Calgary

Invasive shrub removal in South Glenmore Park. Admixing and compaction mitigation was implemented due to depth of the brush grinder being above topsoil, through use of tracked equipment and working in dry conditions.

Soil Handling Recommendations

Best practices to improve restoration work

Q4, 2018

Publication Information

SOIL HANDLING RECOMMENDATIONS: best practices for The City of Calgary to improve restoration work.

INTENT: This document provides soil handling recommendations to increase the effectiveness of restoration plans as per the *Habitat Restoration Project Framework* (The City of Calgary Parks 2014).

PREPARED BY: The City of Calgary, Parks, Urban Conservation

VERSION: 2019 Edition

ADDITIONAL COPIES: To download an electronic copy:
http://www.calgary.ca/CSPS/Parks/Pages/Construction/Park-development-guidelines.aspx

INFORMATION: Corporate Call Centre: 3-1-1 (within Calgary)

Copyright

Copyright © The City of Calgary 2018

No part of this work may be reproduced by any means without written permission from The City of Calgary.

Terms of Use

Soil Handling Recommendations is intended to be used in conjunction with the document *Habitat Restoration Project Framework* (The City of Calgary Parks 2014), as referenced throughout the document, and is made available for use in The City of Calgary effective as of the date below.

February 1, 2019

The 2019 *Soil Handling Recommendations* is presented as accurate and complete as of the date indicated above. Use of this document does not absolve any user from the obligation to exercise their professional judgment and to follow good practices. Nothing in this document is meant to relieve the user from complying with municipal, provincial and federal legislation. Should any user have questions as to the intent of any procedure found in this publication, the user is advised to seek clarification from the lead of Urban Conservation, Parks.

Important: Before using this document please ensure you review the Disclaimer Section on Page 12.

Revision Notice

Subsequent revisions will be released as required.

Cover photograph and Table of Contents photograph taken by The City of Calgary.

Executive Summary

Although The City of Calgary has various requirements for soil handling, they do not address the concept of soil health, also termed the soil food web, as a dynamic complex ecosystem where various organisms function as predators, prey and also maintain symbiotic relationships. Due to this, the soil food web includes everything in the soil such as the beneficial bacteria, fungi, protozoa, nematodes, organic content and inorganic materials that function together to improve and maintain soil health (Soil Food web Canada Ltd. 2017). The most obvious things contained in the soil food web are the plants as the leaves, flowers and stems are above ground; however, many unseen interactions occur below ground. Successful projects that involve earth moving consider the concept of soil health from the planning stages to the final landscaping phases as plant growth is limited by soil health.

This document is meant to assist in carrying out restoration plans and expand on the existing soil handling information as per the *Habitat Restoration Project Framework* (The City of Calgary Parks 2014). The *Habitat Restoration Project Framework* goes into more detail regarding best practices; however, other City documents address soil handling recommendations and requirements. These documents include *Contractor Environmental Responsibilities Package* (The City of Calgary 2012), the *Erosion & Sediment Control Guidelines* (The City of Calgary Water Resources 2017), *Development Guidelines and Standard Specifications: Landscape Construction* manual (The City of Calgary Parks current edition) and *Construction Environmental Checklist*, *Environmental Requirements for City of Calgary Construction Projects* (Environmental and Safety Management 2016). Although these documents discuss the preservation of soil health, additional best practices are highlighted in this document.

Soil health is most critical when soils support complex vegetation communities and as such, this document is primarily intended to provide guidance on best practices for soil handling in Natural Environment Parks, although these best management practices can be used in any soil handling situation. Maintaining the soil food web and soil health will benefit all types of landscaping practices including everything from reclamation (e.g., stabilizing disturbed lands to an ecologically productive use through revegetation) to restoration (e.g., re-establishing target ecosystem function and biodiversity through the process of returning the vegetation community to its natural [reference vegetation community] state). Regardless, the more complex the revegetation work is, the more important soil health is to a successful outcome.

Since soil has taken a very long time to form, it can be very difficult, if not impossible, to reverse negative effects of construction activities. *Soil Handling Recommendations* focuses primarily on proactively maintaining the soil food web and soil health, although corrective measures are discussed.

Healthy plants make for aesthetically pleasing communities and a healthy environment but plant vigor is reliant on the state of the soil in which they are growing in. Additional costs and time are incurred during plant replacement, reseeding, watering and weed control when revegetation is performed using unhealthy soil. When soil is healthy, costs are minimized as maintenance is significantly reduced.

A reduction in maintenance, both during the vegetation establishment phase and in the long term, reduces the amount of carbon released into the atmosphere by vehicles, propagation of replacement plants, fertilizer manufacturers and irrigation methods. Soil conservation, reuse and best handling practices contributes to carbon sequestration in soil through the preservation of soil organic matter (Ecological Society of America 2000). This is turn leads to additional soil stability which minimizes soil loss and maximizes carbon sequestration due to a healthy vegetation cover and the ability of plant roots to bind soil. Essentially, maintaining the soil food web significantly decreases atmospheric carbon dioxide and prevents climate change. Due to the importance of soil health in carbon sequestration, both directly by carbon storage and indirectly by reduced landscape maintenance, this document fulfils many of the objectives set forth by The City of Calgary's *Climate Resilience Strategy* (The City of Calgary 2018).

In order to ensure clarity, required soil handling practices as indicated in *Development Guidelines and Standard Specifications: Landscape Construction* (The City of Calgary Parks current edition) are outlined first in this document. Recommended practices and mitigation measures are then further discussed in depth.

As *Soil Handling Recommendations* discusses construction phases from the planning to the FAC stage, it is important that all personnel involved in earth moving become familiar with these best practices.

Proper soil handling practices shown through minimizing stockpile depth and clearly delineating access routes.

Table of Contents

Introduction

Healthy soils are fertile soils. This document provides guidance on how to maintain the integrity and health of the soil food web which includes everything in the soil such as the beneficial bacteria, fungi, protozoa and nematodes that live in the soil and also the soil organic matter that function together to improve and maintain soil health (Soil Food web Canada Ltd. 2017). *Soil Handling Recommendations* is meant to be used in conjunction with other City of Calgary documents. These documents include the *Habitat Restoration Project Framework* (The City of Calgary Parks 2014), *Contractor Environmental Responsibilities Package* (The City of Calgary 2012), *Erosion and Sediment Control Guidelines* (The City of Calgary Water Resources 2017), *Development Guidelines and Standard Specifications: Landscape Construction* manual (The City of Calgary Parks current edition) and *Construction Environmental Checklist*, *Environmental Requirements for City of Calgary Construction Projects* (Environmental and Safety Management 2016).

The soil food web is the ecosystem that is mostly hidden within the soil. Although plants are the most visible components, maintaining the natural biological interactions underground is critical to soil health and supporting vegetation, both chemically and physically.

Although other City of Calgary documents have requirements for soil handling, this document focusses on the soil food web as an ecosystem and the conservation of soil health, stressing proactive measures while covering reactive/corrective measures when required. An outline for operational procedures for soil handling best practices is provided as a flowchart in Appendix 2.

The topics covered in *Soil Handling Recommendations* include:

- Document purpose;
- City of Calgary soil handling requirements;
- Background research/desktop review prior to project initiation;
- Soil testing;
- Best practices for stripping;
- Best practices for stockpiling;
- Best practices for compaction and admixing mitigation (e.g., preventative and corrective actions);
- Soil rebuilding and improvement;
- Soil and vegetation conservation;
- Soil import (e.g., topsoil import, subsoil import and subsoil creation);
- Site preparation to maximize seeding efficiency; and,
- Site preparation based on drainage.

This document should be reviewed by all staff involved in any City of Calgary projects that involve earth moving and/or landscaping. It is important to ensure that this information is shared with field staff and that heavy equipment operators are familiar with this document. Consistency in the use of these practices from the planning phase through to FAC will contribute to quicker completion times, significant cost savings and decreased maintenance.

Lastly, it should be noted that there is overlap in this document as measures taken to preserve soil health often conserve multiple elements of the soil food web. *Soil Handling Recommendations* attempts to explain how certain activities can proactively contribute to many factors of soil health. Due to these interconnections, some repetition is present in this document.

Strategic alignment

In March 2015, Council approved *Our BiodiverCity, Calgary's 10-year strategic plan* and the Biodiversity Policy. Within the strategic plan, various procedures were developed to meet the plan's goals. Procedure 2 commits to improving the city of Calgary's ecological functions. In order to improve Calgary's ecological functions, a commitment was made to develop and implement landscaping design guidelines related to soil fertility, volume and management.

Additionally, Council approved the *Climate Resilience Strategy* and *Action Plans* June 25, 2018. *Soil Handling Recommendations* contributes to satisfying the requirements under the *Climate Resilience Strategy* by focusing on adaptation through the development of a new guideline for soil management to provide a functional support system for healthy green spaces and natural infrastructure (The City of Calgary 2018). This document also works to satisfy the climate mitigation plan actions which are designed to continue to promote the restoration of native habitat and naturalization of open space to augment the ability of Parks and Open Spaces to sequester carbon. As mentioned previously, best practices in soil handling bring about ways to reduce atmospheric carbon, both directly and indirectly, through reduced landscape maintenance and carbon storage in the soil organic matter itself (Ecological Society of America 2000). Healthy soils also create healthy vegetation communities which further sequester carbon within plant growth and conserve soil by preventing erosion.

City of Calgary requirements

The City of Calgary has various requirements for soils handling outlined in *Contractor Environmental Responsibilities Package* (The City of Calgary 2012), *Erosion and Sediment Control Guidelines* (The City of Calgary Water Resources 2017), *Development Guidelines and Standard Specifications: Landscape Construction* manual (The City of Calgary Parks current edition), *Habitat Restoration Project Framework* (Parks 2014) and *Construction Environmental Checklist*, *Environmental Requirements for City of Calgary Construction Projects* (Environmental and Safety Management 2016). This document expands on these requirements and provides recommendations and best practices to achieve and maintain the healthy soils. Requirements have been outlined below, whereas further recommendations are provided in *Soil Handling Recommendations*.

Reusing soil

Both the *Development Guidelines and Standard Specifications: Landscape Construction* manual (The City of Calgary Parks current edition) and *Habitat Restoration Project Framework* (Parks 2014) encourage soil reuse wherever appropriate (i.e., contaminated soils cannot be reused) as it is generally more cost effective and environmentally friendly.

Soil reuse is ideal in situations where the desire is to keep the native seed bank (e.g., seeds present in the soil) as intact as possible. This is especially important in natural areas where soil has been disturbed and the intent is to restore the site back to a native plant community. Also, soil reuse is relevant in areas that are or will become natural areas or Natural Environment Parks. Essentially, this is beneficial in any area that will not be converted to mowed turf grass as the seeds already present in the soil accelerate natural recovery (e.g., when an ecosystem is left alone post disturbance to recover on its own) and compliment reclamation, assisted recovery or restoration work.

