Assessing Urban Brownfields for Community Gardens in Vancouver, British Columbia

by

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ABSTRACT

In Vancouver, British Columbia, community gardens are in great demand, but community groups interested in establishing gardens on urban brownfields face several environmental barriers. Identifying and addressing issues related to soil quality and microclimate suitability pose particular challenges. The goal of this study is to aid community groups in overcoming these obstacles through the development of a three-phase Site Assessment Guide. The guide aims to help communities: 1) identify likelihood of soil contamination, 2) assess soil and microclimate quality, and 3) select appropriate management solutions. Interpretive indicators for assessment were selected from trials on three study sites and feedback from soils workshop participants. To ensure accuracy and credibility, interpretive methods were evaluated against corresponding laboratory-based methods. Another outcome of the community workshops was the desire of local gardening communities to learn more about their native landscape and soil. An interpretive map of soil management groups for the City of Vancouver was derived using generalized surficial geology and Google-based topographic maps to produce a "terrain" map. The resulting map of soil management groups in the previously unmapped City of Vancouver is incorporated into the site assessment guide for converting brownfields to community gardens, with opportunity for future expansion.

TABLE OF CONTENTS

List of Tables

List of Figures

LIST OF ACRONYMS

CFAI	Community Food Action Initiative
DTPA	Diethylene triamine pentaacedic acid
EYA	Environmental Youth Alliance
FID	Flame Ionisation Detector
GC	Gas Chromatography
ICAP	Inductively Coupled Argon Plasma Spectroscopy
LFS	Land and Food Systems
MASL	Meters above sea level
MDS	Minimum data set
MOBY	My Own Back Yard (garden)
OSU	Oregon State University
PAH	Polyaromatic hydrocarbons
PCB	Polychlorinated Biphenyls
PHS	Portland Hotel Society
PSAI	Pacific Soil Analysis Incorporated Ltd.
SLAS	Sustainable Living Arts School
VCAN	Vancouver Community Agriculture Network
VCH	Vancouver Coastal Health

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DEDICATION

To my parents, who never cease to give their love and support.
If I accomplish anything at all, it is because of you.

To my dearest friends, Rosemary, Jess, Riika, Nadine, and Christian, who have been with me through many adventures, including this one. You give me reassurance in times of doubt, advice in times of confusion, and lots of laughter – which is always needed.

1 General Introduction

Communities [have] never been a given in this country…
Communities [have] to be created, fought for, tended like gardens.
US President Barack Obama

I can think of no timelier words to begin this thesis than those of the current US President. Indeed this quote seems all too fitting considering the focus of my research: strengthening communities through building their capacity to develop community gardens. Through the majority of his presidential campaign and first autobiography (from which the quote was extracted) Barack Obama emphasized his experiences with "community organizing," a term almost unheard of until 2008, and yet one I became increasingly familiar with over the three years it took for this research to come into fruition. The importance of building community, especially among disenfranchised and vulnerable populations, is important for the health and well-being of our societies. One mechanism through which communities can be strengthened is the creation of community gardens.

Community gardens, just one component of the broader term "urban agriculture", are not new. In fact, government support of urban agriculture has occurred in North America through each substantial economic depression and war. However, as will be discussed in more detail, the reasons behind the recent revival of community gardens are new, and come from individual motive, rather than external political strategy. The importance of urban agriculture is intensified as the Earth faces a mass urban migration. Currently, half of the world's population lives in cities, a number which has steadily been increasing since 1900 (Brown, 2009; Mieszkowski & Mills, 1993). It is projected that by 2030 two out of every three people will be city-dwellers (Hynes & Howe, 2002). As these cities increase in size and number and engulf their surrounding rural areas, the task of feeding urban populations becomes difficult as cities are forced to rely on food sources that are great distances away (Brown, 2009). Thus, in the age of climate change, we must not only overcome the challenge of feeding cities, but do so in a way that decreases the distance our food travels from field to fork.

While the need for community gardens in urban centers is becoming increasingly apparent, as luck, or more correctly, history, would have it, there is an abundance of vacant land in cities across North America. As populations of cities have been increasing, the number of people living in the urban core of these cities has been decreasing since the 1950s (Mieszkowski & Mills, 1993). In surveys of the Chicago and Philadelphia areas, 70,000 and 30,000 vacant lots were identified, respectively (Brown, 2009). Even in cities such as Vancouver, British Columbia, where these vacant lots are not as prevalent, they are still present in large numbers, identifiable through land-use inventories (Kaethler, 2006). These vacant sites are often marginalized and of derelict condition due to neglect. Sites possessing these characteristics have become known as *brownfields* (De Kimpe & Morel, 2000). These brownfields may play a key role in urban food security, but only if they can safely be transformed into food-producing gardens. This situation gives rise to a challenge: How can communities assess the environmental quality of marginalized urban lands to develop safe and successful gardens and thereby restore the ecological function of derelict urban sites?

1.1 HISTORY OF URBAN AGRICULTURE

Throughout North American history, in periods of war, economic hardship, and transition, society has adopted the practice of urban agriculture to meet the needs of populations in crisis (Bassett, 1981; Schmelzkopf, 1995; Hynes & Howe, 2002). *Urban agriculture*, the production, processing and distribution of vegetables, fruit, flowers, and animal-products within the urban core (Baumgartner & Belevi, 2001), has roots in North America leading back to the late 19th century. The history of urban agriculture in North America is not cohesive, but segmented, and has been summarized by Bassett (1981) as seven movements (Table 1.1), each ending as the time of crisis abated, government support ceased, and lands were turned over for real estate development (Hanna & Oh, 2000; Schmelzkopf, 1995; Hynes & Howe, 2002). A similar history can be observed in Europe, most notably in Germany after the devastation of World War I, and in Britain during World War II (Deelstra & Girardet, 2000).

Table 1.1 Historical periods of urban agriculture in North America (adapted from Bassett, 1981)

Period	Years	Historic Event
Potato Patches	1894-1917	The Panic of 1893 (part of the Long Depression)
School Gardens	1900-1920	The transition from rural to industrial society
Garden City Plots	1905-1910	Beautification and civic improvement campaigns

Period	Years	Historic Event
Liberty Gardens	1917-1920	World War I
Relief Gardens	1930-1939	The Great Depression
Victory Gardens	1941-1945	World War II
Community Gardens	1970-Present	Rise of environmental awareness and increase in inflation and unemployment

Economic Depression – Potato Patches and Relief Gardens

The Potato Patch and Relief Garden eras of urban agriculture were both born during periods of economic depression. The prior corresponding to a series of financial errors surrounding railroad financing known as the Panic of 1893, and the latter related to the Great Depression (Bassett, 1981). During these times, vacant lots were transformed into gardens to maintain the mental and physical health of the unemployed, and to produce food supplies with no need for transport (Armstrong, 2000). As these financial crises began to ease, real estate interests took precedent over gardens, although the need and interest for urban agriculture programs was still felt by the poor (Schmelzkopf, 1995).

Civic Duty – School Gardens and Garden City Plots

The School Gardens and Garden City Plot eras were marked by the transition of rural to industrial life, as well as a desire to impress the importance of civic responsibility and city beautification on urban populations. In schools, gardens served as tools for teaching issues such as private care of public property, civic pride, and dignity of labour. Additionally, they were used as training for the industrial process, where garden supervisors, acting as factory foreman, instructed students on how to maximize their efficiency while at work (Bassett, 1981).

Soldiers of the Soil – Liberty and Victory Gardens

The Liberty Gardens of World War I and the Victory Gardens of World War II are perhaps the greatest exemplars of what can be accomplished through urban agriculture. Support programs for these gardens were present in the United States and Canada, though each country differed slightly in their approach and willingness to support such programs. In the United States, these gardens were organized through the National War Garden Committee, a division of the American Forestry Association (during World War I) (Hanna & Oh, 2000) and then by the War Food Administration's National Victory Garden Program (World War II) (Bassett, 1981). In Canada, the Agricultural Supplies Board and the Foods Administration Board of the Wartime Prices and Trade Board headed the garden programs (Buswell, 1980). Though Canada's involvement in World War I and II preceded that of the United States, the Canadian government's support of gardening programs was not constant. In 1918, The Greater Food Production Act entitled citizens to "take possession of vacant, unused tracts of land for cultivation purposes, without paying compensation to the owner" (Buswell, 1980), but as Canada entered the Second World War, the government discouraged gardening for fear that inexperienced gardeners would waste fertilizers, seeds, and other valuable resources (Buswell, 1980). The federal government held this view until the end of 1942, despite the active Victory Garden programs present in the United States and the public outcry for the establishment of similar programs in Canada (Buswell, 1980). In 1942, food shortages among other allied countries propelled the federal government to heed the advice of its citizens and launch a campaign which included access to government services and support (Buswell, 1980). Thanks to this support, in 1943 1,425 gardens had been developed on city-owned land in the province of British Columbia alone. According to the February 22, 1943 issue of the Vancouver News-Herald, if viewed as a consolidated area, the Victory Gardens of British Columbia would approximately equal three times the size of Vancouver's Stanley Park (Buswell, 1980).

> *"If all the Victory Gardens in British Columbia were lumped together, they would occupy a space approximately three times the size of Vancouver's great Stanley Park."*
>
> VANCOUVER NEWS-HERALD, 1943

The establishment of these wartime gardens was motivated by five factors: 1) to increase the amount of vegetables that could be sent to the troops by having people produce many of their own vegetables at home, 2) to reduce demand for the materials needed for industrial canning and food processing, 3) to ease the burden on the railroad, 4) to keep populations healthy and increase morale, and 5) to preserve produce that could then be eaten during shortages (Bassett, 1981). In 1918, during the First World War, 5,285,000 gardens in the United States produced $525,000,000 worth of crops (Bassett, 1981). In 1944, during World War II, that number increased to 20,000,000 gardens, which yielded 40% of all of the fresh produce consumed in the United States that year (Bassett, 1981). Even with this tremendous success, the majority of these gardens were abandoned after the wars ended. With the exception of some creative garden projects promoted by public housing authorities, the tradition of urban agriculture was abandoned until the 1970s (Hynes & Howe, 2002).

The end of the Second World War marked the beginning of industrialized agriculture in North America (Kramer, 2003), partially due to the development of the Haber-Bosch process for fixing atmospheric nitrogen, developed during World War I, which led to the creation of chemical fertilizers (Trewavas, 2002). During this time, agriculture expanded in areas with favourable climates, notably Florida and California, where production increased with the popularization of industrial irrigation (Kramer, 2003). Increased food production due to application of fertilizers, pesticides, and herbicides decreased the necessity for local food production and subsequently affected food self-reliance (British Columbia Ministry of Agriculture and Lands, 2006). Despite the large quantities of food products provided at low cost to the consumer by industrial agriculture, the benefits of local, urban food production through gardening (discussed in Section 1.2), led to a community gardening movement in the face of an ever-industrialized food culture.

A New Take on an Old Practice - Community Gardens

The beginning of the community garden movement, starting approximately 40 years ago, was “quiet, local, and disparate” (Hynes & Howe, 2002, p. 173). Taking advantage of the rise in vacant city lots, this movement was sparked by increased inflation in the 1970s paired with a rising awareness of environmental issues (Bassett, 1981; Breslav, 1991) and has endured for nearly half a century due to the many other services community gardens provide (Hynes & Howe, 2002). Because these gardens are created on vacant lots, land is seldom owned by the society that uses the land. In the United States, less than 5% of community garden land is secure. Often, this land is owned by the city or holding companies, and community groups have to seek permission to use the land legally. Community gardens play different roles and offer different services according to local needs and priorities (Ferris et al., 2001; Holland, 2004). This fact also makes the term 'community garden' difficult to define. The literature provides different definitions due to differing structures and purposes. An integrated synthesis of this literature provides a working definition of *community garden* that I will adopt in my thesis:

Gardens created on vacant land, which communities have legally been bestowed access, and having a governance system and a structure (either allotment or communal) that has been decided and agreed upon by the community.

1.2 Benefits of Community Gardening

The definition provided above takes into account the different roles, priorities, and therefore benefits, these gardens provide to their communities. These benefits, explored and acknowledged by an onset of recent research (examples of which are provided in the subsequent section), demonstrate the wide spectrum of social, environmental, and economic benefits that gardening brings to participants and neighbouring communities. These benefits can be organized into four overarching categories: 1) strengthening community connections, 2) fostering healthy communities, 3) restoring and preserving the environment in the urban core, and 4) increasing the economic stability of financially vulnerable populations.

Strengthening community connections

Community gardens are agents of inclusion for a neighbourhood. They often incorporate segregated groups such as immigrants, the mentally-ill, the elderly, children, and economically vulnerable populations (Garnett, 1996; Hynes & Howe, 2002). Based on my observations at the Hastings Folk Garden in Vancouver, British Columbia, the garden served as a source of therapy for people attending the neighbouring substance abuse rehabilitation centre, but also for community members and volunteers not associated with the centre. These gardens provide a physical location for neighbours to gather, socialize, organize, and share information, and have been shown to improve the organizational capacity and social networking of the communities in which they were located. This is particularly true in the case of lower income and minority neighbourhoods (Armstrong, 2000). In a 2000 study of 63 community gardens in upstate New York, researchers noted that the presence of community gardens led to further neighbourhood organizing by providing a physical location for activities and meetings to occur (Armstrong, 2000). Often, inter-generational and cross-cultural participants of community garden societies have a chance to communicate, educate each other, and share equipment as well as ideas (Hancock, 2001; Wakefield et al., 2007). Participants are given the ability to share something they have produced out of their own garden (Wakefield et al., 2007). This concept of reciprocity is particularly important for low-income participants, whose contributions become apparent.

Fostering healthy and safe communities

Taking part in community gardening not only increases community food security by granting participants better access to fresh, culturally appropriate produce, but actually encourages people to eat a healthier diet. In a survey conducted in Flint, Michigan, people in households with a member who participated in a community garden consumed fruit and vegetables 4.4 times a day on average, compared to non-participant households, who consumed an average of 3.3 fruits and vegetables a day per person (Alaimo et al., 2008). Gardening was found to improve physical health not only through improved nutrition, but also through physical activity (Wakefield et al., 2007). Community gardening has been found to have healing effects on mental health. Time spent in nature can reduce mental fatigue and restore the brain's ability to direct attention (Kaplan, 1995), aid stress recovery (Ulrich et al., 1991), and encourage children to play (Taylor et al., 1998). Positive mental effects extend outside of the realm of garden participants, and have an effect on people who interact with the garden in a passive way. Simply gazing at a plant, for instance, can lead to reduced blood pressure, muscle tension, and decrease feelings of fear, stress, and anger (Ulrich & Parsons, 1992).

In addition to promoting physical and mental health, community gardening can enhance neighbourhood safety. As people grow acquainted with their neighbours, and once-neglected vacant lots turn into active and cared for community gathering spaces, crime is reduced (Hynes & Howe, 2002). In a study comparing vegetation to instances of reported crime, Kuo and Sullivan (2001) found that buildings with a high amount of non-dense vegetation had 52% fewer crimes than those with no landscaping. Furthermore, community gardens can serve as gathering locations where issues such as crime prevention can be discussed and acted on (Hynes & Howe, 2002).

Restoring ecological function in the urban core

Community gardens help to restore and preserve urban environments through direct and indirect means. Gardens promote biodiversity of bird and insect species in the urban core through habitat creation (Garnett, 1996; Hancock, 2001), they aid community waste reduction by providing an outlet for compost (Hancock, 2001), and they create pervious area, promoting rainwater infiltration. Additionally, they serve as a source of local produce, alleviating the need for shipping, and therefore create a food source which does not contribute to carbon dioxide emissions (Hancock, 2001).

In addition to the direct environmental benefits of community gardening, there are also indirect benefits. Community gardens serve as spaces and tools for environmental education, spanning such topics as food production, plant physiology and identification, and soil science. By receiving an education in these fields, participants are better able to make informed decisions regarding the environment and perhaps develop an appreciation for the natural world.

Economic Stability

In North America, community gardens offer more in terms of social and environmental benefits than economic benefits (Holland, 2004). Regardless, positive economic impacts can be observed in the communities containing a garden. As mentioned above, community gardens are sites and tools for education, including job training and skill development (Garnett, 1996; Holland, 2004). Economic effects also transcend the community garden borders. Interestingly, a 2007 study conducted in New York City demonstrated that gardens increased the value of properties within a 300 meter radius, with the greatest impact in disadvantaged neighbourhoods, and increasing over time (Camobreco & Voicu, 2007).

Gardens also serve as means of food-cost savings, especially in urban core locations, where supermarket access may be limited and prices are generally high (Camobreco & Voicu, 2007; Hynes & Howe, 2002). A 2007 survey of community gardeners in Southeast Toronto found that most participants had increased access to food and cost-savings (Wakefield et al., 2007). This cost-saving is particularly important when obtaining some culturally-appropriate foods, which may be more expensive or not fresh when found in stores, if found at all. In a survey of immigrant community gardeners in San Jose California, 36% of recent immigrants said that a major benefit of gardening was to grow vegetables hard to find in American food markets (Lee, 2001). By increasing access to culturally appropriate and affordable foods, community gardens help increase a city's food security.

The growth of urban environmentalism

The benefits of converting vacant city lots into community gardens appeal to a diverse group of stakeholders. Different gardens serve different purposes, with their role in a community matching the needs and priorities of that community. Wide arrays of social, environmental, and economic issues are addressed by adoption of community gardens. These issues are long term in nature, and not the result of individual historic events such as war, economic recession, and social transition. As these benefits are recognized, momentum is added to the *urban environmentalism* movement. This term refers to a form of environmentalism created through interactions with the "natural" environment, including the air, water, soil, and climate, in the urban core (Hynes & Howe, 2002; Wakefield et al., 2007). By having immediate contact with the environment, growers are more likely to notice changes and inconsistencies in the weather, and be concerned with issues such as soil and air pollution (Schmelzkopf, 1995; Wakefield et al., 2007). Indeed, soil and air toxicity have been identified as the top concerns for several urban gardeners (Wakefield et al., 2007). By noticing these characteristics and caring about their effects in a personal way, people are more likely to change their behavior in favour of the environment. The reasons why people may be hesitant to garden is the fear of eating toxic produce due to soil and air contamination. Yet, the local production of fruits and vegetable is one of the most important reasons for people to garden in the first place, since it partially removes a dependence on the transportation and industry responsible for much

> *"Community gardens create and sustain relationships between city dwellers and the soil, and can engender an ethic of urban environmentalism that neither grand central parks nor wilderness – which release and free us from the industrial city – can do."*
>
> HYNES AND HOWE

of the world's pollution. While community gardening is not a new phenomenon in North America, the reasons for its current adoption are new. These numerous benefits make community gardens important additions to urban landscapes, even in the absence of recession or war.

1.3 URBAN SOILS

Land-use conversions from vacant lots to vegetable gardens, despite their many benefits, can also pose health risks, particularly pertaining to issues of soil quality. These environmental and human health concerns caused by increasingly close soil-human interactions, along with the "non-negligible" portion of the food supply provided through urban agriculture in both developing and developed countries, have led to an increased importance of urban and suburban soil assessment and management (De Kimpe & Morel, 2000).

1.3.1 COMMON CHARACTERISTICS OF URBAN SOILS

Human influence plays a significant role in soil genesis. Soils that owe their dominant properties to the influence of human activities are termed as "disturbed", "drastically altered", "urban", "human influenced", or "anthropogenic" (Evans et al., 2000). It is difficult to generalize the common properties of urban soils due to the fact that they can vary tremendously within a single site, not to mention between different locations. This variation stems from the fact that anthropogenic soils are shaped from many different types of human activities and interventions. Modification activities, such as soil stripping, filling, mixing, compacting, and importing/exporting, at varying levels of intensity, are often practiced on urban sites (Evans et al., 2000). Nonetheless, these largely variable soils can, for the most part, possess similar properties (Table 1.2).

