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November 30, 2017 Project B1710649

Nathan P. Kass, P.E., P.L.S. – Branch Manager
Fehr Graham
200 5th Avenue SE, Suite 100
Cedar Rapids, Iowa 52401

Re: City Services Center
500 15th Avenue SW
Cedar Rapids, Iowa

Dear Mr. Kass:

Braun Intertec Corporation evaluated soil and plant tissue in bioswales at the Cedar Rapids City Center in Cedar Rapids, Iowa. The purpose was to determine if soil nutrition may be the cause of the landscaping failure in the bioswales.

The bioswales were designed with 24 or 30 inches of a sand/compost soil mixture above a subdrain. The subdrain consists of perforated HDPE pipe surrounded a minimum of 6 inches of gravel within a trench below the bioswale.

## Methods

Within each of three bioswales, soil samples were collected in areas of living and dead plants, for a total of six soil samples (3 bioswales x 2 conditions live/dead = 6 samples). For each sample, multiple collections were taken from different locations throughout the bioswales. Soil was collected from the upper 6 inches of the soil profile, and corresponding observations of soil texture were made. Within one of the bioswales, plant tissue was collected from individuals of Morrow's sedge (*Carex morrowi*). Samples were sent to Agvise Laboratories in Benson, Minnesota for quantification of plant nutrients.

## Results

Laboratory test results are included in the attached tables. Soil nutrient analyses reveal that plant macronutrients are low or limiting (nitrogen [measured as nitrate], phosphorous, and potassium). Micronutrients such as boron and chloride are also low, and magnesium is slightly low. Other measured parameters are low, particularly organic matter, soluble salts and cation exchange capacity. These variables affect the availability of nutrients in the soil, and the ability of the soil to retain nutrients. For most nutrients and soil properties that are low, measured levels tend to be lower in areas that planted vegetation has died compared to areas of live vegetation.

Sodium is not an essential plant nutrient, but sodium is absorbed by plants. High levels of sodium can negatively affect plant health and soil structure, and elevated soil sodium may occur where road salt is present in runoff water. Five soil samples showed relatively low levels of sodium. A sixth sample, Bioswale 3, in a dead area, had elevated soil sodium at a level of 224 ppm. This level is above the recommended limit of 160 ppm (for agronomic crops), but may not create toxic conditions.

Other parameters are useful in evaluating whether soil sodium may be harmful to plants, particularly soluble salts and percent base saturation by sodium. Soluble salts is a measure of dissolved inorganic solutes, and includes many cations and anions that are plant nutrients as well as sodium. When sodium toxicity occurs, elevated soluble salt levels are typically observed. In the samples from the Cedar Rapids City Center, soluble salt measurements are low, consistent with a paucity of soil nutrients such as nitrate, potassium, magnesium, chloride, and phosphate. Furthermore, the percent base saturation of sodium is low, also indicating that sodium toxicity is not likely present.

Plant tissue test results were compared to recommended levels for perennial grasses, which is a reasonable assumption because typical levels for the species planted in the bioswales are unknown. Overall, many nutrients were found to be low including nitrogen, phosphorous, potassium, sulfur, magnesium, zinc, manganese, and copper. Sodium levels in the plant tissue were not elevated.

Observations of soil texture indicate a great deal of variability. Throughout the two bioswales with an east-west orientation, soils appear to be either sand or organic matter, suggesting soils were poorly mixed when the bioswales were constructed. Areas of dead vegetation seem to be randomly located with regards to soil texture or inlets from parking lots. The remaining bioswale, oriented north-south, showed areas of poorly mixed clayey sand and organic matter. Areas of dead vegetation seemed to have heavy clay and organic soil. No evidence was observed for any type of soil contamination from rocks, debris or chemicals.