Besides soil conservation being important to revegetation activities, unwanted soils that end up in various environments can contribute to weed colonization which degrades ecosystem health. In addition, soils that are not properly stabilized can migrate into watercourses and waterbodies (The City of Calgary Water Resources 2017) (The City of Calgary Parks current edition). Sediment loading into water can affect water quality and prevent light from reaching aquatic vegetation as well as harm fish. Reusing soils keeps soils in beneficial areas versus in areas where soils may cause harm such as in waterbodies.

In certain circumstances, soil may be contaminated and unsuitable for reuse. Environmental and Safety Management (The City of Calgary) can assist in determining if soil reuse is possible as they have access to information regarding past contaminants and land uses.

Inspections

Construction sites that require soil stripping and grading are very susceptible to wind and water erosion. Stockpiles have an increased risk of erosion as they create environments that further accelerate various erosion forces due to increased height and slope. *Erosion and Sediment Control Guidelines* (The City of Calgary Water Resources 2017) have inspection requirements that ensure that all erosion and sediment control measures are functioning properly. The inspections are especially important for stockpiles due to their risk of erosion and sediment migration.

The requirements indicate that erosion and sediment control measures must be inspected and documented at least every seven (7) days or at critical times when erosion and sediment releases could occur, including:

- Windy weather;

- Significant precipitation events which are precipitation events that exceed 12 mm within a 24-hour period or precipitation on wet or thawing soils. Shorter duration events with more intensity are also defined as significant; and/or,
- Melting events.

Documentation and correction is required within 72 hours by a Qualified Inspector if the time allowance does not pose a risk to public health or safety.

Soil sieve analysis

During soil testing for any proposed construction site in Calgary, it is necessary to dedicate some soil samples for a soil sieve analysis. Sieve analysis, a City requirement, yields particle size distribution data used to determine soil texture of a particular site. Soil texture assessment is then used to derive a K-value which is plugged into the Revised Universal Soil Loss Equation (RUSLE). This provides an estimate of potential offsite sediment delivery. Without soil sieve analysis, an accurate K-value cannot be produced. Without a site-specific K-value, the Erosion and Sediment Control designer, when creating an erosion and sediment control plan, must resort to using The City's default K-value of 0.079 as per the *Erosion and Sediment Control Guidelines* (The City of Calgary Water Resources 2017). Using the default K-value results in higher sediment delivery estimates and increased erosion and sediment control measures, some of which may not actually be needed.

Requirements for stripping

In order to gain a baseline understanding of stripping depths for undisturbed soils, the pre-disturbance topsoil depth and Soil Great Group as per *The Canadian System of Soil Classification* (Alberta Agriculture and Agri-Food Canada 1998) needs to be indicated in the restoration plan as per the *Habitat Restoration Project Framework* (Parks 2014). This provides information regarding the average soil characteristics and topsoil depth, although local variations occur. The pre-disturbance topsoil depth indicated in The Canadian System of Soil Classification would not be accurate if the soil has been disturbed in the past.

The topsoil (A horizon) should be stripped and stockpiled separately as indicated by the *Development Guidelines and Standard Specifications: Landscape Construction* manual (The City of Calgary Parks current edition). There can be some confusion with what is considered the A horizon but generally, it is the top mineral soil layer enriched in organic matter.

Stripping topsoil and subsoil separately prevents admixing (e.g., the mixing of topsoil and subsoil) and allows the soil to be put back in the order that it naturally occurs so that decomposition processes, biota and the seed bank are maintained.

Requirements for stockpiling

For soils that are stripped on site, the topsoil layer (A horizon) should be stripped and stockpiled separately. *Erosion and Sediment Control Guidelines* (The City of Calgary Water Resources 2017) indicate that:

- Stockpiles in place for more than thirty (30) days on or off-site need to be labelled on construction drawings;
- Stockpiles that are in place for more than thirty (30) days need to be covered and stabilized with mulch and tacifier, vegetative cover or other suitable measures;
- Erosion control measures must be implemented for all small site construction projects although permanent erosion control is recommended for areas that can be brought to grade quickly;
- Soil loss for the entire construction site, including slopes and stockpiles, must remain less than 2 tonnes/hectare/year;
- A physical measure of erosion control is required where soils are likely to migrate downslope such as silt fencing, fibre rolls, compost socks, etc.; and,
- Additional erosion control measures are required for areas within 100 m upstream of a waterbody, contain steep slopes and/or receive runon from adjacent upstream areas.

Requirements to prevent compaction and admixing

The City of Calgary's *Habitat Restoration Project Framework* outlines the requirement for soil handling procedures (The City of Calgary Parks 2014). Although compaction and admixing are not explicitly mentioned, these requirements are aimed to minimize both. Recommendations in the *Habitat Restoration Project Framework* also further prevent compaction and admixing by stripping soil types separately, stockpiling separately and minimizing stockpile height and duration that the soil is stockpiled for (The City of Calgary Parks 2014). Lastly, *Development Guidelines and Standard Specifications: Landscape Construction* manual indicates that dry topsoil should be replaced during dry conditions (The City of Calgary Parks current edition). Dry conditions are important to reduce rutting and therefore mitigate for compaction and admixing.

Conclusion for City of Calgary requirements

It should be noted that The City of Calgary's soil handling requirements are often reiterated in multiple documents as mentioned above. Requirements that reduce admixing and compaction often work to mitigate both. In subsequent sections of *Soil Handling Recommendations*, further methods meant to preserve soil health are discussed.

Who should use this document

Soil Handling Recommendations is meant to provide a resource to persons involved in any type of earth moving. Persons who will find this document helpful include environmental professionals, City of Calgary Project Managers, developers, City land managers and land stewards, internal operations staff and external contractors. The information presented here should be reviewed by all persons involved in soil handling, both directly in the field and in a planning and supervisory capacity. This will improve project performance both in the operational stage and planning stages as staffing and equipment needs can be matched to the degree of accuracy required during soils handling.

This document expands on the Soil Management section cited in the *Habitat Restoration Project Framework* (The City of Calgary Parks 2014). *Soil Handling Recommendations* is also meant to provide supplemental information to Chapter 5 of the *Development Guidelines and Standard Specifications: Landscape Construction* (The City of Calgary Parks current edition) to assist in achieving successful revegetation work in sensitive landscapes and/or Natural Environment Parks. The soils information in The City of Calgary Parks (current edition) is catered towards large developments which tend to focus on soil health that is appropriate for developed landscapes such as residential lawns. Although Natural Environment Parks and Environmental Reserves are generally protected during the development process, there may be circumstances where environmentally sensitive areas that support native vegetation communities need to be restored. These areas require a higher level of soil health and often, a deeper topsoil profile and as such, this document provides information most appropriate for soil handling in native landscapes.

Disclaimer

Soil Handling Recommendations does not replace expertise, experience or professional qualifications, nor is the document intended to replace the user's own due diligence and research. Nothing in this document is meant to relieve the user from complying with municipal, provincial and federal legislation. This document provides general recommendations to maintain soil health and fertility. It does not replace a site-specific approach to a coordinated soils handling management plan. The use of *Soil Handling Recommendations* does not guarantee revegetation results post construction due to the complex nature of managing biological systems.

Using this document does not equal approvals from City of Calgary staff or stakeholder engagement with key personnel.

Should any user have questions as to the intent of recommendations found in these guidelines, the user is advised to seek clarification from the lead of Urban Conservation, Parks.

Section I: Rationale for soil handling recommendations

What gap does this document fill?

There are certain requirements regarding soil handling that are outlined under *Contractor Environmental Responsibilities Package* (The City of Calgary 2012), *Erosion and Sediment Control Guidelines* (The City of Calgary Water Resources 2017), and *Development Guidelines and Standard Specifications: Landscape Construction* manual (The City of Calgary Parks current edition). Also, soil management practices such as soil conservation and stockpiling are discussed in *Habitat Restoration Project Framework* (The City of Calgary Parks 2014). This document is meant to expand on these requirements in order to conserve, maintain and restore the functionality of the soil food web (Figure 1). The conservation of the soil food web is not discussed in any of these documents and as such, this document aims to fulfil that gap.

The soil food web includes everything in the soil such as the beneficial bacteria, fungi, protozoa and nematodes that live in the soil and also the organic matter present in the soil that function together to improve and maintain soil health (Soil Food web Canada Ltd. 2017). Although soil handling procedures have drastically improved over time, the concept of the soil food web and its association to soil health is relatively new to science.

With the invention of the electron microscope, scientists have been able to get a better understanding of the soil food web and its importance (Lowenfels & Lewis 2010; Lowenfels 2017). This technology allowed scientists to study the microscopic components of soil which was very important as productivity in agricultural practices was continuing to decrease. In the past it was thought that agricultural production would be maximized through soil additives such as fertilizers and pesticides that kill off the biotic soil components. Generally, the living components in soils, with the exception of plants, were thought to be pests. Unfortunately, this was not the case and productivity of farm fields generally decreased with time and artificial inputs. Due to the decrease in productivity and the scientific studies that tried to understand why this was occurring, the discovery of the soil food web came about.

Soil fertility and its ability to support vegetation are completely intertwined. Some early successional/colonizing species do not rely on healthy soils and these species tend to be weedy. They can improve soil health by breaking up compacted soils, contributing to building organics and, in the case of legumes, providing bioavailable nitrogen. Just as the land above goes through succession, so does the soil below. In some cases, the role of these weedy species in the ecosystem can be exploited by humans to improve unhealthy soils. Regardless, once the soil food web has been compromised, it is very difficult, if not impossible, to restore it back to the way it once was in its ideal state and it may take many years, if not decades, to bring it back to being healthy (Lowenfels & Lewis 2010; Lowenfels 2017).

In the meantime, this unhealthy soil food web will lead to an unhealthy vegetation community with decreased ecosystem services and lower biodiversity.

It is critical to preserve as much of the soil food web as possible during construction activities in order to ensure that those soils can support healthy vegetation communities. In turn, these healthy vegetation communities directly contribute to various ecosystem services and biodiversity. These areas further affect the landscape on a larger scale as water quality, air quality, water retention, wildlife habitat (e.g., pollinators) and carbon sequestration all rely on healthy landscapes (Lowenfels 2017).

There is still a lot that is unknown about the soil food web; however, in the last decade scientists have discovered that its preservation is very important. This conflicts what was done in earlier agricultural practices as it has been observed that the less humans interfere in the landscape, often the healthier it remains. *Soil Handling Recommendations* provides information on how to preserve the soil food web during construction practices and as such, is filling the need to examine soil as a complex, dynamic ecosystem.