Table 1.2 Common properties of urban soils and their causes (adapted from Craul, 1992)

Soil Property	Cause(s)
Degree of vertical and spatial variability	Past land-use; export/import of soil; and natural variability
Modified soil structure leading to compaction	Human and mechanized traffic on the site
Presence of a surface crust on bare soil that is usually hydrophobic	Compaction; lack of vegetation

Soil Property	Cause(s)
Modified soil reaction (pH), usually elevated	Various causes. May include influence of construction rubble, ash
Restricted aeration and water drainage	Compaction; lack of vegetation
Interrupted nutrient cycling and a modified soil organism population and activity	Inhospitable environment for plant growth due to factors such as compaction, high pH and contamination
Highly modified soil temperature regimes	Small lot size and therefore greater influence of the surrounding area's characteristics
Presence of anthropogenic and other contaminants	Remnants of past land use; neglect

Urban soils are often compacted. Transportation and displacement of soil disrupts soil horizon arrangement, causing abrupt changes at one or more levels within the vertical soil profile. Importing and removing soil may destroy the soil structure, leading to compaction. Foot and light wheel traffic on wet soils causes compaction through the destruction of soil aggregates and the rearrangement of pore space. This traffic also destroys ground cover, thereby reducing soil organic matter, one of the agents that enhance soil structure. Additionally, rainwater can add to compaction of the exposed soil surface by disintegrating soil aggregates and dispersing fine soil particles into pores. Do to compaction, urban soils have a pronounced tendency to form a surface crust that increases runoff, reducing water infiltration, which in turn lessens the amount of available water in the soil (Craul, 1992). Examining infiltration rates on nine urban lawns, Kelling and Peterson (1975) found that discontinuities in the soil profile caused the greatest hindrance to infiltration. Water intake in these disturbed soils was approximately 35% that of soils with an unaltered profile.

Urban soils may experience greater heat loading and higher temperatures than their rural or forest counterparts. In urban settings, buildings and street surfaces absorb heat from the sun and reflect and/or reradiate it onto the soil. Internal heating of buildings and expulsion of hot air by air conditioners also contribute to a warmer urban environment. Because soils often occupy small areas in the urban core, their temperature regimes are influenced by their surroundings (Craul, 1992). Halverson and Heisler (1981) found soil temperatures to be significantly higher under trees grown in a parking lot than under trees grown in a nearby field. This influence causes heat flux, a predominately vertical process in natural soils, to become a horizontal process in many urban soils. Subsequently, this makes urban soil temperatures difficult to predict (Craul, 1992; Halverson & Heisler, 1981).

In most cases, pH values are higher in the urban soils than in undisturbed, natural soils. Craul (1992) attributes this to the common calcium sources found in cities: calcium-rich irrigation water and construction dust and rubble high in calcium that can be dispersed on the soil as particulate matter or be mixed in as fill. Halverson et al. (1982) found that pH of rainwater increased from 3.99 to 7.64 after passing over concrete surfaces. Despite its tendency towards alkalinity, the pH of urban soil is highly variable, and phenomena such as the settling of acidic particulate matter from atmospheric pollution may cause pH values to become lowered (Craul, 1992).

> *"Anthropogenic soils will require more extensive chemical analysis than natural soils, primarily to detect and characterize contamination"*
>
> EVANS FANNING AND SHORT

1.4 URBAN SOILS AND CONTAMINATION

Contaminants and anthropogenic artifacts are commonly present in urban soils. The sources and risks associated with these pollutants are as varied as the pollutants themselves. The following sections explore some of the most ubiquitous urban soil contaminants and their respective sources, exposure pathways, and associated health risks.

1.4.1 CONTAMINANTS

Urban soil contaminants come in metal, metalloid or organic forms. Of these, common organic pollutants include polychlorinated biphenyls (PCBs) and polyaromatic hydrocarbons (PAHs), and widespread metal contaminants include cadmium, copper, lead, nickel, and zinc. For in-depth lists of metal, metalloid, and organic contaminants, as well as their anthropogenic sources and health effects, please refer to Table A. 1 and Table A.2 in Appendix I.

Polychlorinated biphenyls (PCBs) are widely used in a number of every-day items including dielectric fluid for capacitors and transformers, fire retardants, caulking, and cable insulation (Safe, 1990; Environmental Protection Agency, 2009). They were used in the manufacture of these items from 1929 until 1977, when their production was banned (Environmental Protection Agency, 2009). Exposure pathways are mainly inhalation, dermal, and through ingestion (Agency for Toxic Substances and Disease Registry, 2000). The health effects of PCBs include cancer, as well as adverse effects on the human immune, nervous, endocrine, and reproductive systems (Environmental Protection Agency, 2009).

Polyaromatic hydrocarbons (PAHs) come from natural and anthropogenic sources, and arise from the incomplete burning of such things as coal, oil and gas, garbage, or tobacco (Agency for Toxic Substances and Disease Registry, 1996). Anthropogenic sources are far more prevalent than natural sources and are closely tied to vehicle use. Exposure pathways are inhalation and ingestion, due to the fact that PAHs can bind tightly with particles and bio-accumulate in plants and animals (Agency for Toxic Substances and Disease Registry, 1996). Negative health effects include harm to the human pulmonary, gastrointestinal, renal, and dermatologic systems.

Metals such as cadmium, copper, lead, manganese, nickel, and zinc are ubiquitous in urban environments. Cadmium is created during fossil fuel combustion and is found in phosphate fertilizers, plastics, batteries, paint residues and electroplating (Agency for Toxic Substances and Disease Registry, 2008). Copper is found in plumbing fixtures, pipes, fertilizers, pesticides, fungicides, and preservatives for wood, fabric, and leather (Agency for Toxic Substances and Disease Registry, 2004; Craul, 1992). Lead, once added to paints and gasoline, now has restrictions on use. However, remnants of paints, piping and caulking, as well as gasoline, still linger (Agency for Toxic Substances and Disease Registry, 2007; Craul, 1992). Nickel can be translocated through wet or dry air deposition and is used in electroplating and batteries (Craul, 1992). Zinc is used to make batteries, brass, paint, rubber, dyes, wood preservatives, ointments, and galvanized metals (Agency for Toxic Substances and Disease Registry, 2005; Craul, 1992). It is also used as a coating to prevent rust (Agency for Toxic Substances and Disease Registry, 2005).

These metals can have serious impacts on human health through consumption of plants and animals raised in contaminated environments, and through inhalation of polluted air. Health effects vary in symptom and severity. For a list of adverse health effects of metals, please refer to Table A. 2 in Appendix I. The probability of metal accumulation by plants grown in contaminated soils is dependent on a wide variety of environmental factors and interactions. Thus, it is possible for plants grown in soils containing high metal levels to remain uncontaminated depending on the bioavailability of the metal in question. Several factors affect the bioavailability of metals in the soil matrix. Determining bioavailability is made more complex when synergistic effects are taken into account. Tracking trace element speciation provides clues to bioavailability gradients, as their dissolved forms are mobile, and thus available for uptake by higher plants (Ge et al., 2000; Kabata-Pendias, 2004; Sauvé et al., 2000). Factors affecting speciation, and therefore of particular concern, include: dissolved organic matter, pH, and total metals (Sauvé et al., 2000), as well as redox potential, cation exchange capacity and the presence of iron- and manganese-hydroxides (Kabata-Pendias, 2004).

> *"The partitioning of trace elements between the soil solid phase and solution determines their mobility and bioavailaboratoryility."*
>
> KABATA-PENDIAS

Though the issues of mobility and bioavailability are complex, some generalizations can be drawn. For instance, as soil pH increases, so do the number of sites available for adsorption. Therefore, under alkaline conditions, metals are more likely to bind to particle surfaces (Harter & Naidu, 2001). As far as individual metals are concerned, cadmium and zinc are more likely to become mobile than copper or lead (Intawongse & Dean, 2008; Kabata-Pendias, 2004). Additionally, cadmium, copper, nickel and zinc are more easily bio-available under oxidizing conditions with a pH less than 3 (for copper and nickel), or more than 5 (in the case of cadmium and zinc) (Kabata-Pendias, 2004). Though not easily soluble, metals such as lead can pose health risks to children through soil ingestion (Finster et al., 2004). Calabrese et al. (1997) found that some children ingest up to 25-60g of soil in a single day, making exposure to immobile contaminants, such as lead, hazardous.

1.4.2 Soil Contamination Standards and Regulations

In Canada, government-set standards for metal contamination differ across provinces, are land-use specific, and are given as *total amounts present* not bio-available amounts. The land-uses are categorized by the British Columbia Environment Management Act into the following five groups: agriculture, urban park, residential, commercial, and industrial. Regulatory limits for British Columbia by land-use for 21 elements, as well as light and heavy petroleum hydrocarbons are given in Table A. 3 in Appendix II. Additionally the British Columbia Ministry of Environment has established three contamination intensity levels for 14 elements (see Table A. 4 in Appendix II). Each level represents an "investigation standard" or "remediation standard" for different land uses. An *investigation standard* is a contaminant concentration which requires further detailed investigation to determine the nature and extent of any potential hazards. A *remediation standard* is the contaminant concentration at or above which action needs to be taken to limit human and vector exposure. This action, according to the British Columbia Ministry of Environment, may include: containment, cleanup, or change in land use (British Columbia Ministry of Environment, 1990).

Level A soils possess the "approximate achievable analytical detection limits for organic compounds in soil, and natural background levels of metals and inorganics" (British Columbia Ministry of Environment, 1990, p. 2). Soils at or under the level A standard are considered uncontaminated. For residential land uses, amounts exceeding these concentrations are of the "investigation standard" (British Columbia Ministry of Environment, 1990). For soils with contamination concentrations higher than the Level A standard, but lower than the Level B standard, remediation is not required, and the land is considered to be slightly contaminated (British Columbia Ministry of Environment, 1990).

Level B soils are of an intermediate contamination value, at approximately five to ten times greater than Level A soils (British Columbia Ministry of Environment, 1990). For exclusive commercial or industrial land uses, Level B soils are the "investigation standard", while for residential and recreational land use, this level is the "remediation standard" (British Columbia Ministry of Environment, 1990).

Level C soils contain significant amounts of contamination, and remediation is needed regardless of the land use (British Columbia Ministry of Environment, 1990). For soils exceeding the Level C standard, all land uses must be restricted until remedial measures are taken to lower concentrations to amounts under Level C (British Columbia Ministry of Environment, 1990).

1.4.3 *The "Totals versus Availables" Controversy*

As mentioned above, government contamination standards are provided as total metals, and not plant- or bio-available metals. Because several different, and often interrelated, environmental factors affect the bioavailability of metals, providing standards in terms of bio-available limits is not feasible. The issue with providing standards in terms of total values is that over-estimations of contamination are likely. While this practice follows a "better safe than sorry" mentality, it also eliminates the use of several pieces of land in the urban core that, in actual fact, pose no risk as far as soil contamination is concerned, yet yield values in excess of the government standards. This practice also makes it important to determine the naturally occurring background levels of any given locations. In so doing, high levels of certain elements can be flagged as creating no cause for alarm. For example, in Vancouver, British Columbia, elevated levels of iron and aluminum are to be expected due to naturally high concentrations of iron- and aluminum-oxides characteristic of the region's Podzolic soils (National Research Council of Canada, 1998).

1.4.4 *Anthropogenic Artifacts*

Anthropogenic artifacts include the refuse and rubble commonly found on urban brownfields. Such items include drainage tile, garbage (e.g., food wrappers, drink containers), broken glass, and construction or fire debris. These artifacts can be part of the soil matrix if they are mixed in with fill, or may be found on the soil surface, deposited by passersby. As urban structures are demolished, the resulting rubble is used to fill foundation voids or is hauled away to be used as hard fill elsewhere. This fill contains a high percentage of materials such as processed wood, glass, ceramics, plastic, asphalt, metal, and building stone (Craul, 1992).

Bullock and Gregory (1991) summarize effects of anthropogenic artifacts on soil physical and chemical properties. Physically, anthropogenic materials decrease rooting volume, impede root growth and the mixing and channeling of soil organisms, and reduce the water-holding capacity of the soil. Chemically, anthropogenic materials may alter the chemical composition of soils, especially when they are small in size and possess a high specific surface area. For example, construction rubble adds calcium and magnesium to the soil, raising pH, plastic decomposition (when possible) releases organic compounds into the soil, and the corrosion of iron and steel releases iron into the soil in a free form that may be taken up by higher plants, or form new compounds with other elements (Craul, 1992). An examination of corrosion scales by Sarin et al. (2001) shows the presence of detectable soluble ferrous phases on old iron pipes. Additionally, Gerwin and Baumhauer (2000) found corrosion of iron artifacts increased in sandy and acidic soils. The presence of anthropogenic materials is therefore a form of soil contamination ubiquitous in the urban setting, and as such, compromises the soil's function as a medium for plant growth, and potentially the health of humans and animals that consume plants grown on contaminated land.

These characteristics can hinder plant growth, make consumption of plants hazardous to human health, or endanger children through exposure to immobile contaminants such as lead. In order to meet the rising demand for community gardens and ensure their success, precautions must be taken to ensure potential health hazards associated with urban environments do not jeopardize the capacity of urban agriculture to foster environmental and human health.

1.5 SITE ASSESSMENT

Given the common properties of urban soils, and the ever-present sources of soil contaminants in urban centres, site assessments are a necessary step in the transition of brownfield to garden. The following sections outline the main components of site assessment.

1.5.1 SITE HISTORY

The compilation of a site history is an important first step to a comprehensive soil quality analysis because it provides valuable knowledge about what we may expect to find on the site, including probable contaminants, construction or housing remnants, and/or types of fill materials. Urban soils are tremendously variable so, "until we have a better sense of the range of the properties of these soils, our best strategy is to assiduously collect data on the kinds of human activities that are likely to affect soils, and on the resultant properties of those soils" (Evans et al., 2000, p. 59). By doing this, we also are able to determine which laboratory analyses to prioritize, lowering laboratory testing costs.

1.5.2 Soil Quality

Soil quality is the "capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health" (Doran et al., 1994, p. 7). The quality of a soil is assessed using *soil quality indicators*, which are practical measures of soil attributes. In turn, *soil attributes* are the measurable properties involved with the processes underlying the soil's function. In order to assess soil quality, one must take a holistic approach to evaluating soil functionality by assessing the biological, chemical, and physical indicators of soil quality, collectively. According to Doran et al. (1994), soil quality indicators must:

1. Encompass different ecosystem processes and functions;
2. Integrate soil physical, chemical, and biological properties and processes;
3. Be accessible to many users, easily measurable, and applicable to field conditions;
4. Be sensitive to variation in climate and management; and
5. Where possible, be components of an existing soil database.

It is not feasible for members of community garden groups, who may have limited access to testing equipment, financial resources, and experience, to run extensive analyses on numerous soil quality indicators. For this reason, it is advisable for a Minimum Data Set (MDS) of soil quality indicators to be compiled. A *MDS* is a list of basic measurable properties chosen to provide an overall assessment of the health of the soil system. If these selected indicators yield results outside of a desired range, further tests can be conducted to identify the source of the problem for a management solution to be selected (Doran & Parkin, 1996).

1.5.3 Microclimate Quality

In addition to soil quality assessment, microclimate assessment is necessary to gain a complete understanding of site characteristics. The term *Microclimates* refers to the temperature, humidity, wind, rainfall, and other meteorological factors, in close proximity to the soil, in the realm of plant and animal life (Rosenberg et al., 1983). Degree of exposure is a key factor through which microclimate affects plants and soil on a particular site. The orientation and aspect of the site, as well as the degree of shade and sun, and wind intensity are all components of exposure (Craul, 1992). Heat loading capacity is another important factor by which microclimate affects soil and plant life. In urban centres, this characteristic is of particular significance. Urban centers are warmer that their rural counterparts, a phenomenon referred to as the *urban heat island effect* (Oke & Maxwell, 1975). This effect is caused through the complex interaction of several atmospheric factors, including the prevalence of concrete and buildings which absorb and reradiate heat, a lower evapotranspiration rate and the artificial heating and cooling of buildings (Oke & Maxwell, 1975; Craul, 1992).

1.6 Goal Statement and Overarching Objectives

The goal of this study was to facilitate the development of community gardens on urban brownfield sites in Vancouver, British Columbia by (a) developing a strategy for site assessment focused on soil and microclimate quality, and (b) working with community groups to build an understanding of soil processes and a repertoire of best management practices for their soils. Although a large portion of my project is based on soil quality, the focus is not solely on soil, but on people, and how they relate to and understand the soil in their urban environment. To this end, my project consists of three interrelated components. These are to: (1) aid in the ecological restoration of vacant lots in the urban centre; (2) enable communities to be the driving force behind urban ecological restoration; and (3) work with communities to address barriers impeding the ecological restoration necessary for community garden development.

To address these overarching objectives, I have used the city of Vancouver, British Columbia as a case study. In order to draw knowledge from a case study that can be applied to other situations and locations, we must first identify the unique characteristics of the case study, including: historical background, physical setting, economic and political contexts, and informants through whom the case can be known (Stake, 1994). Research on Vancouver's environmental context with emphasis on soils, as well as its social policy and history regarding urban agriculture, is key for establishing the distinctiveness of Vancouver as a case study. The information obtained in this study will help in developing similar studies in other urban centres in Canada and North America.

1.7 VANCOUVER'S SOILS

Vancouver is a major urban centre, incorporated in 1886 (City of Vancouver, 2010), prior to a formal soil survey. Consequently, soils in the city of Vancouver were *not* included in the soil survey of the Lower Fraser Valley, composed of areas to the south and east of the city (Luttmerding, 1984). In the absence of a soil survey we rely on the known dominant soil orders to provide information on soil properties. The undisturbed upland soils in the Vancouver area are predominantly of the Podzolic order, characterized by organic surface horizons, under which a light-coloured eluvial horizon (Ae) may or may not be present. They have a reddish-brown to dark brown B horizon, enriched with aluminum- and iron-oxides and/or humus (National Research Council of Canada, 1998). Podzols typically form on coarse-textured and acidic parent materials of glacial origin, under forest vegetation in cool, humid climates (National Research Council of Canada, 1998). In the Vancouver lowlands, the approaching ice from the Fraser Glaciation changed the behavior of the rivers, increasing sediment loads in glacial meltwater streams, and causing the widespread deposition of stream sediments in the coastal lowlands (Slaymaker et al., 1992). As vast outwash plains developed from the advance of the ice, sand and gravel accumulated in coastal inlets and lakes, and buried riverine wetlands, floodplains, and coastal lowlands (Slaymaker et al., 1992). This explains why Vancouver soils are often sandy and rocky in texture, with poor water and nutrient retention capabilities.

Vancouver possesses a humid, maritime climate, characterized by warm, dry summers, and mild winters with high levels of rainfall ((Meidinger & Pojar, 1991; Environment Canada, 2009). This climate is greatly influenced by the presence and proximity of the Pacific Ocean and Coast Mountains (Slaymaker et al., 1992). Vancouver experiences predominantly westerly winds, which are strongest during the winter months, though seldom very strong due to the sheltering effects of Vancouver Island, approximately 70 km offshore (Oke & Hay, 1994; Slaymaker et al., 1992).

Vancouver experiences a high amount of precipitation, with an annual average of 1,167 mm (Environment Canada, 2009). Precipitation levels vary across the Vancouver region and increase with the increase in elevation to the north. This humid climate, especially in combination with the sandy texture of Podzolic soils, can cause leaching of soil nutrients.

Because of this, soluble nutrients, particularly nitrate nitrogen and boron, are commonly deficient in Vancouver's soils during the rainy months.

Vancouver's native vegetation reflects the region's relatively warm temperatures and high precipitation. The Vancouver region is also quite diverse geographically, ranging in elevation and levels of rainfall. Because of this, the Vancouver region is home to four different principle biogeoclimatic zones: Coastal Douglas-Fir, Coastal Western Hemlock, Mountain Hemlock, and Alpine Tundra" (Slaymaker et al., 1992). Specifically, the Vancouver Lower Mainland is dominated by the Coastal Western Hemlock biogeoclimatic zone, as hemlock forests commonly form on Podzolic soils due to their tolerance of acidic soil conditions.

