator status

Given their central role in supporting GSI function, it is important to explore the distribution of wetland plants along the extent of the canal. Obligate wetland plants such as cattails (*Typha* spp.) and sedges (*Carex* spp.) often occur in patchy or contained stands, as is the case along the Canal, where they are interspersed with stretches of bare ground on the lower banks and Canal bed. Figure 14 illustrates this patchiness, with obligate wetland plants (comprised largely of *Carex emoryi* and *Typha angustifolia*) present on only four baselines (B10, B14, B15, and B18). Other obligate wetland plants, including *Schoenoplectus tabernaemontani* (softstem bulrush) and *Sagittaria* spp. (likely arumleaf arrowhead), were sparsely represented, and while they contribute to increased diversity along the corridor, may not be important factors in GSI function.

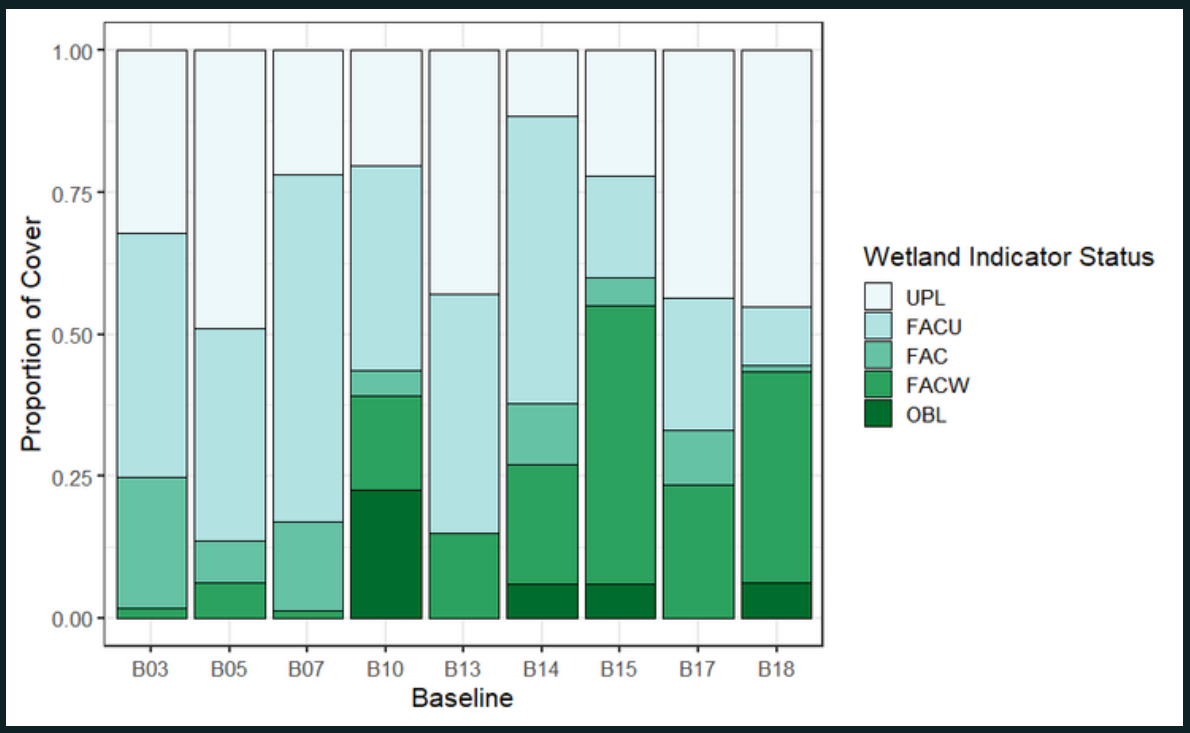


Figure 14. Proportion of plant cover at nine locations (baselines) broken out by wetland indicator status. UPL = Upland; FACU = Facultative Upland; FAC = Facultative; FACW = Facultative Wetland; OBL = Obligate. See text for definitions.

Results and Interpretation

Wetland indicator status

Facultative wetland plants may serve a particularly important pollutant-removal function in this novel GSI setting, because they can withstand periods of drying down better than obligate wetland plants. They are therefore more likely to be evenly distributed along the Reach. We see this pattern in Figure 14, where facultative wetland plants are present in every sampled location, although to varying degrees. Reed canary grass was by far the most abundant facultative wetland plant. Given its prevalence along the lower portions of the Canal (Table 1), and its known role in GSI function, this species is likely to be one of the most important in the system. Other facultative wetland plants that were abundant enough to potentially shape GSI function include the perennial forb western lined aster (discussed above) and the shrub coyote willow (*Salix exigua*).