The original landscaping plan called for soils in the bioswales to be a uniform mixture of 70% washed concrete sand and 30% finely screened compost. It appears that the original plan was not followed correctly because soils were observed to be highly variable ranging from organic (compost) to sand, and in some locations, heavy clay, which should not have been present. The landscaping specifications for the sand and compost mixture were likely based on the volume of each component. The laboratory analyses found average organic matter of 3.2% across six soil samples. It is important to note that this percentage is based on weight loss on ignition (of organic matter), and as such, cannot be directly compared to the desired 70:30 ratio based on volume, since the density of sand and compost differ greatly. However, the 3.2% average organic content is low for optimal plant growth and nutrition. Adequate soil organic matter should be above 4.5% to be considered high or very high.

The variability of the soil texture from areas of predominantly sand to areas of predominantly organic matter not only affects nutrient availability but also permeability and drainage. Sandy soils are highly permeable, low in nutrients, and have little capacity to retain nutrients.

Our assessment of why planted vegetation in the bioswales has failed is due to a combination of factors. Nutrients are lacking, and excessively drained soils means soil infiltration carries nutrients below the root zone. Furthermore, water availability in the soil is highly variable, and the sandy soil provides little water retention during dry periods. Areas of mostly organic matter or heavy clay may create localized pockets that remain too wet for prolonged periods for the species of plants that were installed, or the clay density may be too great for optimal root growth. Without repeated observations of ponding, water tables, and variability of soil moisture, it is difficult to know if excessive moisture is part of the problem. However, based on available evidence, it appears that excessive drainage and droughty conditions contribute to the landscaping failure. The subdrains beneath the highly permeable sand ensures that drainage and water removal from the site is rapid.

The microclimate of the bioswales along a parking lot is prone to extreme environmental conditions, particularly hot and dry conditions during the summer. For plants to survive in the bioswales, they must be deeply rooted to reach moisture and nutrients lower in the soil profile during dry periods. The poor soil fertility and excessive drainage means plant roots likely do not have sufficient resources during temperature and moisture extremes. If plants are already stressed from nutrient deficiency, their ability to cope with stressful conditions is compromised.

While the empirical evidence suggests that sodium toxicity from road salt applied to the parking lots is not a determining factor, it should be noted that the limited sample size does not allow total exclusion of this possibility in all areas. Indeed, where water runoff from the parking lot is greatest, it is expected that saline or sodic soils will eventually develop, which will be a long-term challenge to the success of the bioswales.

## Recommendations

Two options are available to remedy the condition of the bioswales. After replanting, supplemental fertilizer should be occasionally applied and irrigation may be necessary during dry periods. The extent and frequency of fertilization required would have to be determined over time, guided by periodic soil tests to assess nutrient availability. However, this ongoing level of intensive management is contrary to the intent of bioswales that are used for collection and infiltration of rainwater and enhancement of downstream water quality. These basins are generally intended to be self-sustaining in terms of water and nutrients without the need for periodic supplementation. Furthermore, the high percolation rate of water through this soil would result in much of the supplemental nutrients being leached out of the soil through the subsurface drainage.

The other option is to excavate the soils, add an appropriate soil mixture and replant. Various resources recommend bioswales have a soil mixture is 50-60% washed concrete sand, 20-30% compost, and 15-30% topsoil (loamy texture). Iowa Department of Transportation methods suggest using 50% sand, 20% compost, and 30% topsoil in bioswales. The inclusion of topsoil will allow for greater nutrient availability from weathering of soil particles and greater retention of nutrients in the soil profile. It will also reduce the soil permeability and optimize soil tilth for root growth. It is recommended to replace the entire depth of soil in the bioswales, although improved conditions should result from replacing the upper 12-18 inches of soil. To avoid inadequate mixing, soils should be mixed offsite using appropriate equipment such as a twin screw pug mill rather than attempting mixing onsite using shovels or buckets.