1.8 URBAN AGRICULTURE IN VANCOUVER: THE CURRENT SITUATION

In 2006, the City of Vancouver, British Columbia, was home to just over 25 community gardens, but available gardens plots were in great demand, with few possessing available space, and most others relying on waiting lists (City of Vancouver Social Planning, 2010). One garden had even reported a waiting list of over 70 people (Kurbis et al. 2006). Sites for further garden development exist in the city, and in 2006, a land inventory found 77 potential urban agriculture sites located throughout the city (Kaethler, 2006). To increase the number of community gardens in Vancouver and help green the city, the Vancouver Food Policy Council and the City of Vancouver Councillors, through Liaison Councillor Peter Ladner, announced their goal to create 2,010 new garden *plots* by the 2010 Olympics (Kurbis et al., 2006). These 2,010 new garden plots include those found in community, rooftop, and private gardens (Kurbis et al., 2006), and are in addition to the existing 950 plots. By December 2010, the city had surpassed this goal, boasting a total of over 50 community gardens, and an additional 2,029 garden plots, with more to come (City of Vancouver Social Planning, 2010). Even with this significant increase, waiting lists still persist.

Unlike several other North American cities (e.g., Montreal, Toronto, Seattle, and Portland), Vancouver has no umbrella organization to oversee the development, maintenance, and coordination of its community gardens. The City of Vancouver's Food Policy Council (under the City's Social Planning Department) encourages the creation of gardens through education and small grants (Vancouver Food Policy Council, 2010). In 2006, to address the absence of an urban agriculture-focused umbrella organization, Vancouver Coastal Health (VCH), through the Community Food Action Initiative (CFAI) Advisory Committee, issued a call for proposals for a local Non-Governmental Organization (NGO) to temporarily assume this role. The Environmental Youth Alliance (EYA), in collaboratoryoration with the British Columbia Agroecology-Soils Research Group, submitted the winning proposal, and was subsequently chosen to oversee the creation of three to four food-producing community gardens from January 2007 through February 2008. This mandate stipulated that the community gardens be developed in vulnerable neighbourhoods containing communities faced with limited access to resources, including low-income, elderly, and immigrant populations. Additionally, EYA was selected to research prospects for a future city-wide support network for community gardeners. To handle these tasks, the EYA formed a subgroup, the Vancouver Community Agriculture Network (VCAN), whose sole responsibility was to fulfil the 1-year contract with the possibility of extending operations beyond the contracted term (D. Tracey, personal communication, October 13, 2007).

1.9 Case Study-Specific Objectives

While VCAN's instatement as a temporary organizational structure was an important first step for the City's *2,010 garden plots by the year 2010* goal, there were many obstacles to community garden development that VCAN had to address. Socially and economically these barriers included identifying and organizing interested community groups and securing funds that enable them to obtain necessary resources. Additionally, environmental barriers such as poor soil quality, substandard microclimate, and the inability of community members to assess these important components of their future gardens were of particular concern. VCAN's mandate encompassed social and economic barriers to garden development, but lacked emphasis on environmental barriers. Addressing these environmental obstacles and developing means of surmounting them was the focus of this study, and led to my **research questions:**

What environmental barriers hinder the development of community gardens on urban brownfield sites in Vancouver, British Columbia?

How can community groups identify and overcome these environmental barriers to establish safe, successful, and sustainable gardens?

To address these questions, my project consisted of three interrelated components, reflected in the **case-study specific objectives**:

1. To establish an iterative, preliminary framework for the identification of key characteristics and barriers to garden development on brownfield sites in Vancouver, British Columbia
2. To involve communities in garden development from planning through implementation
3. To create a site assessment guide based on the adaptive framework (objective 1), with a focus on community involvement (objective 2).

There are four anticipated **outcomes** which will be achieved by this study:

1. To contribute to the development of three community gardens in the City of Vancouver by working with community groups to assess their sites' soils and microclimates, and address identified environmental barriers to garden creation.
2. To hold collaborative, educational workshops with interested community groups that provide access to background information on soil processes and microclimatic attributes, act as a forum for discussions about garden best-management practices, and create networking opportunities.
3. To develop a practical and comprehensible Site Assessment Guide for community gardeners that will allow them to independently assess their garden sites' soils and microclimates, identify environmental barriers to garden establishment, and address these barriers through the implementation of best-management practices.
4. To create a template for a Soil Inventory and Management Guide for Vancouver, British Columbia, drawing from the City's soils information.

2 MATERIALS AND METHODS

The main outcome of this study was the creation and compilation of a Site Assessment Guide, easily useable by community groups. To accomplish this, four activities, referred to as the four components of this study, were performed. These were: (1) assessments of study sites, (2) collaborative workshops, (3) evaluation of soil quality indicator methods, and (4) a soil survey for the City of Vancouver. The first three components took place iteratively, and were followed by the last component. Each section in this chapter describes one of four major components of this study.

2.1 ASSESSMENT OF STUDY SITES

A preliminary site assessment was conducted on three brownfield study sites in the city of Vancouver: the Hastings Folk Garden, the Cedar Cottage Garden, and the 16 Oaks Garden (Figure 2.1).

Figure 2.1 Locations of three study sites where the preliminary site assessment was applied

The assessment guide consisted of three phases. The first phase examined the contamination status of the soil. This was carried out by first conducting a site history, and then analyzing soil for likely contaminants based on the finding of the site history. The second phase focused on the microclimate and soil quality assessment of the site. This included analysis of the site's physical, chemical, and biological soil quality indicators and evaluation of the site's microclimate. The third phase, discussed in the Results and

Discussion chapter, examined management strategies to address issues identified in the first two phases.

The Hastings Folk Garden

The Hastings Folk Garden is located on Hastings and Columbia Street in Vancouver's Downtown Eastside. It is located between two low-rise buildings to the east and west and is approximately 15 m by 40 m in area. The site history of the Hasting Folk Garden site was discovered by speaking with neighbours who had lived in the community for several years. The lot was formerly the Smiling Buddha Cabaret, which burnt down approximately a decade ago. After the fire, the site was fenced off from the public.

Before it was transformed into a garden, the Hastings Folk Garden brownfield was overgrown with grass and had become a place for people to dump refuse. Hazardous materials such as knives, used needles, and dead rats, along with food wrappers, card-board, abandoned clothing items and bricks from the adjacent buildings were ubiquitous on the surface, as well as at a shallow depth. These artifacts, though hazardous, did not pique concern regarding contamination, though the degree of informal dumping was a concern.

Garden development was initiated by two employees of the Radio City Café, an establishment one building over from the Hastings Folk Garden brownfield site. This café is operated by the Portland Hotel Society (PHS), an advocacy group for individuals who are "the hardest of hard to house". The site itself is owned by Concord Pacific, a development corporation. The land tenure of the garden is therefore unstable.

The social organization of the Hastings Folk Garden is different from many of Vancouver's other community gardens. The garden is maintained by the PHS, and is kept gated and locked from the general public. Participants are largely members of local organizations including the neighbouring substance abuse rehabilitation facility and residents of the PHS's single-occupancy hotels.

Figure 2.2 Location of the Hastings Folk Garden in Vancouver, British Columbia

The Cedar Cottage Garden

The Cedar Cottage Garden site is located under the SkyTrain line near the corner of Victoria and Hull Street in East Vancouver. The site is approximately 20 m by 60 m in size. Adjacent to the site is a large, level field. This field was initially thought to be eligible for garden development. Because of this, the Vancouver Community Agriculture Network (VCAN) began to gauge the interest of neighboring residents regarding community gardening and held meetings bringing together interested community members. Not long after this process began, it became known that this property was slated for future housing and could not be used as a garden site. In response, the community, now committed to the idea of a garden, decided to relocate the garden site. Following the example of the My Own Back Yard (MOBY) Garden located on 11th Avenue near Commercial Drive in East Vancouver, the Cedar Cottage community asked Translink's permission to garden under the SkyTrain line which runs next to the originally-intended garden site. Translink complied, on the condition that the garden society obtained insurance.

The Cedar Cottage Garden site history was provided by Vancouver City officials in the Social Planning Department. The construction of the SkyTrain, along with the presence of construction vehicles on the site were two significant impacts of this history. Before the construction of the SkyTrain, a railroad ran through the site. Because of this, presence of petroleum hydrocarbons from creosote, used to treat railroad ties, was a concern.

Though social indicators of sustainability were not formally considered in this research, this community's enthusiasm for creating a neighborhood garden helped them recover from losing an ideal site, and instead allowed them to make the best out of a site that presented some challenges. This immense desire for a community garden, I believe, serves as an indicator of the social sustainability for the Cedar Cottage Garden. Despite this garden's tumultuous beginnings, it continues to grow and expand. The garden now contains 27 plots, an espalier, an expansive composting area, and a shed that was constructed to replicate an old train station which was once found near the garden site. Regardless of this rapid growth, the garden expansion cannot keep up with demand, and the garden society has established a waiting list.

Figure 2.3 Location of the Cedar Cottage Garden in East Vancouver, British Columbia

16 Oaks Garden

The 16 Oaks Garden brownfield site was a large, mostly level site on the corner of Oak Street and 16th Avenue in Vancouver, measuring 35 m^2. The site history was found through speaking with neighbours and the owner of the site. According to these sources, the site once housed a restaurant and parking lot, which had since been demolished. An oil tank and car battery found onsite raised concerns about petroleum hydrocarbon and heavy metal contamination, respectively, though the soil in direct contact with these items had been excavated and piled in the far southeast corner of the site.

The 16 Oaks Garden Society was formed by several neighbors, who joined together on their own accord. As a group, they contacted the private owner of the site, seeking permission to start a garden there. Currently, the garden is organized as an allotment garden, with 30 plots rented annually by people living close to the site. Despite this success, the Vancouver Food Policy Council has the 16 Oaks Garden listed as a "temporary garden site" on their website.

Figure 2.4 Location of the 16 Oaks Garden in Vancouver, British Columbia

2.1.1 Phase I: Determining Site Contamination Level

After a history had been compiled for each site and observations regarding anthropogenic artifacts and the characteristics of the site's surroundings had been noted, this information was used to determine recommended laboratory analyses. For instance, if the site was within close proximity to busy roads, analysis of petroleum hydrocarbon contamination was conducted. Based on the results of these site histories, contaminant analyses for extractable petroleum hydrocarbons (EPHs) and strong acid soluble metals were conducted for all three brownfield sites.

Soil sampling for contaminants was performed using stratified random sampling to address the heterogeneous nature typical of urban brownfields (Tan, 2005). These samples were submitted to local laboratories for analysis (more below). At the Hastings Folk Garden and the Cedar Cottage Garden sites, 5-10 soil pits were excavated at each site to determine the boundaries of each homogeneous section, or *strata*. Once boundaries were determined, soil samples were taken from all pits at a depth of 0-7.5 cm within each stratum. At the 16 Oaks Garden, areas of suspicion where an oil tank and car battery were found, formed the strata, and random samples were taken within a 5 meter radius of each high-risk area. Additional samples were taken near a garden plot at the southern end of the site, by the request of one of the garden society's members. The northeast corner was not sampled, because garden design had designated that area as a social space for the time being. Individual samples from these strata were compiled into a composite sample to reduce analysis costs. Composite samples were thoroughly mixed to ensure equal representation of each stratum. When sampling for metal toxicity, samples were taken with a plastic trowel and stored in glass jars to avoid contamination. When sampling for extractable petroleum hydrocarbons (EPHs), a metal trowel was used and samples were stored in glass jars. All samples were stored in a cooler to keep soil temperature below 10°C until submitted to the laboratory later the same day.

Contamination testing for strong acid soluble metals and extractable petroleum hydrocarbons (EPHs) was carried out at the Cantest Ltd. Laboratory (now Maxxam Analytics), Burnaby, British Columbia. One composite sample was submitted for each analysis for the Hastings Folk Garden and Cedar Cottage Garden sites, and two samples were submitted for each analysis from the 16 Oaks Garden site. Samples for metal determinations were digested using a hydrochloric acid and nitric acid mixture and analyzed using Inductively Coupled Argon Plasma spectroscopy (ICAP) (Chen & Ma, 2001) and mercury levels were analyzed using Cold Vapour Atomic Fluorescence. Light and heavy EPHs were detected using an acetone/hexane extraction and Gas Chromatography Flame Ionisation Detector (GC/FID) analysis (Saari et al., 2007).

Results from the Hastings Folk Garden and Cedar Cottage Garden sites for acid-soluble metals tests revealed amounts of all substances well under the government-set standards (See Appendix VI, Table A. 6 -Table A. 7). Analysis results for the 16 Oaks Garden site showed the southern-most strata, not in close proximity to the locations of the oil tank and battery, had high levels of boron, copper, and tin (see Appendix VI, Table A. 9). The cause of these contaminants is unknown.

2.1.2 *PHASE II: SOIL AND MICROCLIMATE ASSESSMENT*

Following contamination testing, an assessment of soil and microclimate quality was conducted at each of the three brownfield sites. All sites were located on glacial till parent material, as described in section 3.6.

Soil Quality Assessment Minimum Data Set

A minimum data set of soil quality indicators was not formally used to assess each study site. Instead, common soil indicators proposed by the literature, taken in the context of the common characteristics of Vancouver's soils, were identified. These indicators included: texture, structure, coarse fragment content, infiltration, aeration, presence of earthworms and other soil organisms, and vegetation quantity and quality. The three applications of the Soil and Microclimate Assessment yielded a shortened list of soil quality indicators. This modified list was used by participants at soils workshops (Section 2.2). The goal of this assessment was to identify environmental barriers to garden development related to soil quality at each site.

At the Hastings Folk Garden, the decision to scrape and remove the top 30 cm of soil (due to the excessive of anthropogenic artifacts) and import additional soil was made by the garden organizers. Therefore, the soil was evaluated as strictly a subsoil medium. To this effect, the soil was found to be of sufficient depth, with adequate aeration and drainage.

The Cedar Cottage Garden site's soils were highly varied. In some areas the soils were less than 30 cm in depth and there were large amounts of subsurface rocks and concrete. These shallow depths would restrict plant growth and inhibit drainage, posing environmental barriers to garden development.

The 16 Oaks Garden's soil appeared uniform, except for the northeast corner of the site, which was lower in elevation than the remainder of the site, had a finer texture, and was more compact. This was of no concern since this area was not planned to be used for garden plots. The remaining three quarters of the site exhibited minimal compaction, adequate rooting depth, presence of earthworms, and a sandy soil texture typical of Vancouver soils, thus no environmental barriers to garden development were identified.

Soil Fertility Analysis

Soil sampling for fertility was conducted using the stratified random sampling method described in section 2.1.2. Analysis of soil fertility properties was conducted at Pacific Soil Analysis Inc. (PSAI), Richmond, British Columbia. Samples were taken from the Cedar Cottage Garden only, due to the wishes of the garden societies. These samples were analysed for: pH, organic carbon, total nitrogen, percent organic matter, electric conductivity, and available phosphorus, potassium, calcium, magnesium, and boron. Analysis methods for each property are listed in Table 2.1. Soil fertility tests showed adequate levels for most elements, with lower levels of boron and organic carbon (see Appendix VI, Table A. 8).

Table 2.1 Soil fertility testing methods used by the Pacific Soil Analysis Incorporated (PSAI) analytical laboratory in Richmond, British Columbia

Property	Method
pH	Potentiometrically determined using 1:1 soil to distilled water slurry and Radiometer conductivity cell (Thomas, 1996)
Total nitrogen	Colourimetrically determined using a Technicon Autoanalyzer – semi micro Kjeldahl digest (Bremner, 1996)
Organic carbon	Walkley-Black wet oxidation method (Swift, 1996)
Available phosphorus	Colourimetrically determined using ascorbic acid colour development method on a 1:10 soil: Bray 0.03 M NH_4F in 0.025 M HCl extract (Bray P1) (Kuo, 1996)
Potassium, calcium, magnesium	Determined by Perkin-Elmer Atomic Absorption Spectrophotometer on a 1:5 soil to 1 M neutral ammonium acetate extract (Helmke & Sparks, 1996; Suarez, 1996)
Boron	Colourimetrically determined in a hot water soluble extract using the azomethine-H method (Keren, 1996)
Copper, Zinc, manganese, iron	Determined by Perkin-Elmer Atomic Absorption Spectrophotometer on a 1:5 soil to 0.1 M HCl extract (Reed & Martens, 1996; Gambrell, 1996; Loeppert & Inskeep, 1996)

***Methods used by analytical laboratory PSAI**

Soil nutrient testing methods are not standardized in British Columbia and very few laboratories in the province do this kind of analysis. Because of this, the names and locations of the Cantest and PSAI laboratories[1] were provided to community groups, along with the testing methods used by each laboratory. This added measure will help ensure consistency between current and future data, which is particularly important when drawing comparisons among years.

Evaluation of Site Microclimate and Soil-Atmosphere Interaction

In addition to assessing soil quality indicators and submitting soil samples to laboratories for fertility and contamination analysis, I also evaluated the sites' microclimates. Microclimate indicators such as site orientation, shade and sun exposure, wind exposure, and topography (slope and aspect) were observed. Garden design and plant selection were then determined based on these observations by matching the characteristics of different areas of the site with plants that are able to thrive under those conditions. For example, if a section of the site is partially shaded, vegetables such as broccoli and carrots will be more successful than beans or squash. Taking these considerations under advisement will increase the likelihood of successful plant propagation and ultimately aid community garden societies in achieving a productive garden.

The Hastings Folk Garden site's microclimate is largely influenced by its position between two buildings, as well its general location off of a busy street in downtown Vancouver. The two buildings abutting the garden site on the east and west are four stories tall, and cast shadows over the entire site. Despite these characteristics, the garden is highly productive.

The Cedar Cottage Garden site's microclimate is greatly affected by the SkyTrain line which runs directly over the site. Water accumulates on the concrete supports and falls from overhead in concentrated "drip lines" which compact the soil and pose damage to vegetation through impact and overwatering. The SkyTrain and adjacent trees provide considerable shade to the site. Garden design incorporated these unique microclimate

[1] Mention of the names of analytical laboratories does not indicate preference or endorsement.

characteristics, placing the "drip line" on the margins of the garden, and ensuring all plots get at least three hours of sun during the summer growing period.

The 16 Oaks Garden site's microclimate is satisfactory for a garden. A three-story building to the south and a slightly north-facing aspect may prevent the garden from obtaining the maximum amount of sunlight hours, but pose no obstacle to garden success.

2.2 Collaborative Workshops

Three instructional workshops were conducted during 2007-2009. Workshops were conducted in collaboration with interested local organizations and emerging community garden societies to build understanding of soil processes and management requirements, and to develop best management practices for use in their gardens. Additionally, these workshops provided valuable information about the interests and concerns of community groups, later incorporated into the Site Assessment Guide. Participating community groups included: the Sustainable Living Arts School (SLAS), the Environmental Youth Alliance (EYA), and the Cedar Cottage Garden Society. Workshop advertisements and participant consent form and be found in Appendix III. Certificate of approval issued by the University of British Columbia behavioural ethics review board can be found in Appendix VIII. Drawing from the principles of Community-Based Action Research (Stringer, 1999), my role as a workshop facilitator was not to impose my own ideas about garden management and design, but to enable people to make informed decisions and assist in the implementation of those decisions.

Workshops varied in formality and curriculum depending on the needs and desires of the specific community group. Some took the form of an unstructured discussion and question and answer period, while others incorporated predetermined subject matter, informative handouts (Appendix IV), and hands-on activities. Other educational exchanges consisted of group participation in a specific activity, such as soil sampling for fertility, and corresponding instruction and discussion. As a component of some of these workshops, participants took part in a Soil Quality and Microclimate Assessment activity, using aspects of the preliminary assessment guide to assess the three study sites. These interpretive collaborative workshops, no matter how structured or unstructured, provided valuable insights into common soil- and microclimate-related problems, concepts of difficulty, and recurrent concerns of communities across the City. Identifying and addressing these common threads ultimately helped shape the third outcome of my thesis; a community-accessible Site Assessment Guide for community garden development.