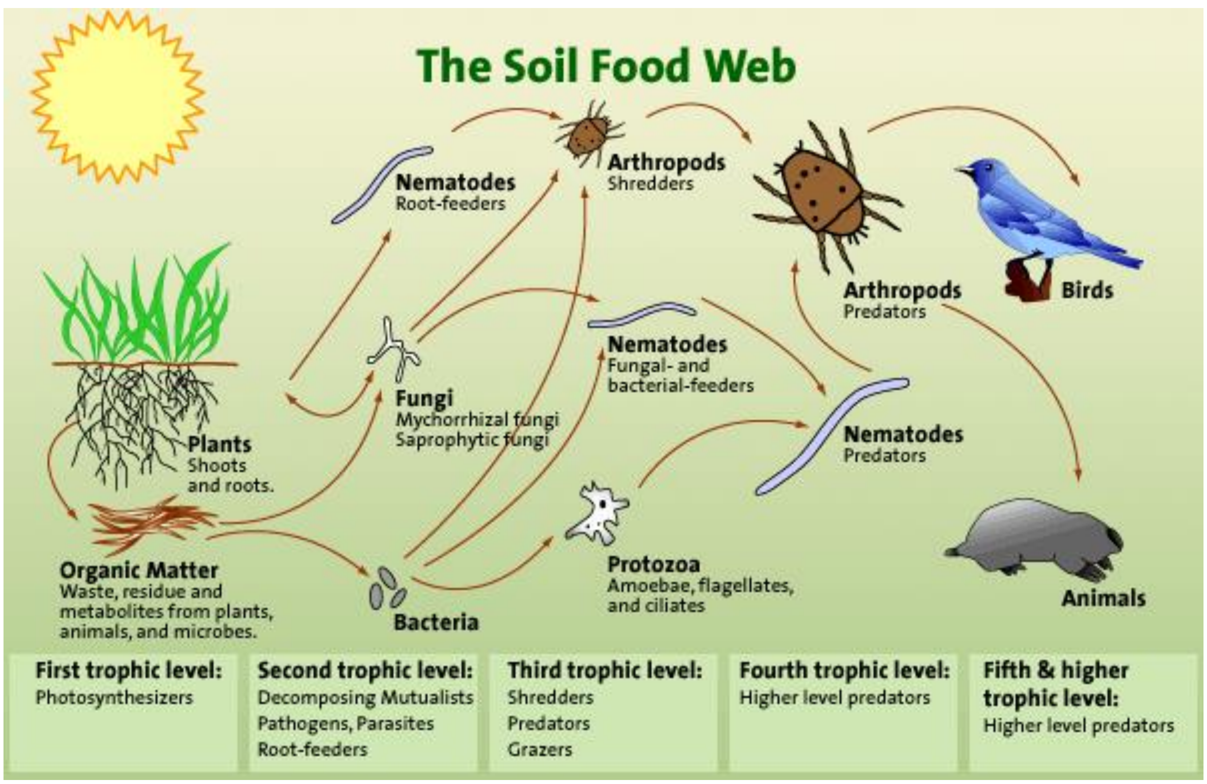

Figure 1 The Soil Food web (taken from Soil Food web Canada Ltd – Soil Laboratory & Research Centre https://www.soilfood web.ca/ accessed September 14, 2017)

Healthy soils and cost savings

During restoration work, if soils are unhealthy, the project performance will be drastically decreased. This increases costs during the establishment period and causes additional long term maintenance expenses. Weed control and revegetation may essentially be endless if soil health has not been considered during restoration activities, especially the restoration of sensitive habitat types. This expense can be extremely large and may result in issues regarding compliance under the *Alberta Weed Control Act* (Province of Alberta 2011). The lack of healthy soils often necessitates a constant cycle of weed control and revegetation. In addition to increased costs due to a lack of healthy sustrate, project delays can substantially increase expenditures by inferring with project timing and phasing. These additional costs negatively affect The City of Calgary and the development industry.

As horizon layers and biota are difficult to restore while admixing and compaction are impossible to completely reverse, it is in the best interest of any stakeholders involved in restoration work, especially where native species preservation is important, to ensure that the soil food web is conserved. In reclamation work where revegetation is the goal versus a native plant community, proper soils handling will result in a more successful outcome and a healthier landscape that requires less inputs. This is because the soil retains its structure which allows for moisture retention, infiltration and cation/anion exchange of nitrogen and phosphorus (Morrison 2017).

Ecosystem benefits of healthy soil

Although soil health and revegetation are tied together, conserving soil health is beneficial from an environmental standpoint versus focusing on the end goal of a successful landscaping project. Soils that are not heavily compacted retain their porosity and water holding capacity which increases infiltration and decreases runoff (Morrison 2017). The water holding and infiltration capacities allow plants to access water contained in the soils. This maintains filtration and allows for vegetated soil to function as a natural “sponge” that traps contaminants and prevents sediment from entering stormwater infrastructure. In addition, healthy soils support deep-rooted plants which bind soils to increase flood resilience. Besides improving the health of the environment and providing food to wildlife, healthy landscapes also reduce maintenance costs and increase the value of adjacent properties. These aesthetically pleasing landscapes are more resistant to weed invasion and less costly to maintain and as such, are often in high demand.

Section II: Soil handling recommendations

Soils should be stripped, replaced and revegetated as soon as possible. Projects should be phased in a way to minimize time between stripping/grading, soil replacement and revegetation. Although it might seem logistically easier to separate project components out by task and perform all stripping initially, this creates opportunities for soil loss, weed invasion and causes soil stockpiles to sit for a longer duration. With the amount of soil storage required when a large project site is stripped all at once, large stockpile depths and compaction are guaranteed to occur. Instead, project sites should be split up into smaller areas and completed from start to finish (e.g., phases). This requires more coordination; however, it saves costs regarding maintenance issues and results in healthier landscapes. Operational best practices are outlined in Appendix 2 – Operational Soil Handling Flowchart.

Background research

Prior to actual physical work on the ground, background research will determine average soil conditions within the project area. Soil maps are beneficial and provide information that can assist in determining the average soil characteristics of a site. For example, MacMillan (1987) provides soil survey information for the Calgary urban perimeter which provides correlation to average topsoil and rooting depth. In areas that are outside of the disturbed soil polygon located in the central portion of Calgary, soil polygons can be further examined through the Agricultural Regions of Alberta Soil Inventory Database (AGRASID) (Alberta Agriculture and Forestry 2018). This viewer is located here:

https://soil.agric.gov.ab.ca/agrasidviewer/

Once average conditions are determined in the project area, potential local variations in soils need to be examined. This can be done through studying aerial photographs/remote sensing mediums over a variety of years and seasons. This allows for the identification and relative delineation of various habitat types which correspond to smaller local changes in soil composition and structure. Studying historical aerial photographs will provide information on whether contamination issues may be present and whether admixing and compaction may have occurred due to historical development. This can be determined based on past existing infrastructure on or adjacent to the proposed project site.

Additionally, upon request, Environmental and Safety Management will conduct a “Utility Circulation Environmental Screening Report” for the project area to determine if the soil has been impacted. If it is determined that soil in the project area may be contaminated, Environmental and Safety Management can assist to facilitate soil testing. This service can be reached at utilityscreening@calgary.ca.

Sources of contamination that may impact soil quality include: commercial/industrial uses, chemical use and storage, landfills, oil and gas extraction facilities, etc. To determine if there are actual or potential soil contamination concerns, a review of historical usage should be performed. In addition to aerial photographs, documents that can reviewed include Phase 1 & 2 Environmental Site Assessments. If actual or potential contamination concerns are identified, this review can also guide future soil testing for contamination. If there is evidence of actual or potential contamination, a qualified environmental professional should be engaged to determine next steps.

In addition, soil map units are often at too broad of a scale to account for local variations and transition zones. Prior to the commencement of earth moving activities, physical and chemical tests at an appropriate sampling frequency can further refine project planning such as topsoil and subsoil stripping depths across the project site. Gathered background information helps plan how many soil samples should be taken where and at what frequency. Further refinement of sampling effort and locations can be done in the field once soil pits are examined for topsoil and subsoil depth. To ensure soil characteristics are understood across habitat types, sampling effort can be decreased or increased as warranted.

Soil testing

Comprehensive soil sampling plans are developed by gathering extensive background information in conjunction with professional judgement to ensure local variations are accounted for and to confirm, if required, that the environmental quality of the soils are suitable for their intended use. Soil testing is also important in order to understand soil characteristics prior to ground disturbance so that any issues can be addressed prior to revegetation. Using the same testing methods and/or lab can also aid in soil sampling as there are multiple ways to test for certain physical and chemical characteristics. The results are also displayed differently and becoming familiar with how the information is presented can assist in interpretation.

During soil sampling, soil needs to be collected from the field. Although a spade can be used, many environmental professionals prefer a core sampling tool, especially for depths below 15 cm (Alberta Agriculture and Forestry 2004). For shallow depths, many environmental professionals opt to use a spade to prevent admixing. Hand augers and core samplers may mix the topsoil and subsoil at shallow depths. This can be attributed to high organic content and the granular to subangular nature of the material which can cause the upper portion of soils to be rather loose.

During the sampling process, physical characteristics are determined. These characteristics include unanticipated local changes in soil composition, topsoil depth, subsoil depth, the presence of coarse substrates such as large rocks and the presence of heterogeneous subsoils. Texture can be determined in the field but lab testing yields more accurate results. Also, as previously mentioned, determining soil sieve size is required and this needs to be measured in a laboratory. This allows for the erosion and sediment control measures to be engineered appropriately to prevent soil loss (The City of Calgary Water Resources 2017). Using the City of

Calgary default soil sieve size may cause unnecessary precautions to be required for erosion and sediment control whereas using the actual soil sieve size, the engineering and sediment control measurements are appropriately engineered.

Compaction issues which are common in fine grained soils can be determined by using a penetrometer. This piece of equipment utilizes a rod that sinks into the soil and measures penetration. The less soil penetration indicates more resistance and higher compaction. Although this method is commonly used, variation occurs due to the force of the individual user as well as the soil moisture which makes it important to measure compaction against a control. Additionally, vegetation can be examined to determine if soil compaction is negatively affecting plant growth. If plants are exhibiting significant lateral root growth and showing signs of stress, this can be due to compaction issues and/or hardpan (e.g., a dense layer of soil found below topsoil) soils.

The methodology of the soil tests depends on what questions are being asked during the investigation. Soil testing effort and sample locations also differ based on what has been determined during the background research phase. For example, areas that support various vegetation communities and where soil maps indicate multiple soil types may need to have a more comprehensive testing methodology to ensure local variations are captured. Soil testing points need to be numerous enough to determine average conditions in each habitat/soil type. Soil tests also need to be able to detect or support visible changes in transition areas.