The existing, surviving plants can be retained and reused. New plantings should include species regionally suited for raingardens and should be salt-tolerant. Many native Iowa species fit these criteria, such as the following:

| Native Iowa Plant Species with Salt Tolerance | |
|---|---|
| **Species** | **Common Name** |
| *Asclepias incarnata* | Swamp milkweed |
| *Carex crinita* | Fringed sedge |
| *Carex vulpinoidea* | Fox sedge |
| *Doellingeria umbellata* | Flat-top aster |
| *Elymus canadensis* | Canada wild rye |
| *Eupatorium perfoliatum* | Boneset |
| *Helenium autumnale* | Sneezeweed |
| *Juncus canadensis* | Canadian rush |
| *Juncus torreyi* | Torrey's rush |
| *Lobelia cardinalis* | Cardinal flower |
| *Monarda fistulosa* | Wild bergamot |
| *Panicum virgatum* | Switchgrass |
| *Parthenium integrifolium* | Wild quinine |
| *Physostegia virginiana* | Obedient plant |
| *Ratibida pinnata* | Yellow coneflower |
| *Rudbeckia hirta* | Black-eyed Susan |
| *Schizachyrium scoparium* | Little bluestem |
| *Scirpus cyperinus* | Wool grass |
| *Schoenoplectus acutus* | Hard-stemmed bulrush |
| *Schoenoplectus tabernaemontani* | Soft-stemmed bulrush |
| *Solidago rigida* | Stiff goldenrod |
| *Spartina pectinata* | Prairie cordgrass |
| *Sporobolus heterolepis* | Prairie dropseed |
| *Symphyotrichum laeve* | Smooth blue aster |
| *Symphyotrichum novae-angliae* | New England aster |
| *Teucrium canadense* | Germander |
| *Verbena stricta* | Hoary vervain |
| *Zizia aurea* | Golden Alexandars |

We appreciate the opportunity to provide our professional services to you for this project. If you have questions concerning this correspondence or the project in general, please call Daniel DeJoode at 952.995. 2459.

Sincerely,

BRAUN INTERTEC CORPORATION

Daniel R. DeJoode, Ph.D.
Senior Scientist

Attachment:
Laboratory Test Results

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**Laboratory Results** **Cedar Rapids City Center** **October 31, 2017**