The one-half day workshop with SLAS was conducted in September 2007, at the Means of Production Garden. Approximately 15 participants were in attendance, most with previous gardening experience. The event began with an informal discussion on soil-related topics of interest. Topics discussed included: toxicity in urban soils, soil fertility and toxicity testing and result interpretation, mulching, and the advantages of till versus no-till techniques. A formal discussion ensued, encompassing issues such as characteristics of Vancouver's soils and soil quality assessment. The workshop ended with two concurrent activities: planting a nitrogen-fixing cover crop (crimson clover) and digging a soil pit. The first group discussed nitrogen fixation and the effects of cover crops on soil processes, while the second observed the soil profile and gained an understanding of soil horizon characteristics.

The two-hour workshop with EYA took place at the Cottonwood Garden in October 2007. There were approximately 10 participants, all youth interns with the EYA. This workshop was the most organized and formal of the three. The interns had already received a workshop on soil science, and this served as a refresher for many concepts they had previously learned. The workshop started out with a review of soil science concepts. A soil assessment activity followed. Using an earlier version of the Soil and Microclimate Assessment, participants worked in groups of two to three and assessed different areas of the garden's soil. A debriefing session followed, where participants discussed what they learned and issues they had with the assessment content and format. All materials used during this workshop can be found in Appendix IV.

The Cedar Cottage Garden two-hour workshop was conducted in March 2009 at the Cedar Cottage Garden. There were approximately five participants, largely members of the garden society. The workshop covered topics including: Vancouver's soil, and soil assessment, and concluded with an exercise on interpretation of soil fertility results using the analysis obtained by the Pacific Soil Analysis Inc. laboratory for the Cedar Cottage Garden.

2.3 EVALUATION OF SOIL QUALITY METHODS

Based on the experiential knowledge and participant feedback gathered from the study site assessments and workshops of the first two study components, I was able to modify the Soil Quality and Microclimate Assessment (one aspect of the Site Assessment Guide) to make it easily accessible to the general public and address local conditions and community concerns. In February 2009, the soil quality component of the revised Soil and Microclimate Quality Assessment (Table A. 5 in Appendix V) was applied to three additional study sites in Vancouver, BC: The Cedar Cottage Garden expansion site, The Land and Food Systems (MacMillan) Orchard Garden, and the York House School Garden (Figure 2.5).

The Cedar Cottage Garden expansion site is under the SkyTrain line, and adjacent to the existing Cedar Cottage Garden (described in section 2.1.1). The Land and Food Systems Orchard Garden is on the campus of the University of British Columbia, west of the H.R. MacMillan Building (Faculty of Land and Food Systems). The site was an orchard until the early 1970s, and more recently has been the location of several portable buildings which were removed in 2006-2007. The York House School Garden is located on East Boulevard and 16th Avenue. The school building is a refurbished house, and the area of the garden under inspection was a corner of the yard where a propane tank was once housed for an undetermined period of time.

Figure 2.5 Locations of three additional study sites in Vancouver, BC where assessments using interpretive and laboratory-based methods were conducted in 2009

The revised assessment is composed of interpretive (i.e., practical and user-friendly) methods for soil quality indicator measurement. An *indicator* is an observable, measurable attribute of the soil and microclimate at a site. These are physical, chemical and biological soil parameters that reflect soil quality (Doran & Parkin, 1996). In addition to the measurement of indicators using interpretive methods, soil samples were taken at all three sites for analysis using laboratory-based methods (Table 2.2.). Results for each interpretive method were then compared against results for corresponding laboratory-based methods to decipher the accuracy of the interpretive methods used in the preliminary Site Assessment Guide.

Three assessments using interpretive and laboratory-based methods took place in February, 2009. Field measurements for interpretive methods were taken before analysis of laboratory-based methods to eliminate bias.

2.3.1.1 Interpretive and Laboratory-Based Assessment Methods

Table 2.2 summarizes the interpretive and laboratory-based methods used to characterize all three sites. For the interpretive methods, measurements were taken by excavating one soil pit per site, up to the top of its parent material, and making inferences based on the experience of digging, as well as visual observations from the pit side walls and excavated material.

Table 2.2 Soil attributes, indicators, and corresponding interpretive and laboratory-based methods

Attribute	Indicator	Interpretive Method	Laboratory-Based Method
Compaction	Penetration resistance (Interpretive methods) Bulk density (Laboratory-based method)	Puddling observation: severity, % area Force of shovel insertion Structure observation using diagram*	Core method (at surface) for soil bulk density determination (Culley, 1993)
Soil depth	Penetration resistance (Interpretive methods) Bulk density (Laboratory-based method)	(Determined by observing soil pit) Rooting depth (if plants are present) Presence of human artifacts that form a restrictive layer Depth of penetrable soil	Core method (7.5-15 cm) for soil bulk density determination (Culley, 1993)
Stoniness	Coarse fragment percentage	Observation (counts) and rating	Sieving (2-mm sieve – percent by volume)
Texture	Percent sand, silt, clay	Hand-texturing following a guide*	Wet sieving/decanting (Kettler et al., 2001)
Soil organic matter	Total carbon	Colour observation (using Munsell colour guide)** Soil structure Earthworm presence	Loss-on-Ignition for soil carbon determination (Nelson & Sommers, 1996)
6. Soil reaction	pH	pH field kit	pH probe in 1:1 soil:water suspension (Thomas, 1996)

*** Structure diagram and hand-texturing guide provided in Appendix V**
**** Colour can be used to approximate soil organic matter content (Burras et al., n.d.)**

For laboratory-based methods, seven samples were taken from within a two-meter radius of each soil pit. Soil bulk density was determined as mass of dry soil per unit volume of field moist soil. Coarse fragments (diameter >2mm) within the sample were screened out and weighed. Volume of coarse fragments was determined from dry mass assuming a particle density of 2,650 Kg/m^3. Bulk density was calculated as the mass of dry, coarse fragment-free soil per volume of field moist soil where volume was also calculated on a coarse fragment-free basis. Those samples containing more than one third coarse fragments, on a volume basis, were discarded. Texture was measured using a simplified method for particle-size determination combining wet sieving and decanting methods (Kettler et al., 2001). Total carbon was found using Loss-on-Ignition method (Nelson & Sommers, 1996). Soil pH was measured in deionized water using a glass combination electrode (Thomas, 1996). An average of the seven replicates was calculated for each analysis and compared to interpretive method findings. Interpretive and laboratory-based methods for organic matter, coarse fraction, and pH were only taken at a depth of 0-7.5 cm, and not at the lower depth of 7.5-15 cm.

2.3.2 *Comparison of Interpretive and Laboratory-based Method Results*

Data obtained by interpretive methods were compared to laboratory-based data to determine accuracy. Observations for interpretive methods were assigned a ranking system corresponding to laboratory-based method values. For instance, one interpretive method for measuring compaction is the difficulty required to insert the shovel into the soil surface. Difficulty was ranked as "easy", "difficult", or "impossible". A ranking of "easy" or "difficult" corresponded to a non-compact soil, while "impossible" corresponded to a soil subjected to compaction. Discrepancies between interpretive method rank and laboratory-based method value revealed inaccurate interpretive method selection.

Compaction, soil depth, and organic matter content results were compared based predetermine data correlations (Table 2.3). Stoniness, texture, and soil reaction were compared based on the accuracy with which the interpretive method estimated the result found using the laboratory-based method. Observations within a 5% range for stoniness, a textural class adjacent on the textural triangle, and a soil reaction with 0.5 pH units were the selected ranges of accuracy because errors falling within these ranges would not affect management practices.

Table 2.3 Comparison of data derived by interpretive and laboratory-based methods for compaction, soil depth, and organic matter content

Attribute Designation	Laboratory-Based Result	Corresponding Interpretive Observation
Compact	Bulk density at 0-7.5 cm depth > 1.3 g/cm^3*	Several puddles (>2 per 10 m^2 area) Impossible shovel insertion Platy or massive structure
Non-compact	Bulk density at 0-7.5 cm depth ≤ 1.3 g/cm^3	No to few (≤ 2 per 10 m^2 area) puddles Easy to difficult shovel insertion All other structure types (e.g., granular, blocky)
Shallow soil depth	Bulk density at 7.5-15 cm depth > 1.3 g/cm^3	Few roots at depths above 15 cm Presence of restrictive layer Soil impenetrable at a depth of 15 cm
Adequate soil depth	Bulk density at 7.5-15 cm depth ≤ 1.3 g/cm^3	Abundant roots to a depth of 15 cm Absence of restrictive layer Soil penetrable to a depth of 15 cm
Low organic matter content	Soil organic matter ≤ 3.4%**	Light colour Non-granular structure types No to few (<10) earthworms
Adequate organic matter content	Soil organic matter > 3.4%	Dark colour Granular structure Few to abundant earthworms (≥ 10)

*** 1.3 g/cm^3 is a commonly observed density for arable land (Brady & Weil, 2007) and pertains to coarse-textured soils.**
**** A decline in soil quality occurs when soil organic matter drops below 3.4% (Loveland & Webb, 2003). The coarse-textured soils of Vancouver, British Columbia are dependent on a higher percentage of organic matter to maintain adequate water storage and cation exchange capacity.**
In addition to quantity, analysis of organic matter components is critical to soil quality.

After interpretive methods have been selected for the final Site Assessment Guide, the penultimate draft of the Guide was given to four community stakeholders for review. These stakeholders are actively involved with community garden development and organization, youth engagement in urban agriculture, and soil science education. Their comments and suggestions were incorporated into the final version of the Site Assessment Guide.

2.4 SOIL MANAGEMENT GUIDE

Based on field examinations and community feedback gathered from 2006-2008, it became obvious that an additional resource for the identification of Vancouver's native soils was needed. This resource would take the form of a soil management guide. *Soil management guides* are common tools that categorize soil series into management groups and provide useful information about these groups based on their similar characteristics. Because no soil survey has ever been conducted in the City of Vancouver, no management guide has ever been written for the City.

To initiate a method for the soil inventory and management guide, existing surficial geology of the region(Armstrong & Hicock, 1976) as well as soil survey information from the agricultural and forested regions around Vancouver (Luttmerding, 1984) were consulted. Using these sources requires caution as surficial geology maps present time stratigraphic map units. *Time stratigraphic units* indicate materials that were deposited at the same time, thus, they are mapped as one unit by geologists. Because of this, a map unit may contain more than one soil parent material, as defined by pedologists. For example, the mapped Capilano and Vashon unit contains Cloverdale sediments (marine parent material) and Newton Stony Clay (glacial marine parent material). Soil survey mapping units are based on parent material, including homogeneity of soil texture, and slope position (relief/topography). Urban areas where the topography has been altered by human activity no longer reflect the "natural" conditions of the site. Also it is common practice by field geologists and pedologists not to identify minor areas (those occupying less than 10%) of contrasting materials on published maps at scales > 1:20,000. Presence of these contrasting materials may have been due to variation in the glacial environment. For example, a small geographic area of unsorted till-like material may be found amidst a uniformly laid marine deposit. In this case, the inconsistency in soil parent material may have resulted from an iceberg that was left stranded over the marine deposit, and subsequently melted, dropping till-like contents onto the landscape. Inconsistency such as this would be absent on a map.

Using soils information, including: known surficial geology (Armstrong & Hicock, 1976), elevation and topography, as well as known soils series from mapped areas near Vancouver (Luttmerding, 1984), I derived expected soil series for the Vancouver area. Six transects through the city were examined in detail: Fourth Avenue, Broadway, King Edward Avenue, 41st Avenue, Arbutus Street, and Main Street (Figure 2.6). Of these transects, four are of a west to east orientation and two, Arbutus Street and Main Street, run north to south. Elevations along these transects were recorded for each city block using Google Earth. Elevation and topography were then field-checked using a global positioning system. Excavated areas along these transects were examined to ensure they coincided with the expected soil parent material. A series of six cross sections were drawn, corresponding to each transect. These *cross sections* are two-dimensional depictions of elevation changes (y-axis) over the distance of the selected transect (x-axis). Using the soil series identified in neighbouring areas and drawing from The Soil Management Handbook for the Lower Fraser Valley (Bertrand et al., 1991) as a template, an abridged Soil Management Guide for the City of Vancouver was developed. This new management guide was integrated into the Site Assessment Guide.

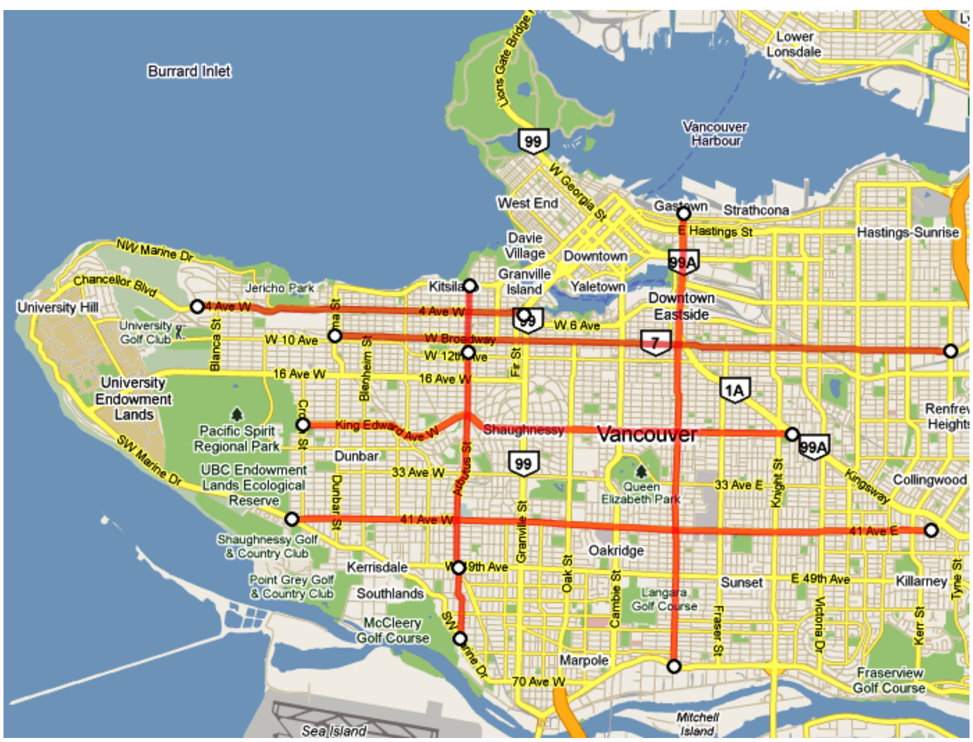

Figure 2.6 Six transects through the city of Vancouver, British Columbia, where elevation data were collected for the Soil Inventory and Management Guide

3 Results and Discussion

The following chapter provides an overview of the results of three activities that lead to the development of the final version of Site Assessment Guide. These activities included: study site assessments, community-driven workshops, and laboratory evaluation of interpretive methods.

3.1 Study Site Assessment Findings

At each of the three initially selected study sites environmental barriers to garden development were identified through phases I and II of the Site Assessment. Once these barriers had been identified, practical management strategies were designed to address them. Management strategies vary, and may include such activities as roto-tilling to break up compact soils, rock picking in areas possessing a high coarse fraction percentage, or importing soil to create a new growing medium or increase soil depth. Due to different environmental barriers, different management strategies were applied at each site.

Hastings Folk Garden

The greatest environmental barrier to garden development present at Hastings Folk Garden brownfield site was the large amount of anthropogenic, and possibly hazardous, materials at the surface and at shallow depths. Because of this, the garden society decided to remove the top 30 cm of soil by scraping with a backhoe and removing it from the site. This decision was made before the site assessment took place. Assessment of the soil as a subsurface medium showed that the soil was not compacted, and would not cause the formation of a perched water table. Following the removal of surface material, a sand/compost mix was brought in from the City Landfill following an application process. This soil mix was conditioned with poultry manure to raise soil nutrient levels.

Figure 3.1 The Hastings Folk Garden brownfield (a) and the subsequent garden (b) in 2007

Cedar Cottage Garden

At the Cedar Cottage Garden brownfield site, insufficient rooting depth posed the greatest environmental barrier to garden development, as the depth of penetrable soil was less than 30 cm in some areas. The garden society overcame this barrier by importing additional soil to the site and creating raised garden beds ranging from 15 cm to one meter in height above the soil surface. The imported soil was sourced from Lawnboy Landscape Supply and was mixed with the City's yard trimmings compost.

Figure 3.2 The Cedar Cottage Garden brownfield before (a) and after (b) garden development in 2008

16 Oaks Garden

The sporadic contamination on the 16 Oaks brownfield site posed the greatest barrier to garden development. Two areas of the site were sampled: the southern area where an oil tank and car battery were found, and the northern area. Analyses of strong acid soluble metals and extractable petroleum hydrocarbons revealed copper, tin, and boron levels that exceeded government set limits in the northern area only (Table A. 9). The 16 Oaks Garden Society took a more disparate approach to overcoming this barrier, with some gardeners choosing to import soil to their individual plots because of fear of site soil contamination.

Figure 3.3 The 16 Oaks brownfield site (a) (2008) and subsequent garden (b) (2009)

3.2 COLLABORATIVE WORKSHOP FINDINGS

The second activity instrumental to the development of the Site Assessment Guide was conducting interpretive workshops. Three workshops, which took place between 2007 and 2009, varied in content and level of formality based on the needs and desires of the communities. Each workshop provided valuable feedback and insight on how to increase the practicality and usability of the assessment. During these sessions, I gauged participant receptivity and interest to facilitator-introduced topics, recorded themes among participant-introduced topics, and facilitated exercises and discussions about the latest versions of the Soil and Microclimate Assessment. These responses were incorporated into Site Assessment Guide, which was tailored to the interests and concerns of the communities.

3.2.1 *Response to Facilitator-Introduced Topics*

A list of the topics initiated during the three workshops and a ranking of participant interest (high, medium, low) is provided in Table 3.1. Topics of high interest in all three workshops included: characteristics of urban soils, urban soil contamination sources, laboratory soil testing logistics, and test result interpretation. A high level of interest in Vancouver soil characteristics was also expressed at these workshops and participants voiced a desire to learn more about their local soils. In response to this demand, an inventory of Vancouver's soils and a corresponding soil management guide was developed. The inventory and management guide are presented in Chapter 4.

Table 3.1 Responses of community groups to topics discussed at workshops taking place in Vancouver, British Columbia from September 2007 to March 2009

Facilitator-Introduced Topic	**Participant Response** (low, med, high priority)		
	SLAS	**EYA**	**Cedar Cottage**
Basic soil science information (terminology, key concepts)	Med	High	High
Characteristics of Vancouver soils	High	High	High
Urban soil contamination, common sources	High	High	High
Soil sampling techniques	Low	Low	Low
Laboratory analysis logistics (cost, protocols for sample submission)	High	High	High
Interpretation of laboratory results	High	High	High
Importance of soil and microclimate assessment	Med	Med	Med
Soil quality indicators (physical, chemical, biological)	Low	High	Med
Best-management practices (e.g. mulching, cover cropping, composting)	High	N/A	Med

SLAS: Sustainable Living Arts School
EYA: Environmental Youth Alliance (interns)
Cedar Cottage: Cedar Cottage Garden Society

3.2.2 *Participant-Introduced Topics*

Common themes emerged among the three workshops (Table 3.2). Concern about urban soil contamination and desire to install raised beds, regardless of contamination test results, were often expressed. These concerns were also voiced outside of the workshops by the coordinators of the 16 Oaks Garden and the Cedar Cottage Garden. This is consistent with information obtained from other community garden groups that I had contact with over the course of this study. Participants at all three workshops expressed a strong desire to understand the characteristics of Vancouver's native soils. Knowledge of native soils can explain the cause of gardening issues, and lead to solutions to these problems. For example, issues raised by participants about lack of soil water retention may be explained by sandy soils common throughout Vancouver. Adding organic matter can increase the water retention lacking in these sandy soils.