The reliance on separate soil samples or one composite sample is determined by a number of factors, including the results of the background research phase and the variability of surficial geology within the project area. For example, areas that have a lot of local variation will rely on separate soil samples whereas, areas that are homogeneous will still rely on multiple samples but the samples will be mixed together into one composite sample in order to determine average soil conditions. A composite sample also saves lab costs but should only be used when the project area shows little variation. Generally, topsoil (A horizon) and subsoil(s) (B horizon) are tested separately.

Composite samples are the preferred method for testing stockpiles. It should also be noted that soil present on the outside of the stockpile may be much different than what is on the inside of the stockpile, especially if stockpiles have been sitting for an extended period of time.

After the cores are collected, analytical tests can be performed at a lab. Depending on what has been determined in the background research phase, tests can be catered to ensure that the appropriate parameters are captured (e.g., contamination, salt content, etc.). Where further nitrogen and sulfur evaluation is needed or where problem soils are encountered, composite samples should be evaluated at 0-15 cm, 15-30 cm and 30-60 cm (Alberta Agriculture and Forestry 2004). Details on analytical tests are outlined in the Standard Analytical Soil Tests section.

It should also be noted that adherence to soil testing procedures is paramount to ensure accurate results. Often soils need to be air-dried and sieved to 2 mm prior to being taken to the lab for testing. In addition, it is important to clean the sampling equipment prior to digging soil cores/pits so that cross-contamination does not occur. Soils may need to be refrigerated or frozen prior to transport for testing. Although guidelines are provided by Alberta Agriculture and Forestry (2004), consultation should occur with Environmental and Safety Management and the local laboratory prior to taking samples so that soils are sampled properly and the field methods adhere to the laboratory methods.

Soil testing across project sites

Generally, random soil sampling is the procedure that is performed to test homogenous lands as the samples are mixed into one composite sample. As mentioned previously, topsoil and subsoil are usually tested separately. Using conglomerated samples to send for chemical testing will result in an average of all characteristics.

In a heterogeneous environment containing many vegetation community/soil types, a homogenized composite soil sample will not be very useful; however, a composite sample per habitat/soil type may be useful as it will provide the average condition of each local variation in landscape type.

Soil sampling should be implemented at a frequency that mirrors changes in the vegetation communities along with changes in soil map units and adequately represents the geographic extent. Soil sampling can also to test unique areas of land. Stratified random sampling can be done in a particular area which takes random samples from a designated area. A composite sample of the topsoil and a composite sample of the subsoil will provide average characteristics of both the topsoil and subsoil.

Soil testing for stockpiles

It is important that soils from stockpiles that are going to form the soils in habitats that are to support deep-rooted native vegetation and/or areas of conservation concern such as wetlands, native prairie, etc., be tested prior to reuse. Essentially, if the soil at the time of stripping is supporting the desired vegetation community, the reused soil properties should match the pre-disturbance characteristics. In some situations, soil is imported from other locations and reused. Testing this soil is very important as the history of the soil may be unknown.

It is critical that soil sampling be representative of the entire stockpile. Topsoil and subsoil should be tested separately and it should be clear as to which stockpile contains what (e.g., topsoil, upper subsoil and lower subsoil). Also, the preference is to have annual testing of stockpiles since stockpiles are generally very large.

The soil properties within the stockpile likely vary throughout so it is paramount to take multiple samples over a wide range of areas and depths within the stockpile. These samples can then be tested individually or amalgamated in order to provide average soil attribute information.

Ideally, soil characteristics should match pre-disturbance characteristics, especially when the soils will support a native vegetation community. If soil properties have changed after soil has been stockpiled, there may be some solutions that can be employed to restore soil health. These include things such as adding amendments, de-compaction, etc. which is covered later in this document. These tests are relevant to situations that require both soil conservation/replacement and soil import.

The City of Calgary Waste and Recycling Services has soil testing protocols related to clean fill disposal. Clean fill refers to uncontaminated soil that is free of oversized foreign material such as large rocks, construction materials, tree branches, etc. Clean fill is valuable as it can be reused by the Calgary landfills for various operational activities. As clean fill provides a resource to The City landfills, the disposal/drop off fee is nominal; however, soil testing may be required to prove that the soil, clay or gravel (e.g., less than 6 inches) is in fact clean.

Depending on each individual soil handling situation, soil testing methodologies will vary; however, The City of Calgary Waste and Recycling Services has protocols that can be used as a reference. These protocols indicate that at least one composite sample per 500 m^3 of soil is required from commercial sites while one composite sample per 1000 m^3 of soil is required from residential sites. The composite sample is also required to be composed of 10 to 12 point samples in order to analyze average conditions within stockpiles.

Standard analytical soil tests

Soil analysis should be completed where there is evidence of actual or potential contamination or where in-ground planting of produce intended for human consumption is contemplated. Generally, soils quality must meet the *Alberta Tier 1 or 2 Soil and Groundwater Remediation Guidelines* (Alberta Environment and Parks 2016) for a given land use (e.g., natural area, agricultural, residential/parkland, commercial and industrial). This is discussed further in Section IV: Importing Soils. Parameters that must be included in the analysis include: general and inorganic parameters, hydrocarbons, metals and volatile organic compounds. The choice of the parameters to be tested will depend on the site history. Soil sampling and analytical testing should always be completed by a qualified environmental professional. Environmental and Safety Management has a list of pre-qualified environmental consultants that can be used for this purpose.

The soil tests outlined by The City of Calgary Waste and Recycling Services are for determining if the soil can be disposed of as clean fill, they are outlined below. As previously mentioned, background investigation is also important as a desktop review can provide information on whether soil issues such as contamination may be present. Also, it is important to use the same methods to retest soil chemistry so that changes in values are because of soil changes, not due to a change in testing methods.

The commonly used test name is shown in brackets, if applicable. The City of Calgary Waste and Recycling Services soil testing requires the following tests:

1. Total Petroleum Hydrocarbons (TPH);
2. Benzene, toluene, ethylbenzene and xylene (BTEX);
3. Total and toxicity characteristic leaching procedure (TCLP);
4. pH;
5. Salinity (electric conductivity [EC], chlorides, sodium absorption ratio [SAR]);
6. Flash point; and,
7. Paint filter.

The TPH, BTEX, TCLP, flash point and paint filter soil tests are applicable to see the level of contamination of chemicals and byproducts of the petroleum industry or other industries in which chemical byproducts are formed or released.

Standard tests for soils in areas that are not expected to be contaminated would include pH and salinity, among others. Since the goal of the soil tests is to determine how to revegetate the area, these tests should mirror those recommended by Alberta Agriculture and Forestry (2004). For surface (0-15 or 0-30 cm) agricultural soils, the tests include the analysis of:

1. Nitrate-nitrogen;
2. Available phosphorus;
3. Available potassium;
4. Extractable sulfur;
5. pH;
6. Salinity (EC);
7. Micronutrients (boron, chlorine, copper, iron, manganese and zinc);
8. Organic matter; and,
9. Texture.

Ideally, nitrate and sulfur analysis should be completed for subsurface/subsoil samples (15-30 and 30-60 cm). Depths are only an estimate based on average agricultural conditions so it is important to talk to the lab prior to taking soil samples as well as observe the topsoil and subsoil depths related to the project area. See Best Practices for Stripping for more information.

Texture can be measured in the field but in order to get a more accurate result or if the soil sampler does not have a lot of experience texturing soils, lab tests can be completed for a more precise texture analysis.

Lastly, comparable soil salinity can be tested in the field so that salinity differences can be determined between upper and lower subsoil. Most often, a fizzing reaction will be seen if there is considerable calcium carbonate present in the lower subsoil. This is discussed further below.

Best practices for stripping

The topsoil (A horizon) is generally delineated through its darker appearance than the upper subsoil layer (e.g., subsoil is classified as the B horizon) and where the organics are most concentrated after the organic (O horizon) surface layer is removed (Figure 2). Topsoil is often stripped based on colour change (AECOM 2012).

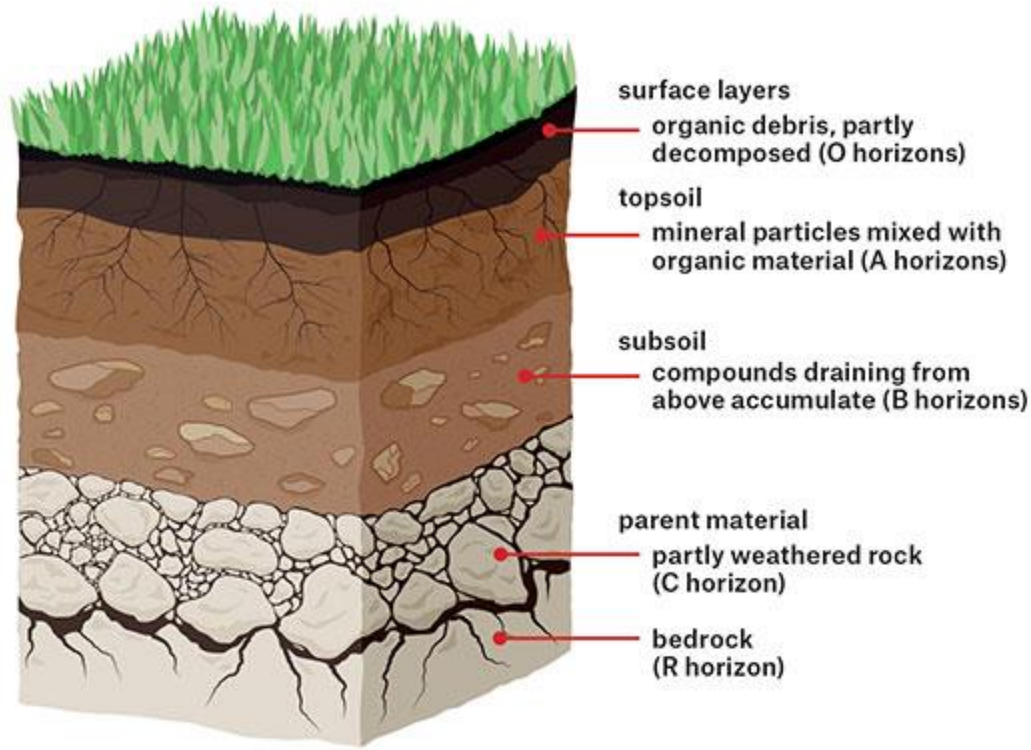

Figure 2 Typical soil composition and horizons although all horizons may not be present.

Taken from https://www.timberpress.com/blog/2015/07/how-soils-form-and-age/ Accessed December 20, 2017

Although topsoil preservation is very important, overstripping topsoil will ultimately decrease the soil's functionality as subsoil and topsoil will be mixed together resulting in a possible decrease of organic carbon content, infiltration and seedling emergence post reclamation/restoration while increasing the clay content, bulk density, salinity, sodicity and pH (Landsburg & Cannon 1995).