Finally, a group of interest is facultative plants, as they are likely to withstand the greatest amplitude of moisture conditions. We found that facultative plants occur in most locations along the stretch (Figure 14) and are particularly prevalent on the middle banks (data not shown), with these mid-bank locations likely to experience the most marked wetting and drying cycles. This presence of facultative species within the local species pool thus suggests a degree of resilience to anticipated changes in hydrology. Two abundant facultative species include the perennial forbs showy milkweed (*Asclepias speciosa*) and Indian hemp (*Apocynum cannabinum*), which also function as pollinator resources.

Figure 15. Showy milkweed (left) and Indian hemp (right) are facultative species that can withstand marked changes in water availability. They represent potential resilience to hydrology change associated with implementation of GSI.

Results and Interpretation

Soil health

Urban soils are often disturbed in ways that exacerbate runoff. For example, they may lose structure due to low soil organic matter or via compaction from vehicle- or pedestrian traffic, which can reduce water infiltration and storage. Urban soils can also become saline from the use of de-icing salts, urine from pets, or when irrigation water cannot leach to deeper soil layers.

The High Line Canal represents a unique situation in that its soils are unlikely to be highly degraded like those occurring in high-density urban spaces, yet they have undergone significant disturbance over time (Canal dredging, heavy maintenance equipment, high-volume foot and bike traffic, proximity to streets and parking lots, etc.). Given the Canal's land use history, it is of interest to gauge soil health in areas where GSI is now being implemented.

Figure 16. Soil quality often differs between natural and urban areas. The High Line Canal, with its unique land use history, may lie somewhere along this continuum, with implications for GSI function.

Results and Interpretation

Soil health

Soil texture shapes soil function both directly via its effect on water infiltration rates and holding capacity, and indirectly in terms of how it interacts with other soil factors. Soil texture on the Reach was predominantly sandy loam (50% of samples), sandy clay loam (17% of samples), and loam (21% of samples; Figure 17). These texture classes are often recommended for built GSI because they balance water infiltration against water holding capacity and nutrient retention, thereby supporting multiple facets of GSI function (City and County of Denver, Ultra-Urban Green Infrastructure Guidelines 2016). This finding thus indicates good support of GSI function.

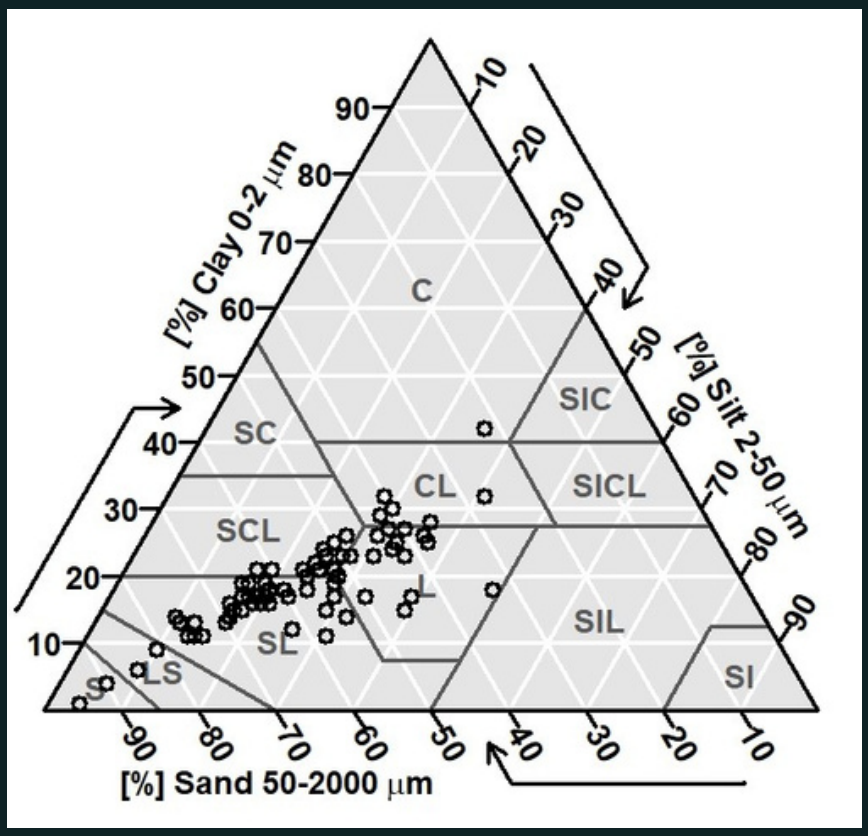


Figure 17. USDA soil texture triangle showing the distribution of soil samples from Reach 30 of the High Line Canal across texture types. Pure sand (S), silt (SI), and clay (C) are in the corners of the triangle and indicate nearly pure amounts of that fraction.