Table 3.2 Themes introduced by community groups at three workshops taking place in Vancouver British Columbia from September 2006 to March 2009

Theme	Expressed by
Concern of urban soil contamination	SLAS, EYA, Cedar Cottage
Desire to import soil or install raised beds, regardless of contamination	Cedar Cottage
Confusion over terminology (e.g. cation exchange capacity, water retention)	SLAS, EYA, Cedar Cottage
Confusion over basic soil science concepts (e.g. soil nutrients are cations, cations have a positive charge)	EYA, Cedar Cottage
Lack of confidence regarding sampling and assessing soil	SLAS, EYA, Cedar Cottage

SLAS: Sustainable Living Arts School
EYA: Environmental Youth Alliance (interns)
Cedar Cottage: Cedar Cottage Garden Society

3.2.3 Soil and Microclimate Quality Assessment Feedback

The EYA workshop provided valuable insight on the preliminary version of the Soil and Microclimate Quality Assessment, one component of the Site Assessment Guide. Participants stated that they wished the assessment provided more instruction, less terminology, and fewer assessment measurements. Additionally, some indicators, such as cation exchange capacity estimation, proved difficult to comprehend. Following the workshop, edits were made along these lines. The most current version of the Soil and Microclimate Assessment was provided for review to the participants at the Cedar Cottage Garden workshop. Participants did not work through the assessment as an activity, though each indicator was discussed. Several of the shortcomings discovered at the EYA workshop had been rectified, though the Assessment was still too lengthy. Extraneous assessment indicators were removed, and remaining indicators were simplified in light of this feedback.

3.3 Evaluation of Interpretive Methods

The third congruent activity in the development of the Site Assessment Guide consisted of the laboratory evaluation of interpretive soil assessment methods. The evaluation took place at three potential/current garden sites: the Cedar Cottage Garden expansion area, the Land and Food Systems (LFS) Orchard Garden, and York House School Garden expansion area. A list of interpretive methods was compiled resulting from literature review, three study site trials, and feedback and consultation from community-collaborated workshops. Amalgamating these experiences resulted in a preliminary soil and microclimate quality assessment made up of 14 interpretive methods, composed of microclimatic and soil properties (Table A. 5. in Appendix V). At each of these sites an additional seven soil samples were collected at 0-7.5 cm and 7.5-15 cm depths for determination of bulk density (two depths), coarse fragment percentage, particle-size distribution, soil carbon, and soil reaction.

Raw data collected using interpretive methods are given in Appendix VII. Data from interpretive and laboratory-based methods is shown in Table 3.3 and Table 3.5.

3.3.1 Comparison of Interpretive and Laboratory-Based Methods

Comparison of interpretive and laboratory-based method results demonstrated similarities for measurements of compaction and soil texture. Coarse fraction observations and pH test-kit findings were varied widely laboratory results (Table 3.4). Soil bulk density values were all under 1.3 g/cm^3, coinciding with interpretive methods findings. At all sites the soil was easy to excavate, and designated as “uncompacted”. Which findings did not precisely match, textural classes found using each method were similar (in adjacent locations on the textural triangle). Differences to this degree have no bearing on prescribed management practices.

Table 3.3 Data from laboratory-based methods obtained at three additional study sites in Vancouver, British Columbia

Site Name and Depth	Bulk Density (g/cm^3)	% Sand	% Silt	% Clay	Textural Class	Coarse Fraction %	pH (H_2O)	Organic Matter %
York House School (0-7.5cm)	0.920	69	24	7	Sandy loam	13	6.0	7.9
York House School (7.5-15 cm)	0.790	73	22	5	Sandy loam	7	5.4	N/A*
Cedar Cottage (0-7.5 cm)	1.28	82	14	4	Loamy sand	4	5.7	5.5
LFS Orchard (0-7.5 cm)	0.886	84	13	3	Loamy sand	6	5.6	8.7
LFS Orchard (7.5 -15 cm)	1.10	85	12	3	Loamy sand	12	5.6	N/A*

*** Organic matter was not taken at a depth of 7.5-15cm**

Table 3.4 Data from interpretive and laboratory-based methods applied to three study sites in Vancouver, British Columbia

Site Name and Sample Depth	Compaction		Textural Class		Coarse Fraction		pH	
	Laboratory-based	Interpretive	Laboratory-based	Interpretive	Laboratory-based	Interpretive	Laboratory-based	Interpretive
York House School (0-7.5cm)	0.92 g/cm^3	UC	SL	LS	13%	1 -2%	6.0	6-7
York House School (7.5-15 cm)*	0.79 g/cm^3	UC	SL	LS	7%	N/A	N/A	N/A
Cedar Cottage (0-7.5cm)	1.3 g/cm^3	UC	LS	SCL	4%	10-15%	5.7	8
LFS Orchard (0-7.5cm)	0.89 g/cm^3	UC	LS	SL	6%	5-7%	5.6	6-7
LFS Orchard (7.5-15 cm)*	1.1 g/cm^3	UC	LS	SL	12%	N/A	N/A	N/A

*** Data for pH was not taken at a depth of 7.5-15 cm. Coarse fraction was taken at a depth of 7.5-15 cm only as a correction for bulk density measurements.**

UC – Uncompacted
LS – Loamy sand
SL- Sandy loam
SCL – Sandy clay loam

Table 3.5 Data from interpretive methods obtained at three additional study sites in Vancouver, British Columbia

	York House School	Cedar Cottage	LFS Orchard
Puddling	N/A	N/A	N/A
Difficulty excavating soil pit	Easy	Easy	Easy –difficult due to grass roots
Structure observation	Granular/crumb	Granular/crumb	Granular/crumb
Rooting depth	30 cm	No plants present	25 cm
Thickness of uncompacted layer	Depth of pit (50 cm)	Depth of pit (50 cm)	Depth of pit (50 cm)
Depth until restricted layer (caused by human artifacts)	No restrictive layer	10 cm	No restrictive layer
Depth on penetrable soil	Depth of pit (50 cm)	10 cm	Depth of pit (50 cm)
Percentage stones	1%-2%	10%-15%	5%-7%
Soil texture (0-7.5 cm)	Loamy sand	Sandy clay loam	Sandy loam
Soil Colour (0-7.5 cm)	10YR/2/2	5YR/3/2	10YR/3/2
Earthworm abundance	Abundant	Abundant	Abundant
pH reagent	6-7	8	6-7

Observed estimates of coarse fraction percentage varied widely between interpretive and laboratory-based method results at two of the three sites. This could be due to the fact that coarse fraction percentage was calculated using cores from the bulk density samples, which exclude larger stones and cobbles. Additionally, smaller gravel, just over 2 mm in diameter, is difficult to detect with the naked eye. For this reason, the interpretive method for coarse fraction percentage was altered following the method evaluation. At one of the sites, soil pH determined by a field test kit also differed greatly from that determined in the laboratory in a water solution. Due to this inconsistency, I recommended that participants not purchase pH test kits, and instead get pH tested through a commercial laboratory. Soil organic matter content ranged between 6% and 9% (Table 3.5). The Munsell soil colour chart provided colour values of: 10 YR 2/2 (very dark brown), 10YR 3/2 (very dark grayish brown), and 5YR 3/2 (dark reddish brown). Structure observations were all "crumb" and earthworm prevalence ranked between “some present” to “several present”. All methods provided adequate estimations for a medium level of organic matter (5%-10%).

Table 3.6 Organic matter data derived from four different methods applied at three study sites in Vancouver, British Columbia

	Loss-on-Ignition	Munsell	Structure observation	Earthworm counts
York House School (0-7.5cm)	7.9	10YR 2/2	Crumb	Abundant
York House School (7.5-15 cm)	N/A	N/A	N/A	N/A
Cedar Cottage (0-7.5 cm)	5.5	5YR 3/2	Crumb	Abundant
LFS Orchard (0-7.5 cm)	8.7	10YR 3/2	Crumb	Abundant
LFS Orchard (7.5-15 cm)	N/A	N/A	N/A	N/A

3.4 Final Site Assessment Guide

Based on the literature, the information obtained at the three initial study sites, and the community feedback provided at workshops, a set of interpretive methods was developed. The accuracy of these interpretive methods was tested by comparing results with those from the laboratory. The methods whose results most closely represented those found in the laboratory were incorporated into the final version of the Site Assessment Guide. In some instances, more than one method corresponding to a soil quality indicator was selected.

The Site Assessment Guide is a tool, aimed at community members with limited knowledge of soil science, with the objective of turning urban brownfields into community gardens. It is organized into three phases: 1) Determining soil contamination; 2) Soil and microclimate assessment; and 3) Management and soil importation. The dichotomous key (Figure 3.4) depicts the structure of the complete Site Assessment Guide. In this dichotomous key, each phase corresponds to a different colour: orange for phase one, green for phase two, and blue for phase three.

The Site Assessment Guide was designed as a document-based tool, but can easily be adapted to a web-based format. Participants who use the guide follow a dichotomous key, or decision tree, from the top and work their way downward. The key consists of five boxes, each containing a question or activity, stated in bold lettering. The first question asks: “Does the site’s history or location present a contamination risk?” Each question serves as a chapter heading or link (depending on the format) which contains information and guidance that allows the participant to answer the question. Depending on the participant's response (yes or no) they proceed to a different subsequent question or activity. For instance, if the site is not likely to be contaminated then the next step is to carry out the Soil and Microclimate Assessment. The goal of each phase of the Site Assessment Guide is to identify barriers presented by soil contamination, or insufficient soil and microclimate quality, and address them (if possible) through management practices or soil importation.

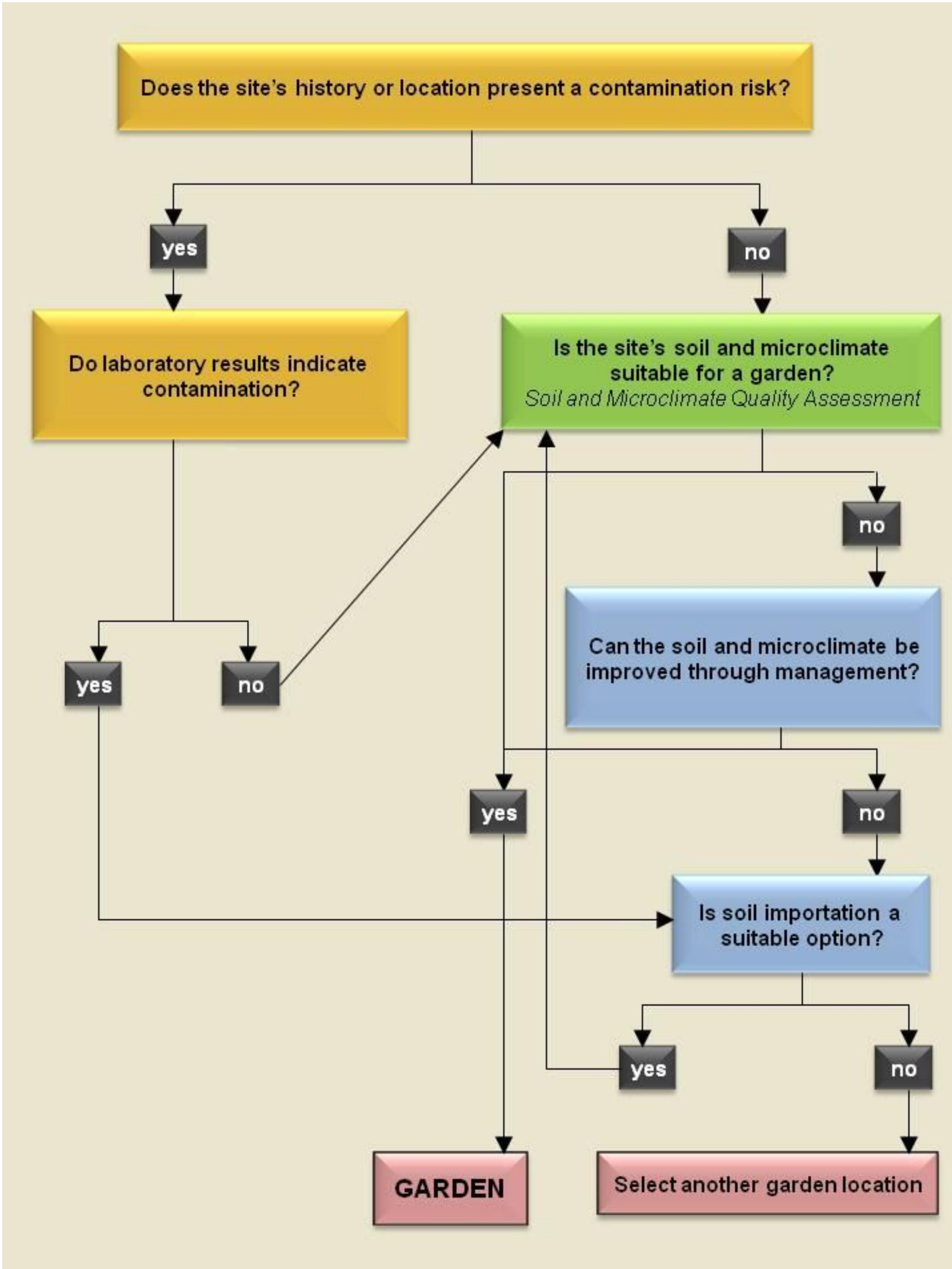

Figure 3.4 Dichotomous key used in the Site Assessment Guide to provide a decision-making structure for turning brownfields into community gardens

The completed Site Assessment Guide, titled *Starting a Community Garden: a Site Assessment Guide for Communities*, can be found in Appendix IX: Site Assessment Guide. Each phase of the Guide is briefly explained below.

3.4.1 Contamination Risk Assessment

Determining if a site contains contaminated soil is the first action that should be taken when assessing a site for garden development. To ensure a site's soil is not contaminated, laboratory testing for contamination is required. These tests are expensive and not always financially accessible to community groups. Regardless of whether laboratory analysis is conducted, a site's history should be investigated. Knowledge of a site's history provides an indication of the risk level associated with the site's soil, as well as probable contaminants. Conducting a site history (sometimes referred to as a *site profile* in the literature) is recommended by government-set protocols, including those created by the British Columbia Ministry of Environment (2009), and by studies which assess soil contaminants (Myers & Thorbjornsen, 2004).

There are four main ways to gather information on the current and past land uses of a particular brownfield: 1) contacting city officials, 2) accessing historical documentation, 3) talking with local residents, and 4) taking note of artifacts found on site.

Resources available to the public for determining site history include: the City of Vancouver's Social Planning and Engineering Departments, the Vancouver City Archives, and the people who have contact with the site, such as local residents. This latter group can provide the most relevant and useful information when conducting a site history, indicating past, as well as present land uses. In one instance, a brownfield seemed to have low-risk land use history based on the information received from the Social Planning Department and the City Archives. Upon speaking with a neighbour, I learned that another neighbour had been using the brownfield to dispose of the refuse oil from the oil changes he had been performing on his car. This key piece of information would not have been made available to me if I had not spoken with this neighbour. People who live, work, or frequently pass by brownfields have information about the kinds of activities that occur on the site that no government official nor historical record can provide. In some cases, neighbours who have lived or worked in the area for a long time may be able to recount the history of the site, filling in some of the historical gaps of archival information.

3.4.2 *Contamination Testing*

Depending on the site history findings, soil laboratory analyses may be recommended. Two tables, Land-Uses and their Associated Contaminants (Table 1 in Guide) and Common Contaminants and their Sources (Table 2 in Guide), are provided for participants to determine probable contaminants. A soil sampling guide, local laboratory contact information, and a brief price list are provided. A table of government-set standards for metals and extractable petroleum hydrocarbons is provided for result interpretation following laboratory analysis (Table 4 in Guide).

3.4.3 *Soil and Microclimate Assessment*

If the site is found to be uncontaminated, a Soil and Microclimate Quality Assessment should be conducted. This 11-step assessment is shown in Figure 3.5. The Quality Assessment should be conducted in several locations around the site. Each Quality Assessment should take no longer than 15 minutes to complete and require a shovel, a compass, a hand texturing chart (provided), a trowel, plastic bags (for sample collection), a meter stick, and a pick-axe if the soil is compacted. Assessments of this nature are common in farming communities, though they assume more knowledge of soil terminology, and expect the assessment to be conducted over a large area several hectares in size (Doran & Harris, 1996; Romig et al., 1995).

Soil and Microclimate Assessment in 11 Steps

1

Looking over the entire garden site, do you observe features (large stones, concrete slabs, pooling water, etc.) that would detract from a garden site?

A site free of extraneous material, that allows water to penetrate and not puddle, is ideal.

2

Is the site covered in vegetation? If so, does it appear healthy?

Presence of healthy, abundant vegetation is a good indication that soil conditions are conducive to plant growth.

3

While digging, take note of the level of difficulty required to excavate the soil at different depths.
Determine whether difficulties are due to dense plant cover, compaction, or the presence of rocks or human artifacts.

A productive soil will have ample rooting volume that is not restricted by numerous large stones or human artifacts, a rooting depth of 20 cm, and uncompacted soil to a depth of 50 cm to allow for adequate drainage is recommended.

4

Does the soil near the surface appear to be dark brown or black?

Organic matter is important as a source of nutrients, water-holding capacity, aeration, and nutrient holding capability can usually be recognized for its rich dark colour.

5

Are earthworms abundant in your soil (are they easily spotted when digging)?

There should be an abundance of earthworms near the surface under moist conditions.

6 **Observe the pile of soil you excavated from the pit. Are there several stones greater than 2 cm in diameter that may make gardening difficult?**

If several stones are present, they may restrict the rooting volume of your plants and hinder their growth.

7 **Take a handful of the soil you excavated from the pit and determine the texture of your soil, following the hand-texturing guide provided.**

A texture that demonstrates characteristics of all three textural classes (loamy) is preferred. Sandy or clayey soils can be augmented with organic matter to improve textural characteristics.

8 **Take a handful of the soil you excavated from the pit. Do the soil particles clump together to form aggregates?**

Good structure is characterized by the presence of aggregates, or clumps of soil particles.

9 **Is the site located on a slope? If so, which direction is the slope facing (aspect)?**

A slightly sloping site with a south-facing aspect provides the most access to sunlight.

10 **Are there any objects, such as buildings, on or adjacent to the site that block access to sunlight?**

The fewer restrictions on sunlight the better, though most plants require a minimum of six hours of sunlight a day, with 8-10 hours a day preferred.

11 **Are important nutrients such as nitrogen, phosphorus and potassium found in adequate levels in your soil?**

Laboratory analysis is required to determine these levels. Take samples for analysis. Information on sampling and result interpretation is provided below.

Figure 3.5 11-Step Soil and Microclimate Assessment included as one component of the Site Assessment Guide

Determination of soil fertility (step 11) requires additional instruction. A soil sampling guide and local laboratory contact information is provided.