In certain cases, it is advantageous to employ alternative soil handling procedures that vary from the standard stripping of topsoil and subsoil separately. Stripping the topsoil and subsoil separately is termed a two-lift procedure (Pettapiece & Dell 1996).

The most common alternative method of soils handling employs a third level of stripping called a three-lift procedure. Essentially, when significant physical and/or chemical differences are present in a soil layer and the particular soil layer is thick enough to separate (e.g., upper subsoil greater than 15 cm [Pettapiece & Dell 1996]), an additional round of stripping will maintain the integrity of soil. Other characteristics identified by Pettapiece & Dell (1996) and Agriculture Canada (1987) that may warrant a three-lift procedure include:

- The upper subsoil is non-gravelly/non-stoney and the coarse fragment depth (e.g., greater than 2 mm in diameter) of the lower subsoil has a content of greater than 35% if gravelly and less than 20% if cobbly; and,
- The lower subsoil is very saline and the difference between the Electric Conductivity (EC) (dS/m) of the upper subsoil and lower subsoil is greater than 4 dS/m.

Three levels of stripping means that three (3) separate types of soil are stripped (i.e., topsoil, upper subsoil and lower subsoil) and that three (3) separate types of soil piles should exist. These separate stockpiles should be placed at a distance great enough from one another to prevent accidental mixing (i.e., greater than five (5) metres) (AECOM 2012). Stockpiles should be clearly identified in order to prevent accidental mistakes in soil placement and account for shift and personnel changes.

Due to Calgary's saline (e.g., Solonetz) soils, the most common application of a three-lift procedure will strip the lower saline subsoil separately. This will contribute to plant health and increase revegetation success by ensuring that salt is not brought closer to the soil surface when the soil is put back into place.

Other less common situations may be encountered that require a different approach to soil stripping instead of stripping topsoil and subsoil separately and placing them back to mimic the natural order of soil types. These include conditions where the upper subsoil is of poorer quality than the lower subsoil or where the subsoil is composed of either bedrock or gravel.

Depending on the future land use of the site, considerations must be given to how stripping activities will contribute to the success of future land use. For example, a major factor to determine prior to soil handling is if the site will be retained as natural area with native vegetation or will be converted to a more manicured environment. In cases where subsoils are saline but a saline natural area will be retained, separating that subsoil into more than one layer while stripping would be based on the EC difference, as mentioned above. If revegetation is planned using species that cannot tolerate salt, it might be advantageous to remove the layer of subsoil where salts have accumulated or perform desalination activities. This is challenging in itself; however, there may be an opportunity to replace saline subsoils with less saline subsoils which may help revegetation activities.

As mentioned previously, these are decisions that need to be weighed by an environmental professional familiar with the project site as no two sites are the same. A site-specific approach using professional judgment to address soil anomalies within the site and soil map unit is critical.

If during site stripping, contamination is identified, the requirements/actions set out in The City of Calgary *Contractor Environmental Responsibilities Package* (The City of Calgary 2012) must be followed. Contaminated sites and associated soils must be managed according all regulatory requirements. Discovery of contamination will likely require a soil management plan, additional site assessment and/or site remediation. A qualified environmental professional must be engaged when contamination is discovered.

Best practices for stockpiling

It is required that topsoils and subsoils be stripped separately. As previously mentioned, there are instances when topsoil and subsoil stripping may be more complex and require a three-lift procedure.

Erosion and Sediment Control Guidelines (The City of Calgary Water Resources 2017) require that sediment loss from a project site is not to exceed 2 tonnes/hectare/year. In order to achieve erosion and sediment control thresholds, all erosion control measures should be regularly inspected, especially after high precipitation events when these measures are more important and more likely to fail. Detailed inspection requirements as per The City of Calgary Water Resources (2017) are outlined earlier in the document in City of Calgary requirements. Stockpiles tend to be very susceptible to erosion and it is recommended that slopes on soil stockpiles should be minimized and not exceed 3:1 (AECOM 2012). Erosion control measures need to be installed to the manufacturer's specifications in order to be most effective.

When using erosion control measures, the length of time they are needed and how they will affect the outcome of the project must be carefully considered. For example, if a tackifier is used to prevent erosion, the duration of how long the soil pile will be sitting needs to be taken into account as well as any other methods that will influence the breakdown of the tackifier such as exposure and depth. Tackifiers that have not broken down and are still present in soil that is to be reused may hinder revegetation success by reducing seed to soil contact. The usage of a tackifier has to be approved by The City of Calgary Parks for restoration projects as per The City of Calgary Parks (2014) and is likely a solution that may be implemented for long term soil storage over multiple seasons which eventually will break down the tackifier. Regardless, long term soil storage is not recommended unless absolutely necessary.

Using vegetation to maintain soil health and prevent erosion is a good practice; however, native vegetation is often slower to germinate and requires a more stringent seeding time frame in order to break down the seed coat. When using native species, it should be noted that vegetation that is not decomposed will lead to a reduction in seed to soil contact and germination when the area is reseeded. Also, most native vegetation species are perennials and as such, the root mass will generally be larger and deeper than an annual species. This needs to be accounted for in the project plan.

An agronomic annual cover crop may be a good method of erosion control and stockpile stabilization; however, there are drawbacks that must be considered. Although the root mass of agronomic cover crops tends to be lower, mechanisms must be taken to ensure that the species does not persist when the soil is to be reused in the restoration of a native plant community. For example, annual ryegrass (*Lolium multiflorum*) often survives winter and will self-seed if the seeds are left to mature (e.g., planted early enough in the season for seed maturity, not mowed, etc.). Since mowing a soil stockpile may not be feasible, these are factors that need to be thought about during the project planning phase.

In industry, especially in large developments, it is not always possible to achieve topsoil heights and storage time lengths as indicated below in *Soil Handling Recommendations*. Regardless, for sensitive environments such as wetlands and healthy grasslands containing a high percentage of native species, maintaining the soil food web is an important component of successful restoration. If the below recommendations cannot be achieved on the entire project site, ensuring that soils within sensitive habitats are handled according to best practices will conserve their health and improve revegetation efforts.

Ideally, stockpile storage of organics should be minimized and it is recommended that topsoil stockpiles are stored no more than 1.3 m (4 feet) for less than one year and ideally for less than six (6) months (Center of Environmental Excellence 2008). Long term soil storage leads to many issues which essentially breaks down the soil structure and compromises the soil food web. Compaction occurs in the bottom and central portions of the soil and the lack of plant root growth in these portions combined with the settling causes decreased oxygen levels so that the natural soil fungi and microorganisms die off. Abiotic conditions also cause seed death and seed bank loss. The lack of soil biota is problematic as it will take many years until the soils will be able to support a complex vegetation community.

The height of the stockpiles should be minimized to prevent compaction, anaerobic conditions and a loss of soil biota. Essentially, the stockpiles should mimic their depth to no more than the rooting depth of pre-disturbance vegetation (Tate and Klem 1985). The maximum topsoil height referenced in Center of Environmental Excellence (2008) is 1.3 m; which would likely be relevant to a site that will or has supported foothills/mountain rough fescue (*Festuca campestris*) grassland. Deep topsoils are typical of rough fescue grasslands since rough fescue may have a rooting depth of 2 m. The remaining rooting depth would be made up by the subsoil.

In some cases, soil stockpiles will need to be stored for longer-than-ideal timeframes and at larger heights than what is recommended. This is more likely on large long-term projects that take place on sizable pieces of land. Regardless, if at all possible, the areas that contain and will remain as native vegetation communities should be flagged for short term soil storage at minimized stockpile heights. That is a compromise that will retain the soil biota in areas that have more complex plant to soil relationships. This will allow native species to be restored more effectively while putting less restrictions on the areas that will be seeded with faster growing non-native species.

To mitigate for large stockpile depths, aeration has also been used to maintain the biological processes in the soil. Both active and passive aeration techniques have been utilized.

Lastly, contaminated soil must be stockpiled in a manner to ensure that there is no release of contamination to the stockpile area or to adjacent areas. Releases may be mitigated by the use of liners and the implementation of erosion and sediment control practices. Once contamination is identified, a management plan should be established to ensure that the contamination soils are handled appropriately. Any management of contaminated soils must be clearly documented and should be overseen by a qualified environmental professional. Contaminated soils may need to be removed from site as soon as possible; however, a qualified environmental professional can assist in recommendations and methods.

Best practices for compaction and admixing mitigation

Prevention

Soil compaction and admixing negatively affects soil structure which in turn causes problems with revegetation. Compaction causes a reduction in soil pores and water infiltration which negatively affects plant growth. Compaction increases soil erosion as water cannot effectively penetrate the soil layer and as such, compaction over large areas may decrease ground water reserves. Admixing also impacts plant growth as nutrient poorer subsoil is brought to the surface. This causes nutrients not to be available for plant growth and also reduces the organic matter present in the topsoil which is important for water retention. Similarly to compaction, this can also lead to soil erosion.

Although certain soil compositions are more susceptible to compaction than other soil types such as soils with a high clay content, all soils are subject to compaction. Unfortunately, during development, soils are always at risk of being compacted. The effects of compaction combined with a loss of soil structure, biology and functionality often cause soils to function more like impervious surfaces which increase urban runoff, erosion and tend to decrease water quality (Toronto and Region Conservation Authority 2012). Best practices to avoid compaction and admixing and maintain soil health were outlined in the previous sections; however, there are additional ways to mitigate for these potential effects besides during stripping and stockpiling.

The best way to mitigate for compaction and admixing is to do it proactively as once soil types have been mixed together and/or compacted, it is almost impossible to reverse those effects, especially over the short term. Job planning before project initiation is the key to preventing soil admixing and compaction. A flowchart is provided in Appendix 2 designed to optimize soil food web health and to summarize various steps in project planning, soil testing and construction.

These mitigation measures include:

- Using well marked access routes consistently;
- Constricting vehicle and machinery traffic to those access routes only;
- Mirroring future access routes to past or proposed rights-of-way;

- Being aware of the weather, season fluctuations and possible weather extremes;
- Using proposed infrastructure locations for staging areas, turn-around areas, stockpike locations, equipment storage, etc.
- Reducing travel on the site by optimally planning access and egress routes (Landsburg & Cannon 1995).
- Using lighter equipment, when feasible;
- Using equipment that distributes weight over a larger surface area (e.g., tracked equipment, wide tires, low pressure tires, etc.); and,
- Using methods other than equipment to distribute weight over maximum surface area (e.g., rubber rig matting for staging and storage areas).

Many areas of Calgary, especially the eastern portion of the city, contain soils used for agricultural production along with remnant native prairie. When construction activities occur when these soils are wet, disturbance to vegetation and the soils themselves are substantially increased. For example, accessing the site during wet conditions can cause rutting which leads to compaction and admixing. This can be avoided by taking advantage of seasonal variations in climate (Alberta Energy Regulator 2003). For example, construction during dry and/or frozen conditions can significantly reduce impact to vegetation and soils. Also, accessing the site only during dry conditions can mitigate for soil damage if soils are to be reused that are present on the access routes. Since the Calgary area frequently experiences chinooks in the colder months, factoring that into construction planning is also very important as frozen conditions and heavy snowfall can change into very wet thawed conditions literally overnight.