Results and Interpretation

Soil health

Higher bulk densities indicate increased compaction, with levels considered problematic for plant growth differing by soil texture (Table 2). We found that bulk density ranged from 1.191 ± 0.033 to g/cm3 to 1.311 ± 0.063 g/cm3 across the nine baseline locations (Figure 18). This is well within the ideal range for plant root growth and movement of water through the soil profile for the observed soil textures.

Soil Texture	Ideal bulk densities for plant growth (g/cm3)	Bulk densities that affect root growth (g/cm3)	Bulk densities that restrict root growth (grams/cm3)
Sands, loamy sands	< 1.60	< 1.69	> 1.80
Sandy loams, loams	< 1.40	< 1.63	> 1.80
Sandy clay loams, clay loams	< 1.40	< 1.60	> 1.75
Silts, silt loams	< 1.40	< 1.60	> 1.75
Silt loams, silty clay loams	< 1.40	< 1.55	> 1.65
Sandy clays, silty clays, clay laoms	< 1.10	< 1.49	> 1.58
Clays (< 45% clay)	< 1.10	1.39	> 1.47

Table 2. Range of bulk densities and how they affect plant growth broken out by soil texture.

Results and Interpretation

Soil health

Further, while we hypothesized that bulk density would be higher on the upper banks, where large maintenance equipment and high pedestrian traffic are common, this was not the case (mean ± SD upper banks = 1.26 ± 0.09; middle banks = 1.26 ± 0.12; lower banks = 1.23 ± 0.09). As such, there is no indication that plant growth, including desirable root proliferation through the soil, will be inhibited by compaction, even in highly trafficked areas near the Canal trail.