To aid with laboratory result interpretation, a list of recommended nutrient amounts (Table 3.7) and links to credible result interpretation guides are provided in the Site Assessment Guide (Appendix IX). There is no plant nutrient guide specifically for the Vancouver region, thus a reference guide was used from a similar region in the Northwest. The Oregon State University (OSU) guide (Marx et al., 1999) was found to be especially useful for most interpretations. Recommended values from the OSU guide are similar to those derived from Neufeld (1980). Neufeld rates soil property values ranging from very low to very high (e.g., L-, L,L+,M-M,M+, H-,H,H+,H++). Because the majority of Vancouver soils contain a high percentage of coarse fragments (>2 mm), most recommend amounts found in the Site Assessment Guide coincide with Neufeld's "High" rated concentrations. It is difficult to provide recommendations for micronutrients due to the lack of research upon which to base interpretation. The OSU guide offers interpretation of copper, zinc, iron, and manganese following a diethylene triamine pentaacedic acid (DTPA) extraction. The Pacific Soil Analysis Inc. uses a 0.1 M HCl extraction for these micronutrients. While results yielded from these two different extraction methods are correlated following a regression, the OSU interpretation guide should not be used for these micronutrients without taking these differences into consideration

Table 3.7 Recommended* and excessive values for selected soil properties of Vancouver soils

Soil Property	Recommended	Excessive	Method of Determination‡
pH	6-7.5	-	Potentiometrically determined using 1:1 soil to distilled water slurry and Radiometer conductivity cell (Thomas, 1996)
Organic matter	>10%	-	Walkley-Black wet oxidation method (Nelson & Sommers, 1996)
Total nitrogen	>0.2%	-	Colourimetrically determined using a Technicon Autoanalyzer – semi micro Kjeldahl digest (Bremner, 1996)

Soil Property	Recommended	Excessive	Method of Determination‡
Phosphorus	40-100 ppm	>100 ppm	Colourimetrically determined using ascorbic acid colour development method on a 1:10 soil: Bray 0.03 M NH_4F in 0.025 M HCl extract (Bray P1) (Kuo, 1996)
Potassium	250-800 ppm	>800 ppm	Determined by Perkin-Elmer Atomic Absorption Spectrophotometer on a 1:5 soil to ammonium acetate extract (Helmke & Sparks, 1996; Suarez, 1996)
Calcium	1000-2000 ppm	-	
Magnesium	180 ppm	-	
Boron	1-2 ppm	-	Colourimetrically determined on a hot water soluble extract using the azomethine-H method (Keren, 1996)
Sulfate-sulfur	>10 ppm	-	Hi-Bismuth reducible method on a 1:2 soil to calcium chloride extract (Tabatabai, 1996)

***recommended range for Vancouver's soils adapted from Marx et al. (1999) and Neufeld (1980)**
‡Methods listed for these interpretations are the same as those used by commercial laboratory, PSAI

3.4.4 Management Solutions

Several barriers to soil and microclimate quality can be overcome through management and site design decisions. The Site Assessment Guide's primary function is to identify these barriers. Once identified, corresponding management practices can be employed. A table with soil and microclimate barriers and their corresponding management solutions is given (Table 6 in Guide).

3.4.5 Soil Importation

When native soils cannot be amended to serve as a viable medium for plant growth or a community garden society chooses to install raised beds for reasons of aesthetics or accessibility, soil may be imported to the site. In this case, the native soil should be assessed as a subsoil material, relieved of compaction and free of mobile contaminants. Soil for import may be found opportunistically (e.g., from excavated construction sites or through networking opportunities) or through the City's composting program which provides yard-trimmings compost free of charge to new community gardens. This compost is usually low in nutrients but is rich in organic matter, and might need to be mixed with a mineral component, such as sand and a nutrient-rich material, such as manure or kitchen-waste compost. Additionally, a compost/sand mix is occasionally donated by the City of Vancouver Transfer and Landfill Operations, Delta, following a brief written application process. The volume of imported soil varies per site, and is dependent on the size of the garden as well as the desired soil depth. Applicants need to be sure that the large truck bearing the soil is able to access the site. Additionally, some garden societies have chosen to purchase their imported soil from local gardening and landscaping stores.

3.5 Site Assessment Guide Availability and Access

Starting a Community Garden: a Site Assessment Guide for Communities is currently available in document form. The Guide, or components thereof, are available to the public through several Vancouver-based environmental organizations and institutes, including City Farmer, the Environmental Youth Alliance, the Society Promoting Environmental Conservation, The Pacific Regional Society of Soil Science, and the Faculty of Land and Food Systems at University of British Columbia. Through these groups, the document form of the Site Assessment Guide is distributed at workshops and made available on websites. Recommendations to increase the accessibility of the Site Assessment Guide are outlined in the final chapter of this thesis.

3.6 Soil Inventory and Management Guide

A soil survey has not been conducted for the City of Vancouver. Though urban soils are often influenced by human activity, this influence is sporadic and of variable impact. These impacts may influence the A horizon only, leaving the B and C horizons intact. In some areas, native soil remains. In other areas, soil attributes inherited from parent material can still be identified though they have been subjected to human influence. Urban soil surveys have been conducted elsewhere in North America. A study by Pouyat et al. (2002) designated soil series to areas of New York City, including an intensive soil survey of South Latourette Park in Staten Island. Knowledge of native soils is important in areas that have retained their native soil because those attributes and corresponding management strategies associated with different soils can be easily identified. Knowledge of native soils is important in areas that have undergone alteration because the degree of human influence and the type of human activity conducted on the site is more easily identified.

3.6.1 A PRELIMINARY SOIL INVENTORY FOR THE CITY OF VANCOUVER

Gardening communities expressed a strong interest in the characteristics of Vancouver's soils and how those attributes affect soil management strategies. In response to this demand, the foundation for a Soil Inventory for Vancouver was developed. Cross sections for six of Vancouver's major thoroughfares (4th Avenue, Broadway, King Edward Avenue, 41st Avenue, Arbutus Street, and Main Street) were created. Parent material along each cross section was determined by elevation. Elevations greater than 65 meters above sea level (MASL) indicate a glacial till parent material; elevations between 35 and 65 MASL indicate a glacial marine parent material, and; elevations below 35 MASL indicate a marine parent material (Figure 3.6). Due to time and financial restrictions, parent material identification focused on the three most prominent materials found in the City of Vancouver. Other parent materials, notably peat and glacial alluvial, are found in some areas of the City, but are not discussed in here.

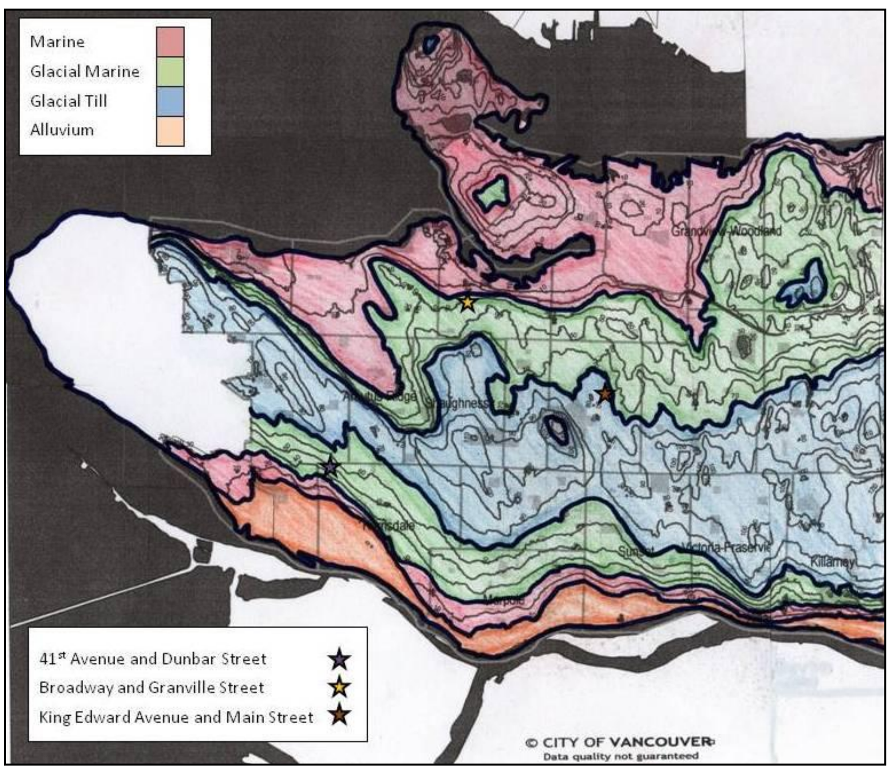

Figure 3.6 Vancouver's predominant soil parent materials developed from the City of Vancouver VanMap contour map (City of Vancouver, 2008)– scale 1:52,500

Till parent materials were deposited directly by the glaciers. This material contains a broad range of particle sizes, from clay to boulders. At depths of 50 to 100 cm, these materials were cemented under the weight of the 1-km thick glacier, forming a hardpan layer. This layer restricts drainage and can cause the formation of a perched water table. Soils derived from this parent material are stony, have a coarse texture, and are well drained until they reach the hardpan (Valentine, 1986). Glacial marine parent materials are influenced by marine and glacial systems. They are finer in texture due to the influence of the sea or ocean, but contain some stones derived from glacial dumping. They have few boulders, and drain moderately poorly (Valentine, 1986). Marine parent materials were influenced solely by the sea or ocean. They are fine-textured deposits, free of stones and boulders. They are poorly drained, but are permeable (Valentine, 1986).

Six cross sections (Figure 3.7-Figure 3.12) show the locations of the three types of parent materials described above. Parent materials cannot be precisely located, since changes from one parent material to another are gradual, and happen along a depositional gradient based on elevation. For this reason, the identified boundary for each parent material is subject to a 10 meter margin of error. For example, a large area of glacial marine parent material is bounded by King Edward Avenue and 33rd Avenue to the north and south, and Manitoba Street and Yukon Street to the east and west. Because the elevation of this area is approximately 70 MASL, the method I employed erroneously depicts it as a glacial till parent material. Soil Management Group descriptions (Section 4.1.1) will aid in the correct identification of soils in these situations.

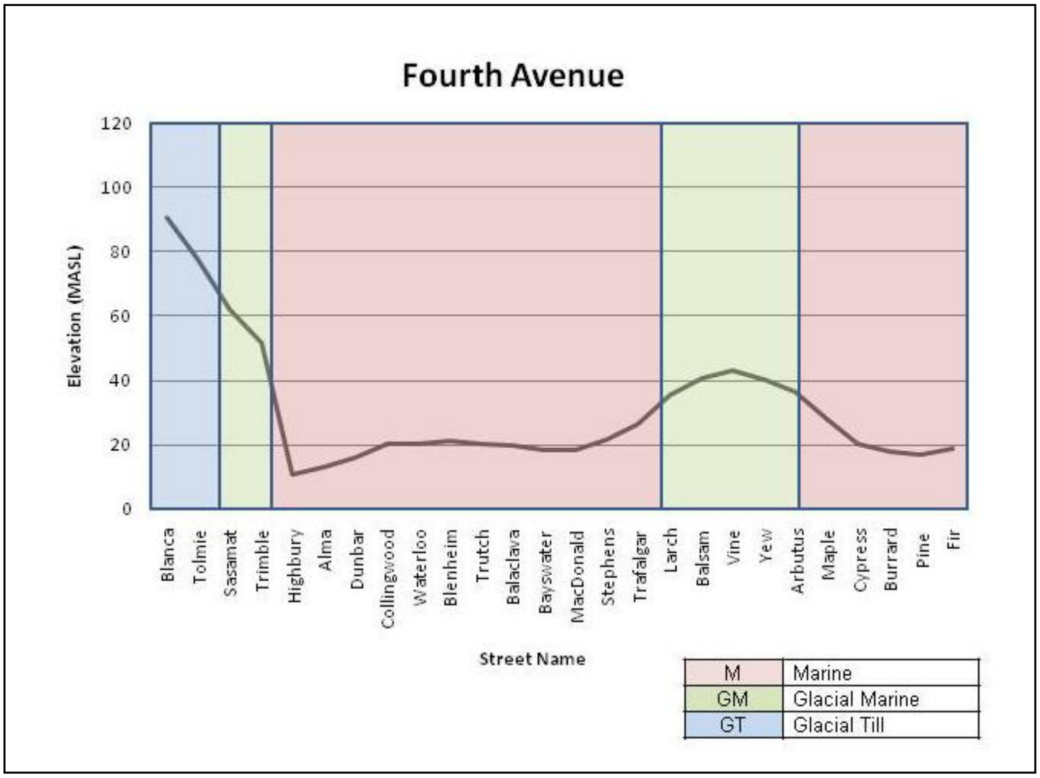

Figure 3.7 Cross section depicting elevations and parent materials along Fourth Avenue in Vancouver, British Columbia

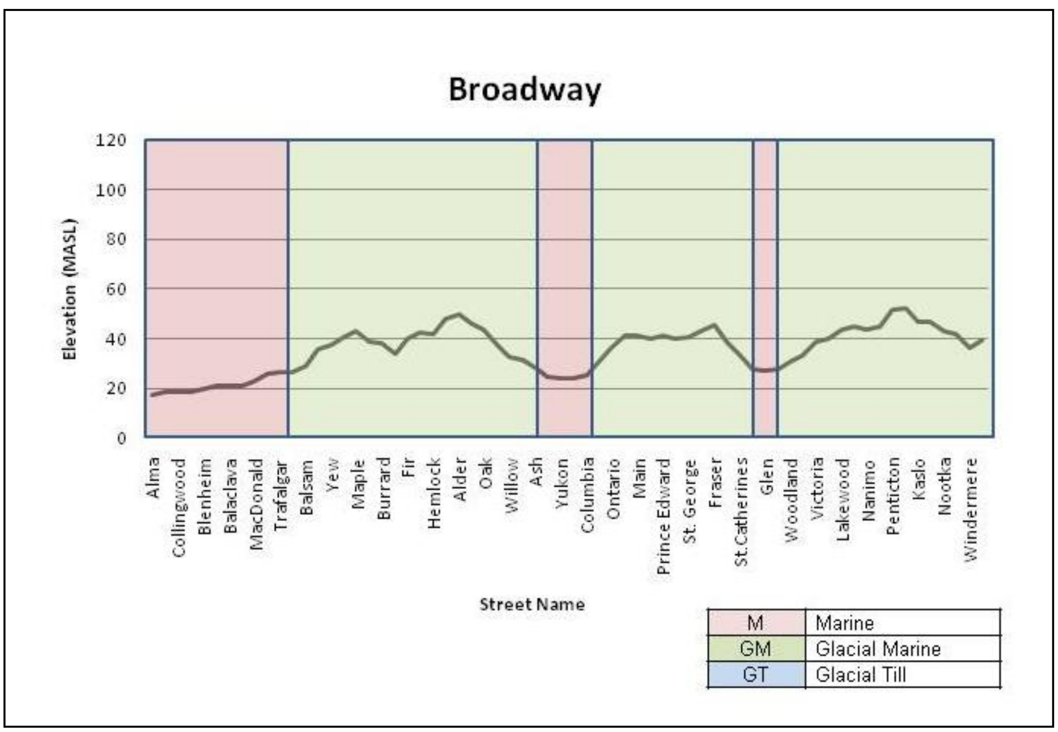

Figure 3.8 Cross section depicting elevations and parent materials along Broadway in Vancouver, British Columbia

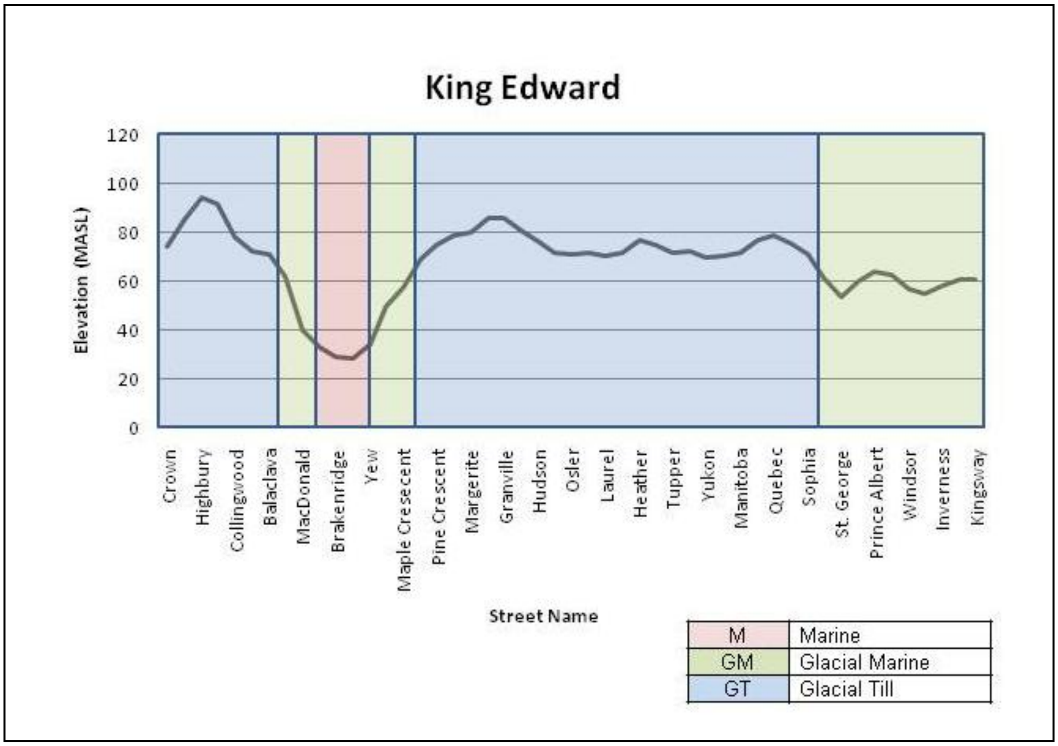

Figure 3.9 Cross section depicting elevations and parent materials along King Edward Avenue in Vancouver, British Columbia

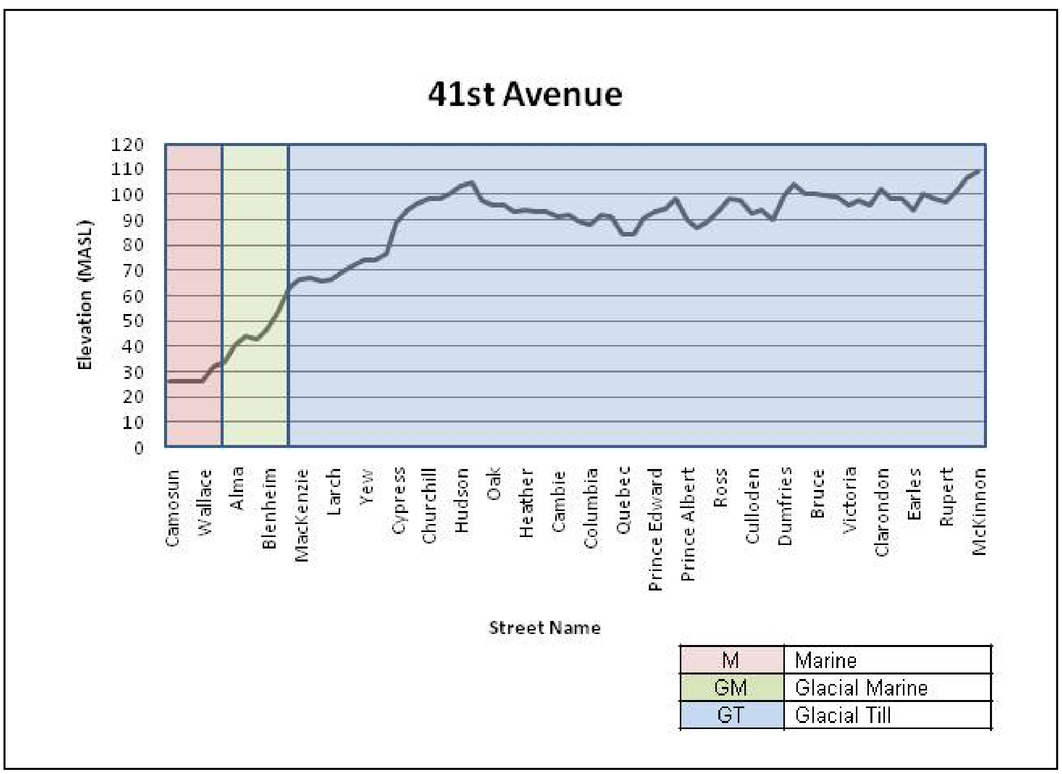

Figure 3.10 Cross section depicting elevations and parent materials along 41st Avenue in Vancouver, British Columbia