Corrections

Since it takes many years to form soil, once soil admixing occurs, it is irreversible to correct without removing and replacing the soil itself.

Although natural processes tend to loosen up soil and reduce compaction such as freeze and thaw cycles, soil organism activity and precipitation, these processes can take a very long time in order to naturally repair the compacted soil. If the soil has been compacted too much, these processes become ineffective, especially at a bulk density greater than 1.7 g/cm^3 (Toronto and Region Conservation Authority 2012) (Schueler 2000). Outlined below are methods that have shown to be effective at reducing compaction once it has occurred.

Tilling can aid in reducing compaction; however, when examining methods to reverse urban soil compaction, Schueler (2000) found that the most effective tillage practices could reverse only one third of the expected increase in bulk density post-construction. This information has shown that conventional tillage alone cannot reduce compaction enough to return soil conditions to pre-disturbance conditions (Toronto and Region Conservation Authority 2012). Although tillage can be beneficial in some cases, the positives and the negatives of tilling need to be weighed out against the fact that tillage may increase the likelihood of erosion, may result in soil moisture loss and lastly, on Solonetzic soils, bring salts to surface (Government of Saskatchewan 2017). Additionally, tilling can be useful for initially incorporating additional organic matter into soils;

however, once the soil structure begins to form and mature, additional tilling destroys the fungal component of soils and soil structure in general. This leads to a rise in soil bacteria levels and an increase in weedy plant growth.

Unfortunately, conventional tilling equipment does not reach deep enough into the soil profiles to address most compacted subsoils and as such, the tilling often reduces compaction on the surface. Instead of using tilling machinery, utilizing equipment that tends to shear the soil at a greater depth has been shown to be more effective. This is called soil ripping or subsoiling and this fractures compacted soils without admixing and adversely affecting plant life, topsoil or surface organics (Minnesota Pollution Control Agency 2016). It is also critical to choose the proper soil ripping equipment based on the site's soil characteristics and operate it to the manufacturer's specifications. Subsoiling should be performed when the soils are not too wet to prevent the machinery from sliding through the soil but not too dry so that they cannot be broken up easily. Also, soils that are high in clay content tend to become admixed using this method so soil composition need to be determined. This is where the knowledge of experienced field staff is invaluable as even the machine's travel speeds can affect the results of the soil ripping as a too high of speed can cause admixing and create furrows where a too low of travel speed may not effectively lift and fracture the soil (Kees 2008).

Urban Conservation, Parks has also utilized other less conventional equipment in order to reduce soil compaction and increase drainage. Pneumatic soil excavation equipment, which means it is operated using compressed air, may be preferred over other methods of decompaction. The benefits of using this equipment include increased working speed, decreased worker fatigue, the lack of sharp metal edges usually found on digging blades and the fact that it is harmless to buried objects. For example, using compressed air in excavation will not damage underground utilities, tree roots, military ordnance or buried hazardous waste containers. This method also ensures that large soil chunks are broken up. Regardless, care must be taken to ensure appropriate air pressure for the job to avoid soil loss.

Another tool for decompaction has some of the same attributes as a piece of tilling equipment; however, certain pieces of machinery can cut through the soil surface using rotating blades that create a wave action, therefore, breaking up compacted soils. Benefits of using this type of machinery is that the surface is disturbed very little and open soil is not created. Along with alleviating compaction, using this machinery assists in preventing weed colonization post-decompaction activities. Since the soil surface is relatively undisturbed, the plant cover remains and the project area is still aesthetically pleasing.

Planting species with deep tap roots have been shown to significantly decrease compaction as well as increase water permeability and soil nutrients. They are able to take advantage of the nutrients and moisture deeper in the soil profile and bring it up to the surface through the taproot. For example, tillage radish (e.g., daikon radish) has a single long thick tuber that can grow up to 18 inches which brings the rooting depth up to four (4) feet or more. These radishes exert 290 pounds per square inch of pressure and can break up even the most compacted soils and hardpan. When they decompose, nutrients are released back in the soil surface that were not available previously to plant growth as they were located so deep in the soil profile. Also, as the radishes decompose, soil porosity is increased which greatly improves soil health (Baerg 2013).

Although tillage radish has seen more popularity recently due to its ability to break up extremely compacted soils, vegetation is commonly used to condition soils. Many farmers rotate their crops frequently with a cover crop. Often these cover crops are legumes which fix atmospheric nitrogen into bioavailable nitrogen. These species also can penetrate compacted soils, although not to the extreme that tillage radish can. They also increase soil nutrients and porosity. Common legume cover crops include alfalfa (*Medicago sativa*) and hairy vetch (*Vicia villosa*).

Another method that can correct compaction is adding moisture to the soil. Toronto and Region Conservation Authority (2012) compared various soil treatments post-construction and in general, the addition of moisture seemed to loosen soils; however, simulated rainfall was not trialed on its own as it was combined with other treatments. Care needs to be taken when adding moisture to soils, especially if they are not vegetated, to prevent soil loss. Regardless, moisture addition may be another useful tool, especially if it is done before freezing to increase the freeze/thaw fracturing of the soil.

Lastly, although subsoils are often not focused on during construction, they do tend to become compacted and lose their ability to allow for water percolation. This is discussed in depth in the Drainage section where recommendations from a diverse group of industries are compared and contrasted.

Soil rebuilding and improvement

Generally, the majority of literature indicates that improving soil post-construction requires a type of mechanical decompaction (e.g., tilling or subsoiling), the addition of organic matter in the form of compost and sufficient soil moisture (Toronto and Region Conservation Authority 2012). These issues can be attributed to biological, physical and/or chemical constraints (Department of Natural Resources and Water 2017).

There could be many reasons why soil improvement is required but some examples include that the soil is:

- lacking organics;
- compacted;
- lacking natural biota;
- not draining properly;
- nutrient deficient;
- alkaline;
- sodic;
- not the proper structure due to added sand, gravel or cobble from anthropogenic activities (e.g., adjacent gravel mining pit, etc.);

- admixed and the horizon layers have been compromised; and,
- not able to support plant growth, other than weedy species, as topsoil is lacking.

Local personnel that consult on soil health agree that soil rebuilding is very difficult. Regardless, in order to get unhealthy soils on the proper trajectory to a healthy soil food web, the addition of organics is key. Local plant nursery experts in the Calgary area have found that adding peat moss at 3.8 ft^3 (standard size bag) for every 150 ft^2 of area can significantly improve soil health. Although some local soil experts have had success with this approach, others do not agree with it as peat moss is a poor nutrient source for plants and it is also not a renewable resource. Peat moss is mined from sphagnum bogs which causes irreversible damage to the source habitat.

In addition, there are some other commercially available products that local plant nursery experts have found that significantly improve poor soil. These products are especially useful when there are factors that limit the quality of stripped soil such as during ground freeze when finer stripping practices are not possible. These organic amendments include glacial rock dust, organic (versus chemical) fertilizers, kelp (seaweed) based plant food and fungus (mycorrhizae) additions. Compost/organic material incorporation is always preferred over inorganic fertilizer addition regarding the maintenance of the soil food web.

Native prairie plants tend to prefer poorer soils which are lower in nitrogen and as such, straight compost addition may hinder a restoration project designed to re-create a native plant community. In contrast, it may be beneficial to amend soils with compost that will support a manicured landscape design that requires more soil moisture and nutrients than native plants.

Compost/organic material incorporation is always preferred over inorganic fertilizer addition regarding the maintenance of the soil food web. Lowenfels and Lewis (2010) state that the addition of inorganic nutrients tends to compromise the soil food web and eliminate certain aspects of it while causing overgrowth of other aspects. Holistically, this overall degrades plant health.

Organics such as compost, various types of decomposed manure and worm castings can be mixed into topsoil when organics are lacking prior to planting. Undecomposed materials such as leaves should be added a sufficient time before planting to ensure decomposition.

Alkaline soils may require additions that will lower the soil pH. Peat moss/sphagnum moss are acidic and are generally the most effective and easy way to lower soil pH. If soils are not the proper structure, importing soils may be the solution which is discussed later in this document.

Removal of unwanted anthropogenic additions may also be appropriate, depending on how much they are mixed throughout the soil horizons. For example, soils can be screened to remove course debris such as aggregate road crush, etc.

Also, applications of liquid organic compost can be made which includes all of the beneficial living organisms within the soil. This is often termed ‘compost tea.’ The high-quality applications are usually made by a soil scientist with the goal in mind of increasing the fungal content of the soil while decreasing the bacteria content in the soil. This can be confirmed by microscopic analysis of soils.

A common problem in the Calgary area and the prairies overall is the presence of saline soils. These soils can be impermeable when wet and extremely hard when dry, especially when there is a high clay content. Although salt will naturally leach out of topsoil with precipitation, sometimes precipitation is not enough to solve the soil salinity problem, especially when the saline soil needs to be reused to restore a vegetation community that is not adapted for salt tolerance. This salinity problem is exacerbated by the use of salts to de-ice roads and pathways in winter. Another soil improvement method that may allow the usage of existing saline soils versus importing soils is the addition of gypsum/lime (Haege & Leake 2014). These products are commercially available and the amount of application will be based on the results of soil testing. If the application of gypsum is combined with irrigation/water of non-saline water, salt can be leached out of soils within a fairly short period of time, although in some cases soil texture may prevent this. This option of removing salt in soils for reuse is often much more cost effective than importing soils. Also, the application of gypsum or lime is generally not a permanent solution as saline soils are generally high in pH and the addition of gypsum or lime will increase that pH.

Water retention

Organics within topsoils retain the most water and aid in reducing runoff. Reducing impervious (I) surfaces while increasing pervious (P) surfaces prevents direct overland runoff into stormwater systems and as such, a smaller I/P ratio is desired.

Increasing pervious surfaces allows for the replenishment of ground water and increases water quality downstream in the watershed. Water is filtered through beneficial vegetation which reduces pollutants and sediment loading into waterbodies.

In all landscapes, maintaining an organic layer and having healthy topsoil and sufficient topsoil depth benefits water quality. Although required topsoil depths are presented by The City of Calgary Parks (current edition), the deeper the topsoil and the more organics it contains, the more absorbent the soil will be. Also, deeper topsoil can better support trees, shrubs and long-rooted grasses which create pores in the soil profile, increasing infiltration.