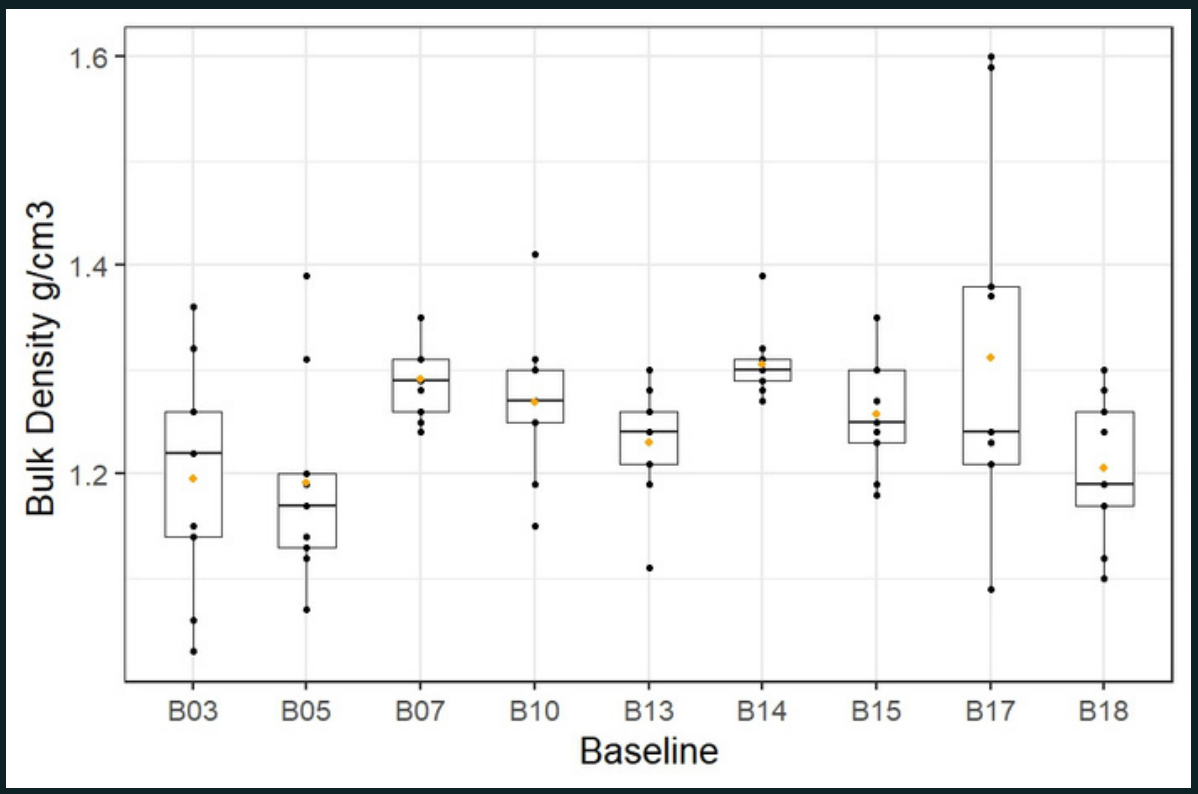


Figure 18. Boxplots of bulk density showing grand means (orange diamonds, based on means of nine baselines) and baseline means (black dots, based on means of 5 transects per baseline). Median is denoted by the horizontal black bar. Whiskers extend to 1.5x the inter-quartile range. Black dots beyond the whiskers (if present) are outliers.

Results and Interpretation

Soil health

Soil organic matter (SOM), which is composed of detritus, humus, plant residues, and microbes, is critical to soil health. It is a reservoir for plant nutrients (e.g., it is highly correlated with nitrogen availability), and it shapes several other soil characteristics such as structural stability, cation exchange capacity and mineral levels, and pH. In disturbed areas, SOM can be stripped away when construction or other disturbances compromise topsoil (Scheyer and Hipple 2005). While healthy SOM levels are context-specific, a helpful gauge is that productive agricultural soils contain between 3 and 6% organic matter (Fenton et al. 2008). Based on this reference point, we found good overall levels of SOM, ranging from mean ± SD of 4.1% ± 1.27 to 8.9 ± 5.8.

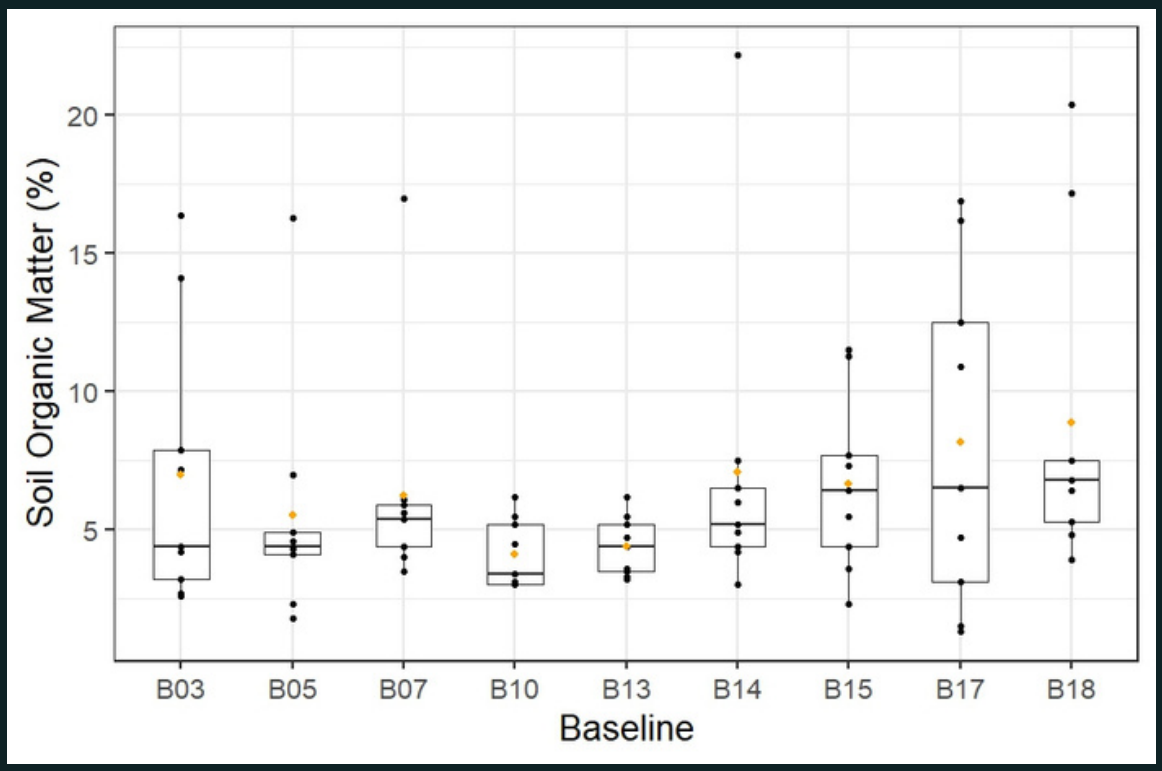


Figure 19. Boxplots of soil organic matter showing grand means (orange diamonds, based on means of nine baselines) and baseline means (black dots, based on means of 5 transects per baseline). Median is denoted by the horizontal black bar. Whiskers extend to 1.5x the inter-quartile range. Black dots beyond the whiskers (if present) are outliers.