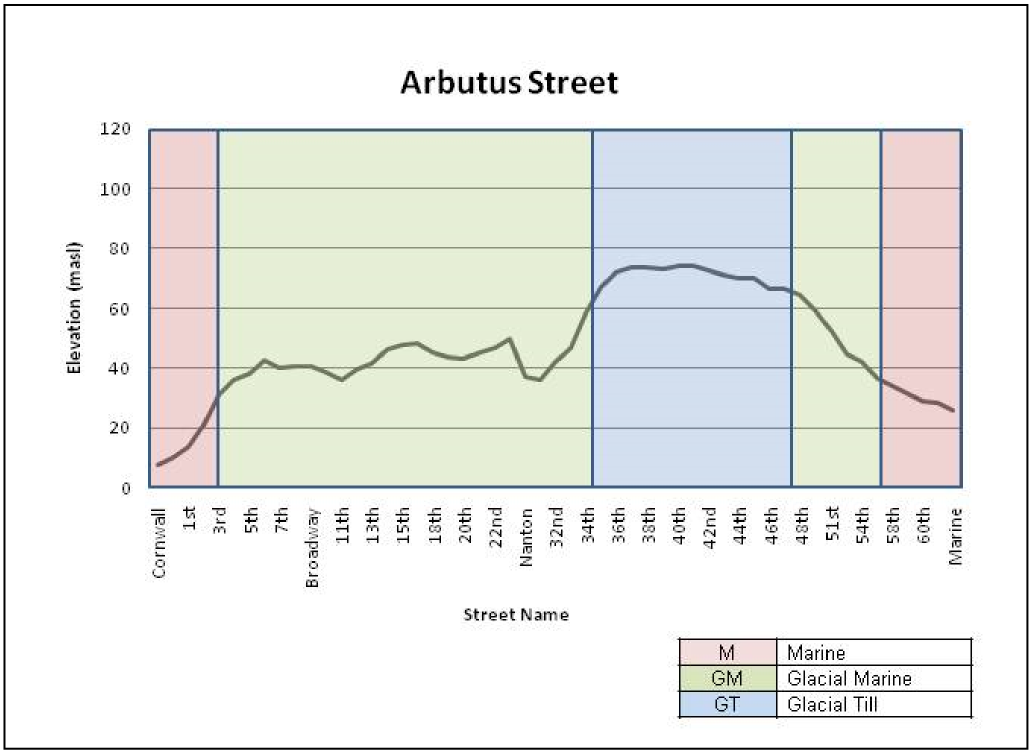

Figure 3.11 Cross section depicting elevations and parent materials along Arbutus Street in Vancouver, British Columbia

Figure 3.12 Cross section depicting elevations and parent materials along Main Street in Vancouver, British Columbia

3.6.2 SOIL MANAGEMENT GROUPS

Each parent material contains a catenary association made up of two dominant soil series. A *catenary association* is a representation of different soil types along a topographic sequence from a knoll to a depression and formed from the same parent material (surficial geologic deposit). The soils differ on the basis of internal soil drainage, ranging from well, to excessive, to poor. Figure 3.13 below depicts the soil series location for each catenary association by topography. These catenary associations translate into soil management groups: Bose-Heron, Whatcom-Scat, and Langley-Cloverdale. Descriptions for the soil series constituting each management group were taken from (Luttmerding, 1984), following the model used in the Soil Management Handbook for the Lower Fraser Valley (Bertrand et al., 1991). Minor inclusions of other soil series (Boosey in Bose-Heron, and Berry in Whatcom-Scat and Langley-Cloverdale) were omitted from management group descriptions due to limited presence. Descriptions for Boosey and Berry soils can be found in (Luttmerding, 1984).

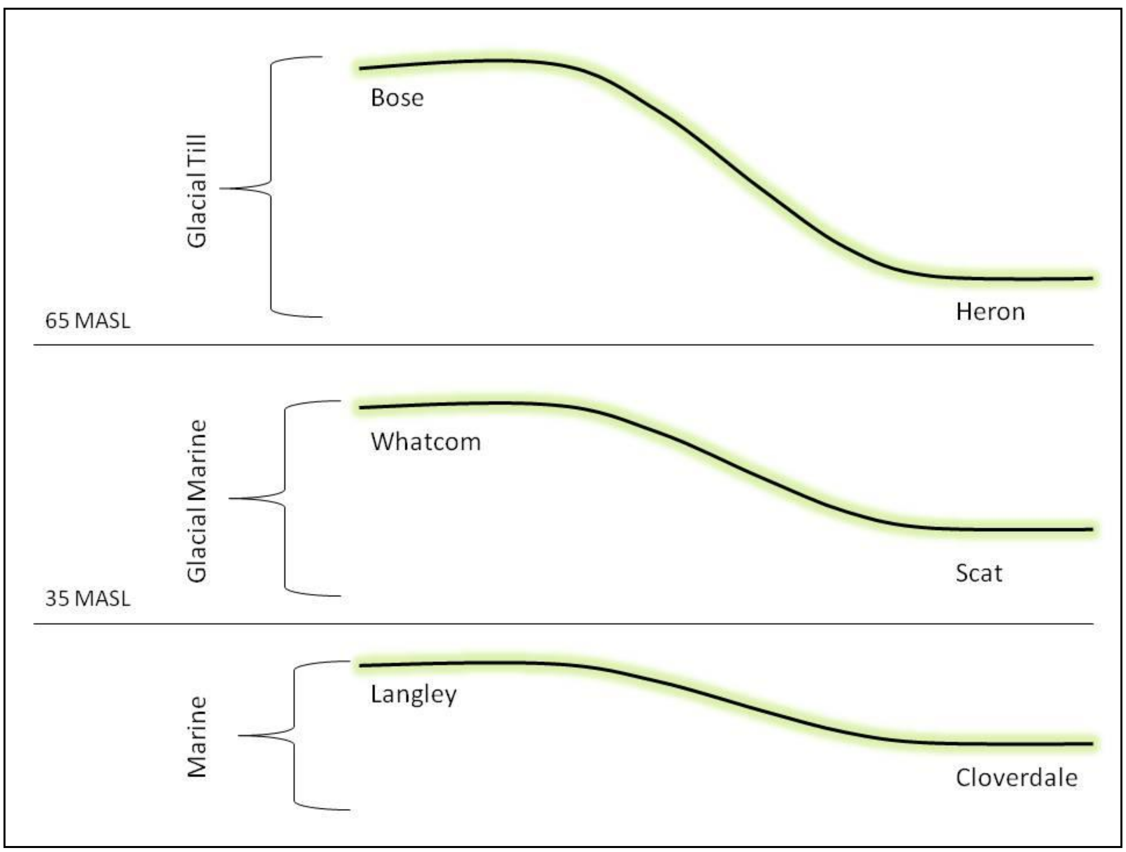

Figure 3.13 Catenary associations within each soil parent material, consisting of different soil series dependent of topography

Bose-Heron Soils, found above 65 MASL, range from moderately-well to well-drained at the knoll, to poorly drained in the depression. They consist of a gravelly sandy loam or loamy sand texture near the surface and are approximately a meter thick. They lie on top of impervious glacial till material. Soils in this management group will have a low water-holding capacity and cation exchange capacity. For gardening, these properties can be improved with the addition of organic matter. These soils also possess a high coarse fraction content that can be remedied through rock-picking. Low-lying areas (Heron Series) may have high water tables that can impact soil rooting depth. Additional soil (in raised beds, etc.) should be supplemented in such cases, especially if drainage cannot be improved via subsurface drains.

Whatcom-Scat soils are found from 35 to 65 MASL. They are moderately-well to well-drained at the slope and poorly drained at the depression. Possessing a finer texture than their Bose-Heron counterparts, Whatcom-Scat soils consist mainly of silt loam and silty clay loam. They overlie glacial marine material, which is not impervious like the glacial till underlying Bose-Heron soils, but does not drain rapidly. Limited rooting depth caused by a high water table in the wintertime, and poor drainage are the limiting factors for gardening in these soils. Installing subsurface drainage or importing additional soil (to increase the soil depth) can correct for these shortcomings in order for perennial crops to be grown. The finer texture of this soil management group leads to increased water-holding capacity and cation exchange capacity. Fewer rocks are present in these soils than in the Bose-Heron management group. Existing rocks can be removed through rock-picking. Overall, these soils possess a good capability for urban agriculture and if present, should be retained on the site and amended if necessary.

Langley-Cloverdale soils are found below 35 MASL. They are moderately-poor to poorly-drained, with a fine texture (silty clay loam or clay loam) and tend to be stone-free. They have developed on top of marine sediments. These soils may benefit from the addition of organic matter in order to increase aeration porosity. Similar to the Whatcom-Scat management group, these soils can suffer from poor drainage and high perched water tables in the winter. For perennial crops, additional soil or subsurface drainage is needed. Heed should be taken in the wetter months to limit traffic on these soils, as they are easily compacted when wet.

3.6.3 *USE OF THE SOIL INVENTORY AND MANAGEMENT GUIDE FOR VANCOUVER, BRITISH COLUMBIA*

The Soil Inventory and Management Guide for Vancouver, British Columbia is a useful tool for gardeners, who can locate their site on the parent material map (Figure 3.6) or along one of the six transects (Figure 3.7-Figure 3.12) to determine the appropriate soil management group for their location. With the topography of their site in mind, they can then identify the particular soil series present onsite within that management group. This information can be used to determine appropriate management practices that are tailored to the specific soil characteristics of the site, aiding with the identification and subsequent amelioration of characteristics that may pose barriers to future garden development if left unaddressed.

4 Conclusions and Recommendations

The following chapter presents conclusions from my research on assessing urban brownfields for community gardens in Vancouver, British Columbia. Following these general conclusions, I outline three recommendations to increase the effectiveness and accessibility of the major outcomes of this study: the Site Assessment Guide and the Soil Inventory and Management Guide.

4.1 Conclusions

This research was an illustrative case study, serving as a model of a community-driven approach to urban brownfield transformation. This study set out to determine:

1. The environmental barriers that hinder community garden development on urban brownfield sites in Vancouver; and
2. How community groups can identify and overcome these environmental barriers to establish safe, successful, and sustainable gardens.

The research demonstrated that an effective and scientifically-credible guide for site assessment that prioritizes community involvement and the incorporation of community values can be an important tool in the transformation of urban brownfields into gardens. By building capacity for community groups to assess local brownfields for garden suitability, they are empowered to be responsible agents of change in their neighbourhoods, converting spaces that were once blights on the community into gardens that are aesthetically pleasing, create spaces that foster community-building and organization, and provide locally grown food. The three main conclusions from this research are outlined below.

Conclusion One: Site assessment resources for community groups wishing to convert local brownfields into community gardens are well-received. The Vancouver city government was outwardly supportive of community garden development, and there was great demand and enthusiasm towards community gardening by the public. Community groups wishing to convert a local brownfield into a garden faced several environmental barriers to garden development however, such as soil contamination and insufficient soil rooting depth. Several community groups in Vancouver were interested in developing gardens on urban brownfields, but lacked the resources and guidance to achieve their goals. These community members were concerned about brownfield contamination and were particularly mindful of the possible human health effects of growing food in contaminated soil. They were enthusiastic at prospect of having a resource to guide their process.

Conclusion Two: Scientifically-credible site assessment methods can be adapted for use by non-specialists who have limited access to resources. A science-based Site Assessment Guide is an appropriate tool for converting brownfields into community gardens if a participatory, community-focused, and adaptive approach is adopted. Presenting soil information in an understandable fashion was welcomed by community groups, who participated enthusiastically in their garden site assessments. Community groups also expressed interest in further information, particularly for a Soil Inventory and Management Guide for Vancouver soils.

Conclusion Three: A Site Assessment Guide is an accurate tool for these communities, but further support by a specialist may be required. Site assessment can be a complex process depending on site history, location, and the goals of the community group(s) involved. Site history, although important, was particularly difficult to assess to ensure site safety. Contamination predictions based on site history were found to be inconsistent. Because of the complexity of urban brownfield sites, a soil scientist should be consulted if the community is concerned or confused by their particular situation.

4.2 RECOMMENDATIONS

This study was conducted as an iterative, participatory research project. The research reflected and incorporated emergent issues as they arose. Therefore it is suggested that this process be continued by the following recommendations.

Three recommendations are advised to further the effectiveness of the Site Assessment Guide and the Soil Inventory and Management Guide for the City of Vancouver:

1. Future revisions and edits to the Site Assessment Guide,

2. Conversion of the Site Assessment Guide to a web-based format, and
3. Expansion of the depth and scope of the Soil Inventory and Management Guide for the City of Vancouver.

The Site Assessment Guide was completed to the best of my ability with the resources available. It is not currently in its finished form, but rather what I hope is the first stage of a series of improvements. Revisions and edits based on the experience of future community groups with garden development projects will enhance the guide's effectiveness. These enhancements can be incorporated most easily into a web-based format. In this case, appropriate space to share experiences, add comments, and make suggestions should be allotted.

Creating a web-based format for the Site Assessment Guide will increase the accessibility of the guide, as well as its ease of use. Though not all community members taking part in developing community gardens will have access to the Internet, and/or proficiency in English, some members of these community groups will. One function of these groups is shared access to resources, and in these cases, the Site Assessment Guide should be distributed by those community members with access, to those without.

To increase the amount of information provided in the Soil Inventory and Management Guide for the City of Vancouver and therefore the usefulness of the Guide, I strongly recommend expanding the depth and scope of this resource. The Soil Inventory was completed in detail along six transects though the City. Increasing the number of transects discussed in this amount of detail would increase the usefulness of this Guide. In the same vein, providing additional details on each management group, including more specific accounting for each soil series present, would provide more practical information. Increasing the scope of the Inventory to cover all of Metro Vancouver, which includes North and West Vancouver, Burnaby, Richmond, New Westminster, Surrey, and Langley, would allow a greater number of people to use this information.

4.3 Empowering Communities for Positive Change

Urban agriculture is not a panacea for the human and environmental health problems prevalent in urban centres. It alone will not create food security, raise a generation of knowledgeable and compassionate youth, or make our neighbourhoods safe – but it is partially responsible for the realization of these goals. By empowering our communities to become involved in the urban agriculture movement, we are helping them to bring positive change to their neighbourhoods. We are encouraging them to care about the sources and quality of their food, to connect with and educate each other, and to become stewards of the urban landscape. Furthermore, we are challenging them to reclaim neglected spaces and transform them into areas that are valued resources and cause for community pride. My hope is that this study has yielded a useful and relevant resource - a site assessment guide for converting brownfields to community gardens - for interested community groups persevering to bring positive change to their neighbourhoods.

To start a community garden, or any urban garden, one must first have a vested interest in the health of the site they wish to convert. To do this means to care, in a personal way, about the history of the site, the presence or absence of contamination, the quality of the soil, air, and water, and the manner in which passersby interact with the site. This, in effect, is the root of *urban environmentalism*, and, I would argue, the root of environmentalism in general. By engaging with our environment and tangibly observing how the health of humans and the environment are intertwined, we are more likely to make informed and responsible decisions than if that interaction had never taken place. With half of the world's population currently living in cities, recognizing the benefits afforded by community gardening and supporting the urban agriculture movement becomes more crucial. The success of this movement depends on many things, of which my study addresses only one: assessing urban brownfields, particularly their soils, for community gardens.

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Appendices

Appendix I: Contaminants, Sources, and Health Effects

Table A. 1 Trace elements, organic contaminants and their anthropogenic sources adapted from the Toxic Substance and Disease Registry (1996, 2008)

Contaminant	Anthropogenic Sources
Cadmium	Coal ash Fossil fuel combustion Batteries Pigments, Metal coatings Plastics Manufacture and application of phosphate fertilizers Waste incineration and disposal *Can be atmospherically deposited onsite*
Copper	Anti-fouling paint Wires and electrical conductors Plumbing fixtures and pipes Coins and cooking utensils Wood, leather and fabric preservatives Pesticides and fungicides Sheet metal
Lead	Batteries and battery oxides Phosphate fertilizers Land application of sewage sludge and animal wastes Coal residues Municipal refuse incineration and wastewaters

Contaminant	Anthropogenic Sources
	Older paints, ceramic products, caulking, and pipe solder Lead can persist in the soil from car emissions emitted before the practice of leading gas had ceased. *Can be atmospherically deposited onsite*
Mercury	Municipal waste incineration; Sewage and hospital waste incineration; Coal and other fossil fuel combustion; Cement manufacturing Used in thermometers and barometers Used in dental fillings Used in some antiseptic creams, ointments, and skin lighteners Used in electrical products (e.g., dry-cell batteries, fluorescent lamps, and electrical switches) used to produce chlorine gas and caustic soda
Nickel	Used in the chemical and food-processing industries and in the medical profession Shipbuilding Plating and catalysis Valves and heat exchangers Used as an electrode material Smelting and alloy-producing processes Employed in electrolyte solution Plating Batteries *Can be atmospherically deposited onsite*
Tin	Used in the glass industry (coatings) Serve as the base for the formulation of colors Food additives dyes Perfumes

Contaminant	**Anthropogenic Sources**
	Soaps Polyvinyl chloride (PVC) heat stabilizers Paints and anti-fouling paints Pesticides and pest repellants Used to line cans for food, beverages, and aerosols. Toothpaste Plastics (e.g., food packages, plastic pipes) *Can be atmospherically deposited onsite*
Zinc	White paints and ceramics Rubber Wood preservatives Manufacturing and dyeing fabrics Major ingredient in smoke from smoke bombs Used by the drug industry (e.g., vitamin supplements, sun blocks, diaper rash ointments, deodorants, athlete's foot preparations, acne and poison ivy preparations, and anti-dandruff shampoos) Coatings to prevent rust Dry cell batteries
Petroleum hydrocarbons	Gasoline Oil Lubricants

Table A. 2 Contaminants and their health effects following consumption adapted from the Agency for Toxic Substances and Disease Registry (2004, 2008)

Contaminant	Human Health Effects
Cadmium	Lungs, sinuses, kidneys, venous and arterial blood systems
Cobalt	Lungs and thyroid. When ingested, can affect the blood, liver, kidneys, and heart
Copper	Liver and kidney damage, anemia, immunotoxicity, and developmental toxicity
Lead	Brain, intestines, and bones
Mercury	Brain and kidneys
Nickel	Lungs, sinuses, and skin
Tin	Inorganic: Lower respiratory system, gastrointestinal system Organotin: neurotoxic, immunotoxic, hepatic and hematological effects
Zinc	Bone, lungs, stomach
Titanium	Skin, mucous membranes, eyes, and lungs
EPHS	Variable

APPENDIX II: GOVERNMENT-SET CONTAMINATION STANDARDS

Table A. 3 Contamination limits for agricultural and urban park land-uses (British Columbia Ministry of Environment, 2010)

Substance	Unit	Agricultural Limit	Urban Park Limit	Lowest Limit*
Antimony	ug/g	20	20	20
Arsenic	ug/g	20	30	20
Barium	ug/g	750	500	500
Beryllium	ug/g	4	4	4
Boron	ug/g	2	-	2
Cadmium	ug/g	3	5	3
Chromium	ug/g	750	250	250
Cobalt	ug/g	40	50	40
Copper	ug/g	150	100	100
Fluoride	ug/g	200	400	200
Lead	ug/g	375	500	375
Mercury	ug/g	0.8	2	0.8
Molybdenum	ug/g	5	10	5
Nickel	ug/g	150	100	100
Selenium	ug/g	2	3	2
Silver	ug/g	20	20	20
Sulphur (elemental)	ug/g	500	-	500
Thallium	ug/g	1	-	1
Tin	ug/g	5	50	5
Vanadium	ug/g	200	200	200
Zinc	ug/g	600	500	500
Light EPHs	ug/g			1000
Heavy EPHs	ug/g			1000

***"lowest limit" refers to the highest standard, or lowest concentration between the "urban park" and "agriculture" land uses.**

Table A. 4 Contamination limits for trace elements at three different intensity levels (British Columbia Ministry of Environment, 1990)

Metal	Level A	Level B	Level C
Arsenic	5	30	50
Barium	500	1000	2000
Cadmium	1	5	20
Chromium	20	250	800
Cobalt	15	50	300
Copper	30	100	500
Lead	50	500	1000
Mercury	0.1	2	10
Molybdenum	4	10	40
Nickel	20	100	500
Selenium	2	3	10
Silver	2	20	40
Tin	5	50	300
Zinc	80	500	1500

Appendix III: Workshop Advertisements and Consent Form

Hello Everybody!