In general, the addition of organics for restoration is likely not necessary as long as soil health has been preserved. Native species tend to thrive in poorer soils and the addition of organics may tie up nitrogen during the decomposition process then release nitrogen after the organics have broken down. This may lead to an increase in weeds in unmaintained landscapes. There may be situations that organic additions are required, but overall, soil conservation using best management practices is preferred. Since Calgary tends to have a high proportion of typical prairie soils, natural topsoil depth is usually quite high whereas the O horizon (e.g., upper organic layer) is shallow. This contrasts with forested areas which tend to have lower topsoil depths and a deeper O horizon. Additionally, soils in British Columbia have a higher sand content. These specific characteristics often warrant the addition of organics to forest soils to ensure soils are more absorbent to be reused for other applications after clearing. This is generally not required for reusing existing healthy soils within the Calgary area.

Section III: Soil and vegetation conservation

Non-vegetated soil

Like goes with like

As previously mentioned, soils can be further divided by the vegetation communities that they support. For example, soils that support forests tend to be Luvisolic soils which contain a layer of decomposing matter on top of a mineral soil (Lavkulich & Arocena 2011). Chernozemic soils are most often associated with grasslands that have a fairly deep brown or black surface horizon 10 to 20 cm deep composed of 4 to 10% organic matter (Alberta Agriculture and Forestry 2005). Generally, grassland soils differ from forest soils as the topsoil layer is thicker and contains more organic matter than forest soils. Soils that support forests have less organic material incorporated into the soil itself but have a thick layer of decomposing organic matter on the soil surface. The soil organisms also go through succession as changes above ground correspond to changes below ground. Grasslands will have more of a balance of bacteria to fungal populations as forests will be more dominated with fungi.

Due to changes such as this that can be very local in nature, it is recommended that soils of similar habitat types are reused in areas that will be restored to alike habitat types. For example, if an area of forest soil is salvaged, those same soils should be used in an area that will be revegetated with woody material. Similarly, native grassland soils that are salvaged should be reused in sites that will be restored to native grassland. Soils that support agronomic grasses should be reused in areas that will be landscaped into lawns. This ensures that the topsoil, subsoil, organic content and texture best match the future of the landscape.

Sod salvage

If feasible, sod should be salvaged intact, especially for areas that will be restored to native plant communities and/or have very specific soil needs such as foothills rough fescue grasslands or saline wetlands. Equipment should be used that can retain the sod’s physical integrity as much as possible (Neville *et al.* 2014). Besides retaining the seed bank from the site, sod salvage retains the biota and soil structure much better than traditional stripping, stockpiling and grading. The seeds are also in the natural placement for germination which optimizes natural recovery. Essentially, sod salvage can drastically reduce revegetation efforts in restoration work and improve natural recovery.

Sod salvage can also provide plants that can be hard to procure for various reasons. It is recommended that sod be salvaged from onsite or nearby locations offsite in cases where the native plant communities are to be salvaged and/or restored (Natural Resources Conservation Service 1996).

Plant salvage

Unfortunately, when development occurs, valuable plant material is often discarded. Normally, during the soil stripping phase, all organic matter is removed using heavy equipment such as brush grinders that turn all vegetation above ground into mulched organic matter which is then removed by heavy equipment such as a bobcat. Some material may be salvaged and composted to add organic contents and preserve the microbial composition or used as large woody debris to assist in revegetation; however, the majority of the time the organics are removed.

The reason why this vegetation tends to not be reused on site or on an adjacent site is that it takes a lot of logistics coordination and labour to be able to salvage this vegetation. This includes additional labour using delicate equipment or manual labour to dig up plants without damaging them. Also, plants tend to transplant better when they are dormant in the spring and fall, when the ground is workable and their roots are not exposed to freezing temperatures. Plant storage is also an issue as construction over several seasons, even years, may be ongoing before the site is finally revegetated. Although some plants can be stored without soil (e.g., bare root), this storage method can only be used temporarily when plants are dormant. In addition, the roots of the plant need to remain moist but not moist enough to induce root rot (i.e., bare root stock has a bag or box over the root ball along with sawdust or peat moss to soak up extra moisture while retaining damp conditions). Storing plant material long term requires that plants be in pots with soil and adequate moisture suited for their growth phase. Moisture requirements vary based on plant species, plant size and whether the plant has been newly transplanted and needs additional moisture to establish new roots in a new growing medium. Also, moisture requirements change with the seasons and associated phases of growth so depending on whether the plant is coming out of dormancy, actively producing vegetative structures, actively producing sexual structures such as flowers or fruit or going into dormancy will drastically affect the water requirements of the plant. In addition, dormancy must be maintained and mimic what occurs in nature so that the plant survives storage and transplant when it is put in its final location. Most cases of plant salvage occur when plants can be harvested and transported directly to another location on site or close to the site to be planted right away.

As mentioned, labour and logistics are the biggest limiting factors in plant salvage. Timing, coordination, networking and botanical knowledge influence these limiting factors. Unfortunately, much to our disadvantage in the long term, buying pre-grown plant material and seed for revegetation activities usually requires less resources than salvaging plant material.

Besides the fact that the plants are suitable for the same region, soils supporting the plants are specific to the plants themselves which is why sod salvage and plant salvage is encouraged, especially in cases where sensitive vegetation communities will be restored or retained. Organics, microbiology, fungi and soil composition vary from site to site and plants have very specific relationships with these factors that science is still striving to understand. Mycorrhizae are fungi that form a mutually beneficial relationship with the roots of vascular plants as they receive carbohydrates from the host. Mycorrhizae function to increase the surface area of plant roots to improve water and nutrient uptake and also use chemical means to transform soil nutrients into bioavailable forms that can be utilized directly by the host plant. Mycorrhizae also secrete substances that bind soil and make plants more resilient when exposed to stressors such as salt, pests, metals and predators. Approximately 90% of all vascular terrestrial plants live in association with mycorrhizal fungi (Pace 2003). These mycorrhizae can be selective and form relationships with only a certain subset of plant species. Although there are commercially available mycorrhizae that can be added to soils, the best mycorrhizae are the ones that are associated with the plant in its natural state. Development usually destroys mycorrhizae and as such, revegetation, especially restoration of native plant communities, is often compromised as the soils have been damaged. The addition of synthetic phosphorus also prevents mychorrhizae from working properly. Even if only for a certain portion of a project area where the restoration needs are more complex, soils should be salvaged intact.

Besides sod salvage, plant salvage can be performed to ensure that the beneficial soil biota is transferred or maintained in the restoration site. Ideally, as much soil as feasible should be left around the plant roots and put into the new or existing site. As mentioned previously, this is very labour intensive but provides a lot benefits and advantages. Conserving soil around salvaged plant material preserves the site specific, and often plant species specific, soil biota.

Section IV: Importing soils

Development Guidelines and Standard Specifications: Landscape Construction manual (The City of Calgary Parks current edition) and *Habitat Restoration Project Framework* (Parks 2014) require that soil reuse occur whenever feasible. Regardless, there are situations that may lead to the requirement to obtain additional soil from elsewhere. These situations along with precautions when importing soils are discussed below. It should be noted that existing soils on site can also be mixed with imported soils that have similar physical and chemical properties in the event that the soil profiles are not deep enough and there is, in fact, some usable soil on site. Again, subsoil and topsoil should be treated individually and not mixed.

Generally, imported soils must not be a source of contamination to the receiving area. The quality of the imported soils must be appropriate to the land use of the receiving area. It is critical to obtain applicable and recent documentation in regards to the source and quality of any imported soil. For typical Parks sites, imported soil need to adhere to the *Alberta Tier 1 Soil and Groundwater Remediation Guidelines* (Alberta Environment and Parks 2016) for natural area, and residential/parkland land use types. However, there may be site specific considerations (e.g. within 10 m of a water body) that will require a more comprehensive view of the soil quality guidelines. It is recommended that a master soil management plan that includes a soil quality review be prepared to guide construction. A qualified environmental professional may need to be engaged as part of the plan development.

Topsoil import

The City of Calgary Parks (current edition) defines topsoil as a fertile, friable, natural loam that contains not less than 4% organic matter for sandy loams to a maximum of 15% and is capable of sustaining vigorous plant growth. In addition, it is free of rocks that are greater than or equal to 50 mm in diameter, is not contaminated with subsoil, roots and weeds with a pH ranging from 7.0 to 8.5. The volume of rock in topsoil is not to exceed 20%.

The most likely situation to warrant importing soil will result from a lack of suitable topsoil on site and as such, topsoil may need to be brought in from elsewhere. Topsoil that is brought in from off site should be reasonably weed free and mimic the type of soil that will be required for the end point of revegetation. Topsoil brought in from elsewhere should be tested for contamination parameters if valid, recent analytical data cannot be provided.

Topsoil storage and stockpiling methods should follow the recommendations outlined in this document to ensure that the topsoil that is brought in is of good quality. Ideally, the on-site location should be inspected multiple times prior to importing the topsoil to ensure best practices are being followed and that the soil is generally weed free. The history of weed control, the location where the soil was imported from and the vegetation community that the topsoil supported previously should be known prior to importing topsoil. To identify weed issues with imported topsoil, observations should be made over the course of a few seasons to ensure that weed control and mitigation has been successful and has occurred for a long enough duration to address future weed issues that may originate in the seed bank of the imported soils.

Another common situation that may warrant importing topsoil is where the subsoil is adequate but the topsoil cannot be used and is stripped and discarded. This may occur in locations that have been contaminated or sites such as brownfields (Haege & Leake 2014). Even with the importing of topsoil, in these types of circumstances where contamination is problematic, there will likely be more required to alleviate the environmental concerns such as subsoil improvement.

Subsoil import and creation

Generally, subsoil is not imported but in certain cases, it may be required. A two layered soil profile consisting of topsoil and subgrade is adequate to support annual herbaceous species, lawns, lower grade sports fields and groundcovers but it is not sufficient to support more complex vegetation communities (Haege & Leake 2014). Although topsoil is often thought to be the key to healthy plants, subsoil plays a major part in vegetation health as it ensures a firm substrate for root anchorage, aeration, water entry and drainage and water retention. A drawback of using a soil profile without subsoil is that drainage and air exchange may be compromised as water will back up and potentially waterlog the topsoil.

Subsoil import is most likely in situations where no existing soil is available or the site is completely manufactured (e.g., green roof or green wall) (Haege & Leake 2014). It is also relatively common in instances of soil contamination. Again, the subsoil profile should match the typical subsoil profile of the desired landscape and as such, importing subsoil that is similar in composition to the desired landscape type would be beneficial. Subsoil should also be inspected prior to import to ensure adequate soil health and minimize the introduction of weedy and non-desirable species; however, due to the lower organic content, imported subsoil is not as likely to introduce as many invasive species in comparison to imported topsoil. Subsoil should also not be imported from areas with naturally occurring saline conditions, unless the recipient site itself is expected to retain saline soils. Imported subsoil should also be tested for contamination parameters if valid, recent analytical data cannot be provided.