Results and Interpretation

Soil health

SOM also exhibited pronounced variability around the mean and quite a few outliers, with several soil samples exceeding 15% (Figure 19). The highest levels of SOM occurred on the lower banks (data not shown) where incoming stormwater will pool. It might therefore be of interest to further explore this vertical zonation (e.g., is there a threshold at which soils with high SOM leach nutrients into incoming stormwater rather than removing it?).

Finally, as with the previous soil metrics, electrical conductivity (as a proxy for salinity) provides evidence that soils along Reach 30 are of generally high quality. All baseline means fall within the non-saline range of 0 to 2 mmhos/cm (Whiting et al. 2015; Figure 20) except for B18, which is only slightly elevated above this threshold. In this range, plant growth is not at all inhibited. However, as with SOM, there is some pronounced variability around the mean, with locations B17 and B18 exhibiting slightly saline (2.1 to 4 mmhos/cm; sensitive plants inhibited) to moderately saline (4.1 to 8; many plant inhibited) soils. Still, the overall pattern suggests low impacts from salinity.

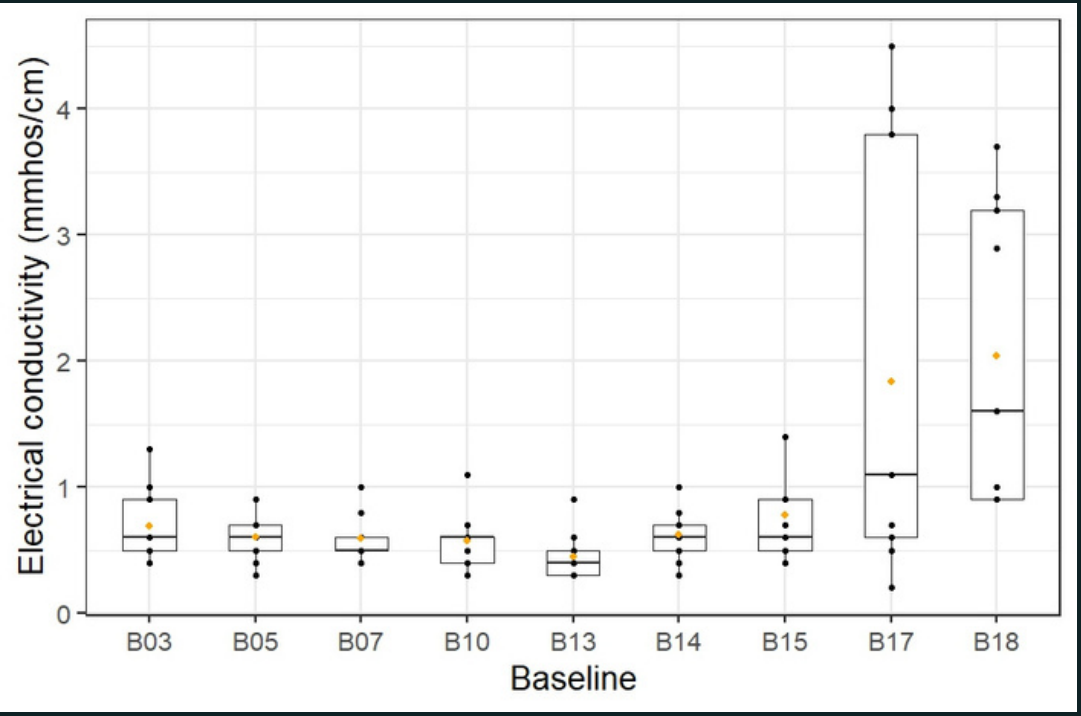


Figure 20. Boxplots of electrical conductivity (a proxy for salinity) showing grand means (orange diamonds, based on means of nine baselines) and baseline means (black dots, based on means of 5 transects per baseline). Median is denoted by the horizontal black bar. Whiskers extend to 1.5x the inter-quartile range. Black dots beyond the whiskers (if present) are outliers.

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Author Biography

Christina Alba is an assistant research scientist at Denver Botanic Gardens. She studies the ecological processes that shape plant diversity and distributions across various scales of organization--from individual plants, to populations, to entire communities. Her research questions fall under the sub-discipline of disturbance ecology, with a focus on plant responses to phenomena such as wildfire, grazing, drought, biological invasions, and management interventions in both urban and wildland systems. Dr. Alba combines sampling approaches from different disciplines—including collections-based botanical floristics and quantitative plant ecology—to improve our understanding of what factors shape plant biodiversity.