**Soil Test Results**

| Nutrient or Parameter | Units | Vegetation: Alive | | | | | Vegetation: Dead | | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Bioswale 1 | Bioswale 2 | Bioswale 3 | Average | Std Dev | Bioswale 1 | Bioswale 2 | Bioswale 3 | Average | Std Dev | |
| Nitrate | lb/ac | 6 | 6 | 12 | 8.0 | 2.8 | 2 | 4 | 3 | 3.0 | 0.8 | Very low, may be limiting |
| Phosphorous | ppm | 20 | 7 | 27 | 18.0 | 8.3 | 7 | 4 | 23 | 11.3 | 8.3 | Very low, especially where vegetation dead |
| Potassium | ppm | 40 | 26 | 157 | 74.3 | 58.7 | 29 | 24 | 193 | 82.0 | 78.5 | Very low, may be limiting |
| Chloride | lb/ac | 39 | 3 | 20 | 20.7 | 14.7 | 2 | 2 | 7 | 3.7 | 2.4 | Low |
| Sulfur | lb/ac | 40 | 14 | 42 | 32.0 | 12.8 | 26 | 8 | 18 | 17.3 | 7.4 | Sufficient |
| Boron | ppm | 0.3 | 0.1 | 0.5 | 0.3 | 0.2 | 0.1 | 0.1 | 0.6 | 0.3 | 0.2 | Low |
| Zinc | ppm | 4.55 | 4.39 | 6.49 | 5.1 | 1.0 | 4.76 | 4.1 | 2.74 | 3.9 | 0.8 | Sufficient |
| Iron | ppm | 27.3 | 33.1 | 44 | 34.8 | 6.9 | 29.2 | 23.9 | 68.9 | 40.7 | 20.1 | Sufficient |
| Manganese | ppm | 1.4 | 1.1 | 2.8 | 1.8 | 0.7 | 1.3 | 0.9 | 5 | 2.4 | 1.8 | Sufficient |
| Copper | ppm | 0.82 | 0.75 | 0.75 | 0.8 | 0.0 | 0.63 | 0.61 | 1.12 | 0.8 | 0.2 | Sufficient |
| Magnesium | ppm | 103 | 41 | 158 | 100.7 | 47.8 | 60 | 45 | 186 | 97.0 | 63.2 | Medium |
| Calcium | ppm | 2245 | 1402 | 2619 | 2088.7 | 509.0 | 1816 | 1277 | 2411 | 1834.7 | 463.1 | Sufficient |
| Sodium | ppm | 27 | 34 | 50 | 37.0 | 9.6 | 27 | 29 | 224 | 93.3 | 92.4 | Elevated in one sample |
| Organic matter | % | 2.7 | 2 | 6.2 | 3.6 | 1.8 | 2.3 | 1.7 | 4.2 | 2.7 | 1.1 | Low for sandy soil |
| Carbonate | % | 0 | 0 | 0 | 0.0 | 0.0 | 0.2 | 0 | 0 | 0.1 | 0.1 | Sufficient |
| Soluble salts | mmho/cm | 0.16 | 0.11 | 0.24 | 0.2 | 0.1 | 0.12 | 0.04 | 0.25 | 0.1 | 0.1 | Low, not limiting |
| pH | pH | 7.8 | 7.6 | 7.8 | 7.7 | 0.1 | 7.8 | 7.7 | 8.1 | 7.9 | 0.2 | Slightly basic but acceptable |
| Cation exchange capacity | meq | 12.3 | 7.6 | 15 | 11.6 | 3.1 | 9.8 | 6.9 | 15.1 | 10.6 | 3.4 | Near lower limit, but at pH > 7.6, CEC may be inflated by high calcium |
| Calcium | % base saturation | 91.2 | 92.6 | 87.1 | 90.3 | 2.3 | 92.9 | 91.9 | 80 | 88.3 | 5.9 | Acceptable |
| Magnesium | % base saturation | 7 | 4.5 | 8.8 | 6.8 | 1.8 | 5.1 | 5.4 | 10.3 | 6.9 | 2.4 | Acceptable |
| Potassium | % base saturation | 0.8 | 0.9 | 2.7 | 1.5 | 0.9 | 0.8 | 0.9 | 3.3 | 1.7 | 1.2 | Acceptable |
| Sodium | % base saturation | 1 | 2 | 1.4 | 1.5 | 0.4 | 1.2 | 1.8 | 6.5 | 3.2 | 2.4 | Acceptable, but measurement may be low due to high calcium levels |

**Plant Tissue Test Results** **Species:** **Morrow's sedge *(Carex morrowii)***

| Nutrient or Parameter | Units | Plant 1 Bioswale 2 | Plant 2 Bioswale 2 | Comments |
|---|---|---|---|---|
| Nitrogen | % | 2.57 | 1.79 | Low or barely adequate |
| Phosphorous | % | 0.2 | 0.33 | Low or nearly low |
| Potassium | % | 1.2 | 1.8 | Low or nearly low |
| Sulfur | % | 0.19 | 0.03 | Low |
| Calcium | % | 2 | 2.03 | Sufficient |
| Magnesium | % | 0.16 | 0.25 | Low or nearly low |
| Sodium | % | 0.01 | 0.02 | Not limiting |
| Zinc | ppm | 33 | 14 | Low or nearly low |
| Iron | ppm | 99 | 42 | Sufficient |
| Manganese | ppm | 23 | 17 | Low or nearly low |
| Copper | ppm | 5 | 3 | Low or nearly low |
| Boron | ppm | 11 | 17 | Sufficient |

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