In some cases where subsoil is absent or not present in enough quantity, subgrade may be improved to form a subsoil layer. Although the cost of improving subgrade (e.g., mineral parent materials above bedrock surface) to transform it to subsoil may be high, the import of subsoil may be more cost prohibitive and as such, subgrade improvement may provide a feasible option during construction activities. Improvement methods may include gypsum/lime application or application of acidifying substances, using chisel ploughs to reduce density and break up subgrade, removal of undesired materials and contouring (Haege & Leake 2014).

Section V: Site preparation and seeding

Soil surface

Topsoil should be loose enough that you can make a depression in it but not so loose that it can be easily pushed aside. In addition, a rough surface is always better prior to seeding and restoration work as microtopography (e.g., very small changes in surface topography) catches and traps seed and moisture while keeping the seed in place. Also, an irregularly scarified surface will keep soil in place better than a smooth surface and prevent soil erosion and soil loss.

Drainage

The main factors that influence water retention in topsoil are soil composition and depth (Cook 2016). Unfortunately, when soil composition is affected through development, its ability to retain water is reduced. Having healthy soils that absorb water ensures that impervious surface run off is not going directly into waterbodies and watercourses. Although topsoil and organic content is stressed in best management practices for soil handling, the ability of water to filter through topsoil and subsoil to regenerate ground water tables is often not discussed. Also, subsoil drainage allows for air exchange in the lower plant root zone which keeps vegetation healthy, allows for respiration and prevents rot and pests. Since this is a very important aspect of maintaining the water cycle, requirements and methods to ensure that drainage is maintained are discussed below. The requirements of various cities and recommendations are compared and contrasted. It should be noted that scarification methods need to be carefully thought out and implemented on a site-specific basis to ensure that the soil structure is not compromised by admixing and/or compaction.

Any soil that has a very high clay content or an impervious parent material/subgrade may have drainage issues. These can be alleviated with soil improvements such as decompaction activities or the addition of organic material and coarser particulate mineral matter.

The City of Calgary requires that the subsoil be scarified to a depth of 75 mm in all areas except for areas which are deemed impractical by The City (The City of Calgary Parks current edition). When significant compaction occurs and is greater than or equal to 95% standard proctor Dry Density, then The City of Calgary requires scarification to 200 mm.

The City of Vancouver compares best management practice documents for subsoil scarification for private industry and generally, the overall recommended subsoil scarification depth is 150 mm (Cook 2016). This contrasts to the comparison between the public realm in Vancouver with only the Vancouver Board of Parks and Recreation Development Standards (2015) citing a requirement for subsoil scarification depth at 200 mm.

Within the city of Toronto, scarification and any other decompaction treatment is cautioned against within 3 metres of building foundations in order to limit the drainage capabilities and prevent water seepage into basements (Toronto and Region Conservation Authority 2012). In addition, existing underground utilities and roots of adjacent existing plants should be considered during decompaction activities. In these cases, shallower uncompacted soils may be required to prevent infrastructure damage and harm to adjacent root systems of existing trees, shrubs and long-rooted grasses.

Besides compaction and physical barriers, lack of drainage may be related to sodicity and/or salinity. Common chemical soil tests were discussed previously in the Standard Chemical Soil Tests section. Salinity is usually determined through EC tests while sodicity is measured by calculating the exchangeable sodium percentage (ESP) and/or SAR (McCauley & Jones 2005).

Section VII: Conclusion

Following best practices in soils handling is very important as once soil health is compromised, improving the soil can be very cost prohibitive and the soil may never be returned to its previous state of health. For these reasons, proactive preventative solutions are favoured over corrective measures.

Section VII: References

AECOM. 2012. Soil Assessment for Rail Yard Expansion. Nova Chemicals Corporation, Calgary, AB.

Alberta Agriculture and Forestry. 2004. Soil Sampling and Testing. Edmonton, AB. https://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex1341

Alberta Agriculture and Forestry. 2005. Agricultural Land Resource Atlas of Alberta – Soil Groups of Alberta. Edmonton, AB.

Alberta Agriculture and Forestry. 2018. Agricultural Region of Alberta Soil Inventory Database. Edmonton, Alberta. https://soil.agric.gov.ab.ca/agrasidviewer/

Alberta Environment and Parks (AEP). 2016. Alberta Tier 1 Soil and Groundwater Remediation Guidelines. Land Policy Branch, Policy and Planning Division. 197 pp.

Alberta Environment and Sustainable Resource Development (ESRD). 2014. Alberta Tier 2 Soil and Groundwater Remediation Guidelines. Land and Forestry Policy Branch. Policy Division. 151 pp.

Alberta Sustainable Resource Development, Lands Division. 2010. Industrial Activity in Foothills Fescue Grasslands – Guidelines for Minimizing Surface Disturbance. Edmonton, AB.

Baerg, M. 2013. Tillage radishes – a new option for improved soil health. Top Crop Manager. Simcoe, ON.

Calgary Parks. 2017. Development Guidelines and Standard Specifications: Landscape Construction. Calgary, AB.

Department of Natural Resources and Water. 2017. Subsoil Constraints. Soil Biology Initiative II, Australian Government, Brisbane. http://soilquality.org.au/factsheets/subsoil-constraints-queensland

Ecological Society of America. 2000. Carbon Sequestration in Soils. Washington, DC.

Environmental and Safety Management. 2016. Construction Environmental Checklist, Environmental Requirements for City of Calgary Construction Projects. The City of Calgary, Calgary, AB. http://mycity/Tools/Environment/index/ieu/pdf/construction-environmental-checklist-2016.pdf

Government of Saskatchewan. 2017. Deep Tillage. https://www.saskatchewan.ca/business/agriculture-natural-resources-and-industry/agribusiness-farmers-and-ranchers/crops-and-irrigation/soils-fertility-and-nutrients/deep-tillage

Haege, E. & Simon Leake. 2014. Soils for Landscape Development: Selection, Specification and Validation. Commonwealth Scientific and Industrial Research Organization, Csiro Publishing, Australia.

Landsburg, S. & K.R. Cannon. 1995. Impacts of Overstripping Topsoil on Native Rangelands in Southeastern Alberta: A Literature Review. NGTL Environmental Research Monographs1995-1. NOVA Gas Transmission Ltd. Calgary, AB. 41 pp.

Lavkulich, L.M. & J. M. Arocena. Luvisolic soils of Canada: Genisis, distribution, and classification. University of British Columbia. Vancouver, BC.

Lowenfels, J. 2017. Who Knew? Recent Discoveries inside the Soil Food Web. Growing a Greener World. The Joe Gardener Company, Atlanta, GA. https://www.growingagreenerworld.com/who-knew-recent-discoveries-inside-the-soil-food-web/

MacMillan, R. A. 1987. Soil survey of the Calgary urban perimeter. Alberta Soil Survey Report No. 45. Terrain Sciences Department, Alberta Research Council. Edmonton, AB.

McCauley, A. & C. Jones. 2005. Soil and Water Management Module 2: Salinity and Sodicity Management. Montana State University Extension Service, Montana, USA. http://landresources.montana.edu/swm/documents/SW%202%20updated.pdf

Minnesota Pollution Control Agency. 2017. Minnesota Stormwater Manual. https://stormwater.pca.state.mn.us/index.php?title=Alleviating_compaction_from_construction_activities&printable=yes

Morrison. 2017. Improving Standards for Preserving and Restoring Soil: Construction Specifications for Implementing Compost amended Topsoils in Ontario. TRIECA Conference. Ontario.

Metro Vancouver. 2012. Stormwater Source Control Design Guidelines. Vancouver, BC.

Neville, M. (Graminae Consulting). 2003. A Guide for Minimizing the Impact of Pipeline Construction on the Native Prairie Ecosystem. Alberta Environment and Alberta Sustainable Resource Development, Edmonton, AB.

Neville, M., J. Lancaster, B. Adams and P. Desserud. 2014. Recovery Strategies for Industrial Development in Native Prairie for the Mixedgrass Natural Subregion of Alberta – First Approximation. Prepared for: Range Resource Management Branch, Public Lands Division, Alberta Environment and Sustainable Resource Development.

Okanagan Basin Water Board. 2012. Topsoil Bylaws Toolkit: An Appendix to the Green Bylaws Toolkit. Government of British Columbia's Ministry of Community, Sport and Cultural Development, BC. http://www.obwb.ca/library/topsoil-bylaws-toolkit/

Owens, Jerry, & Dave Dyer. Propagation of Wetland Plants in the Lake Tahoe Basin. (Special report prepared for California Department of Water Resources). USDA Natural Resources Conservation Service, South Lake Tahoe, CA.

Pace, M. 2003. Hidden Partners: Mycorrhizal Fungi and Plants. The New York Botanical Garden. Bronx, NY.

Pettapiece, W. W. & M. W. Dell. 1996. Guidelines for Alternative Soil Handling Procedures During Pipeline Construction. Soil handling Sub-committee of the Alberta Pipeline Environmental Steering Committee, AB.

Province of Alberta. 2011. Weed Control Act. Alberta Queen's Printer, Edmonton, AB.

The City of Calgary. 2012. *Contractor Environmental Responsibilities Package*. [Online] http://www.calgary.ca/UEP/ESM/Documents/ESM-Documents/cerp.pdf

The City of Calgary Parks. 2014. Habitat Restoration Project Framework. Calgary, AB.

The City of Calgary Parks. 2014. Our BiodiverCity: Calgary's 10 – year biodiversity strategic plan. Calgary, AB.

The City of Calgary Water Resources. 2017. Erosion and Sediment Control Guidelines. http://www.calgary.ca/UEP/Water/Documents/Water-Documents/ESC-2017-Guidelines.pdf

Vancouver Board of Parks and Recreation. Park Development Standards. (2015). http://vancouver.ca/files/cov/VPB_Design_Standards_20150515.pdf

Section VII: Appendices

Appendix 1-Acknowledgements

Thanks to the following people who contributed valuable input into to this document:

Myron Flexhaug, Senior Regulatory Analyst – Biosolids, Water Resources, The City of Calgary

Tracey Etwell, Parks Ecologist, Parks, The City of Calgary

Mathew Swallow, Assistant Professor, Earth and Environmental Sciences, Mount Royal University

Mike Dorion, Principal, Living Soil Solutions

Sadie Garland, Environmental Specialist, Parks, The City of Calgary

Jeff Swingler, Corporate Environmental Specialist, Environmental and Safety Management, The City of Calgary

Paul Leong, Senior Technical Advisor, Environmental and Safety Management, The City of Calgary

Lisa Sutherland, Corporate Environmental Specialist, Environmental and Safety Management, The City of Calgary

David Dinu, Manager – Design & Inspections, Erosion Control Central

Appendix 2-Operational soil handling flowchart

Operational Soil Handling Flowchart