The Free-Folk School with the environmental youth alliance is gladly hosting another
FREE-OF-CHARGE hands-on workshop:
A Layperson's Introduction to Knowing Your (Organic) Garden Soil
(with potluck lunch!)
on
Saturday, September 22nd, 2007 rain or shine
in
Mount Pleasant
from
9am- 1pm

There is limited room for this workshop and our last workshops filled up very quickly, so If you can attend, please **contact Andrew Rushmere no later than Wednesday, September 19th, 2007 to register.** The workshop will be held outdoors rain or shine.

DETAILS: Ask any good Organic Farmer and they'll tell you the key to a healthy garden is healthy soil. If you have never thought much about your soil or thought of it only haphazardly, this workshop is for you. Melissa Iverson, from British Columbia's faculty of Land and Food Systems will lend us her skills as a soil scientist to help introduce us to soil science for the backyard gardener that will be useful in assessing and improving the health of your garden soils. She'll give us a regional perspective on Vancouver's soil composition, tools for asking your soil how healthy it is, and tools for what to do if your soil tells you it's not healthy. Bring some soil samples from your plot and we'll do some simple tests, we'll learn about cover cropping by planting cover crops for a local community garden, and we hope you'll go home with plenty of ideas for how to care for your soils.

Potluck Lunch and Research Discussion: As with the last workshops, this one will be part of an M.A. thesis project being done by Andrew Rushmere at SFU on Free-Folk Learning and Folk Skills. Coming to the workshop does not mean you have to participate in the research, however. The workshop is simply the workshop… and the research portion happens afterwards. We'll end the workshop at noon, and for those who wish to stay an extra hour, you are invited to participate in the research project by staying for a potluck lunch and hour-long discussion. The discussion focus will be different from the last one for those who participated already- you're still more than welcome to participate again!

Figure A. 1 Sustainable Living Arts School (SLAS) Workshop Advertisement

Healthy soil is an essential component of any garden. This hands-on and participatory workshop, hosted by the Environmental Youth Alliance, focuses on soil processes vital for creating and maintaining a healthy growing medium for plants. Come learn about the soils of our region; how to enrich the soil and replenish soil fertility through cover cropping and companion planting; and determine your own soil's texture, organic matter content, and pH. Activities are designed to be practical and applicable to gardening in the Vancouver area.

Figure A. 2 Advertisement for the soil workshop held for the Environmental Youth Alliance interns at the Cottonwood Garden, October 2007

Hi all!

The soils workshop this weekend (Saturday, March 21, 10-12 at Cedar Cottage Garden) will include discussion and exploration on such fascinating topics as:

- Characteristics of our local soils,
- Common characteristics of urban soils, and
- Ways of detecting the quality of our soils

ALSO...

I have nutrient values for the soil native to the Cedar Cottage Garden, as well as nutrient values for the soil we put in our raised beds (yard-trimmings compost + Lawn Boy mix). Let's go over these numbers and see what they tell us! Also, I have nutrient values for several other gardens in Vancouver - how do we stack up?

If there is any other soils-related info you are particularly interested in, please shoot me an email by Thursday so I can add it to the plan!

Looking forward to see you on Saturday!
Melissa

Figure A. 3 Advertisement for the soil workshop held at the Cedar Cottage Community Garden, March 2009

Faculty of Land and Food Systems
Grounded in Science | Global in Scope

Suite 248 - 2357 Main Mall
Vancouver, B.C. Canada V6T 1Z4

Tel: 604.822.1219
Fax: 604.822.6394
www.landfood.ubc.ca

Workshop Participant Consent Form

Project: "Growing Food in a Growing City"

Principal Investigator: Dr. Art Bomke. Professor. Land and Food Systems University of British Columbia
Co-Investigator (*CONTACT FOR STUDY): Melissa Iverson, M. Sc. candidate, Land and Food Systems, University of British Columbia

Purpose: The research goal is to increase sustainability (long term success) of community and backyard gardens in the City of Vancouver. Community education on the topics of soil processes and quality is an essential component to this success. The goal of this workshop is to equip you with the knowledge you need to increase and/or maintain the health of community garden soils, as well as to facilitate sharing of gardener knowledge and questions about soil health. This research will be used in a Masters thesis report, as part of a graduate degree at the University of British Columbia. The final thesis report will be a public document.

Study Procedures: The Soil Workshop will be one 3-hour session. It will include discussions on the following topics:

a) Characteristics of Vancouver region soils,
b) Soil texture,
c) Soil quality,
d) Organic gardening methods for increasing/maintaining soil fertility, and
e) Other related topics of interest to workshop participants.

During this workshop you may be asked questions about your experiences with gardening, soil, or the Vancouver region. Statements and discussions that arise from these topics, or that occur over the course of the workshop, may be included in association with this workshop in the co-investigator's final thesis report or related materials (e.g. class presentations).

Photographs may be taken of you during the soils workshop, and your image may be duplicated for use in association with this workshop. Those not participating will not be photographed.

THE UNIVERSITY OF BRITISH COLUMBIA

Faculty of Land and Food Systems
Grounded in Science | Global in Scope

Suite 248 - 2357 Main Mall
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www.landfood.ubc.ca

Potential Risks: Participation in this workshop poses minimal risk. Your statements and image may be used for publications, reports or presentations in association with this workshop. We cannot control what other participants do with the statements/information discussed during the workshop.

Potential Benefits: Participation in the workshop may facilitate new knowledge about: the soils of the Vancouver region, how to gauge soil health, and methods to increase/maintain healthy soil.

Confidentiality: If you wish to participate in this workshop, your identity will be kept confidential. Data that links your name to your statements or image will be password protected on the co-investigator's computer.

The final thesis report may contain statements or images taken during the workshop. Your name will not be disclosed in relation to any statements or images in association with the workshop for the final thesis report, presentations, or related materials.

Sponsors: We acknowledge the following for financial support of this thesis research project: the City of Vancouver, the Vancouver Coastal Health Authority, the Environmental Youth Alliance, and the Vancouver Community Agriculture Network.

Contact for information about the study: If you have any questions or desire further information with respect to this study, you may contact Melissa Iverson (co-investigator) at:
Dr. Art Bomke (principal investigator) at:

Contact for concerns about the rights of research subjects: If you have any concerns about your treatment or rights as a research subject, you may contact the Research Subject Information Line in the UBC Office of Research Services at 604-822-8598 or if long distance e-mail to RSIL@ors.ubc.ca.

THE UNIVERSITY OF BRITISH COLUMBIA

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Consent:

I, ______________________, understand that my participation in this study is entirely voluntary and I may refuse to participate or withdraw from the workshop at any time without any penalty [for example, employment, class standing, access to further services from the community centre, day care, etc.].

I give my consent to participate in the Workshop for this research project as described in this consent form by signing below.

Your signature below indicates that you have received a copy of this consent form for your own records. Your signature indicates that you consent to participate in this workshop.

____

Participant's Signature Date

____

Printed Name of the Participant signing above

The signature of a Witness is not required for behavioural research.

Version: August 31, 2007 page 3/3

Figure A. 4 Consent form signed by workshop participants

Appendix IV: Workshop Materials

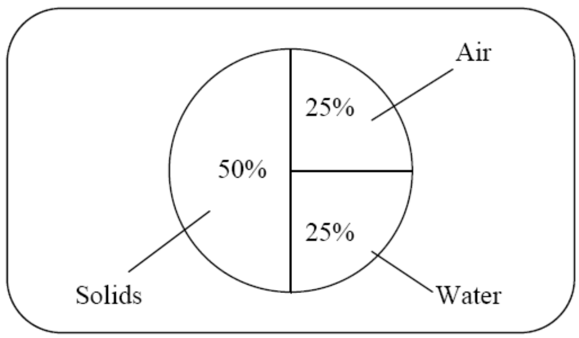
Soils Workshop
Environmental Youth Alliance
Oct. 4th, 2007
10:00 am-12:00 noon

Soil Fun Part II

I. Introduction and Recap

A. What is Soil?

a) Mineral, organic matter, air, and water components



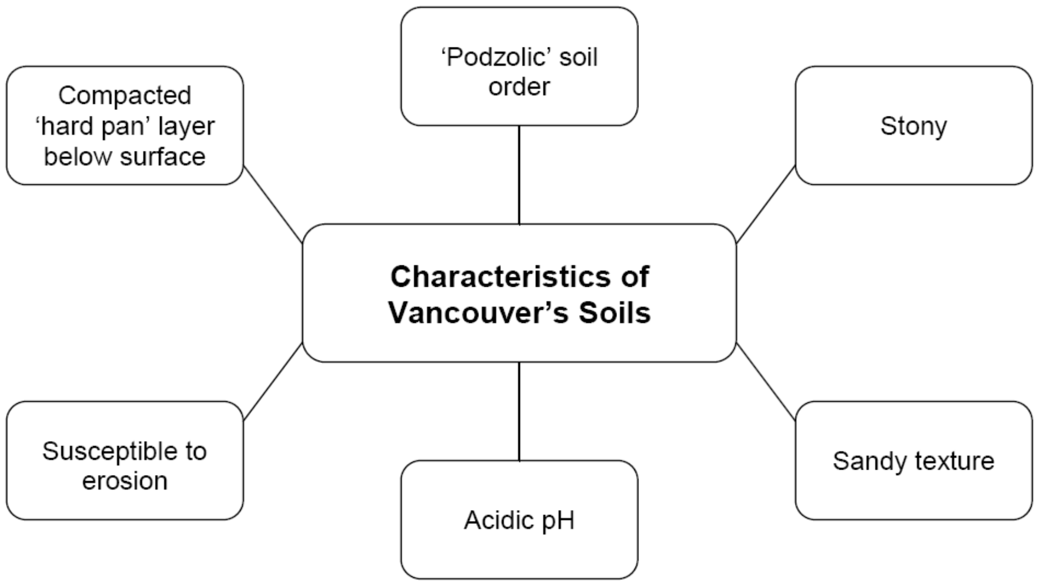
b) Chemical, biological, and physical components of soil

Chemical	Biological	Physical
• pH • Fertility (nutrients) • Contamination (e.g. excessive concentrations of nutrients, chlororganics) • Cation exchange capacity (CEC)	• Organic matter • Vegetation • Soil organisms	• Texture • Structure (aggregation) • Compaction • Drainage • Rooting depth/volume

B. Soil Functions

a) Foundation for buildings and roads
b) Building material (e.g. cob structures)
c) Habitat for soil organisms
d) Growing medium for plants
e) Plus more!

II. Soils of the Vancouver Region



Significance:

Podzolic soil order: Soils are classified into 'orders' based on their developmental characteristics. Vancouver's soils are predominantly of the podzolic soil order. Podzols are red to yellow-brown in colour just under the surface. This is due to the high amount of iron-oxides in the soil, which are not necessarily available to plants.

Stoniness: Stoniness can affect the rooting volume of the soil, which may limit a plant's access to nutrients.

Sandy texture: A sandy texture provides good drainage, but poor nutrient holding capabilities. Adding organic matter to your soil is the best way to improve your soil's ability to hold nutrients.

Acidic pH: An acidic pH is suitable for some plants (e.g. potatoes, parsley) but not others (e.g. onion, spinach). Additionally, having an acidic pH can limit a plant's ability to uptake certain nutrients, such as phosphorus. Liming is recommended for acidic soils.

Susceptible to erosion: Because Vancouver's soils tend to be sandy, and the climate here is so humid, uncovered soils erode very easily.

Compacted hardpan layer below surface: A hardpan layer exists at varying depths below the surface of Vancouver's soils. This hardpan can obstruct drainage and impede root growth.

Soils Workshop
Environmental Youth Alliance
Oct. 4th, 2007
10:00 am-12:00 noon

III. Urban Soils

a) Great vertical and spatial variability

b) Altered soil structure, leading to compaction

c) Presence of a surface crust on bare soil that is usually hydrophobic

d) Soil pH can become more alkaline (raised pH)

e) Restricted aeration and water drainage

f) Interrupted nutrient cycling
- Affects soil organism populations and activity

g) Presence of anthropeic materials and other contaminants

h) Highly modified soil temperature regimes

IV. Soil Assessment Activity

You will need:
1) Assessment worksheets (3)
2) Hand texturing guide
3) Soil pH test kit
4) A rod or spade
5) Your eyes!

V. Debrief on Soil Assessment Activity

Were your areas healthy? Why or why not?

What can you do to make unhealthy soils healthy again?

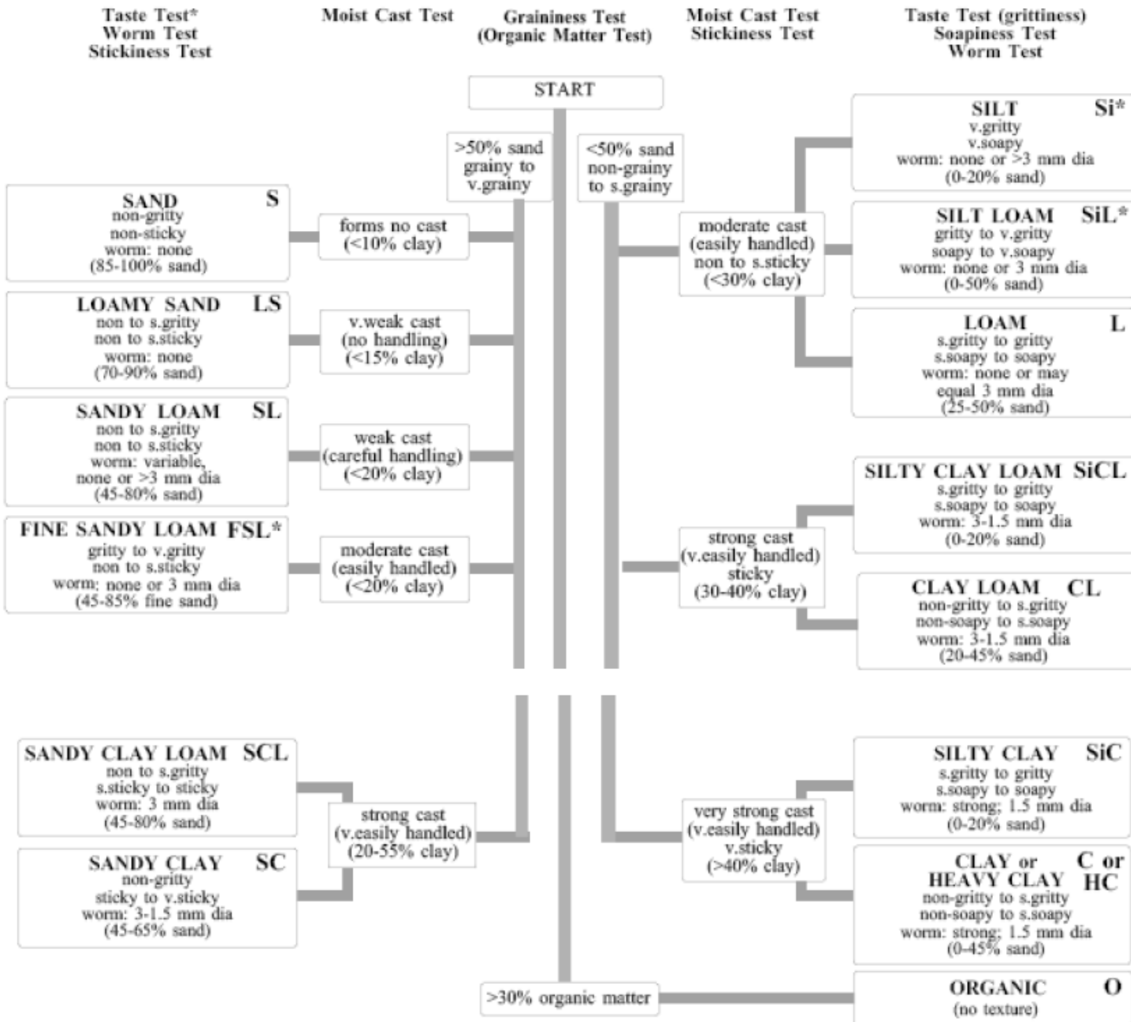
Figure A. 5 Handout distributed at the soil workshop for the Environmental Youth Alliance interns at the Cottonwood Garden, October 2007

APPENDIX V: INTERPRETIVE AND LABORATORY-BASED METHOD COMPARISON

Table A. 5 Interpretive methods for soil quality determination applied to three study sites to evaluate accuracy

Interpretive Method	Observation
Puddling observation: severity, % area	
Difficulty excavating soil pit	
Structure observation using diagram	
Rooting depth (if plants are present)	
Thickness of un-compacted layer	
Depth until presence of human artifacts that form a restrictive layer	
Depth of penetrable soil	
Observation (counts) and percentage of stones	
Hand-texturing following a guide	
Colour observation (using an adaptation of the Munsell guide)	
Earthworms	
pH reagent (from gardening supply store)	

Figure A. 6 Diagram of soil aggregates used for interpretive method data collection (University of British Columbia, n.d.)



* Silt feels slippery or soapy when wet; fine sand feels stiffer, like grinding compound or fine sandpaper.

Key to Abbreviations	Measurement Conversions
s = slightly	3.0 mm = 1/8"
v = very	1.5 mm = 1/16"
dia = diameter	

Fine Fraction	(particle diameter)
SAND ------------- (S)	2 - .05 mm
SILT --------------- (Si)	.05 - .002 mm
CLAY ------------- (C)	<.002 mm

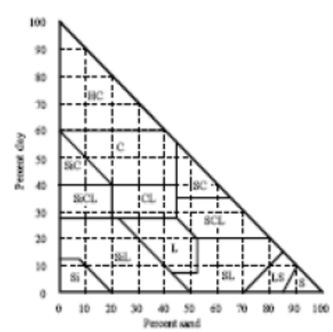


Figure A. 7 Hand-texturing guide used during evaluation of interpretive methods (British Columbia Ministry of Environment, Lands, and Parks & British Columbia Ministry of Forests, 1998)

APPENDIX VI: FERTILITY AND CONTAMINATION TEST RESULTS

Table A. 6 Results for strong acid soluble metal and extractable petroleum hydrocarbon soil analyses preformed by Cantest Laboratory for the Hastings Folk Garden brownfield site

Substance	Unit	Agricultural Limit	Urban Park Limit	HFG** North	HFG South
Antimony	ug/g	20	20	< 10	< 10
Arsenic	ug/g	20	30	< 10	< 10
Barium	ug/g	750	500	68	75
Beryllium	ug/g	4	4	< 1	< 1
Boron	ug/g	2	No limit	1	< 1
Cadmium	ug/g	3	5	< 0.5	< 0.5
Chromium	ug/g	750	250	17	16
Cobalt	ug/g	40	50	6	7
Copper	ug/g	150	100	21	24
Fluoride	ug/g	200	400	N.D.‡	N.D.
Lead	ug/g	375	500	36	29
Mercury	ug/g	0.8	2	0.05	0.06
Molybdenum	ug/g	5	10	< 4	< 4
Nickel	ug/g	150	100	15	15
Selenium	ug/g	2	3	N.D.	N.D.
Silver	ug/g	20	20	< 2	< 2
Sulphur (elemental)	ug/g	500	No limit	N.D.	N.D.
Thallium	ug/g	1	No limit	N.D.	N.D.
Tin	ug/g	5	50	< 5	< 5
Vanadium	ug/g	200	200	35	38
Zinc	ug/g	600	500	80	84
pH*	pH units	No limit	No limit	7.4	7.8

***pH tests were included with elemental analysis**
****HFG - Hastings Folk Garden**
‡ N.D. - No data

Table A. 7 Results for strong acid soluble metal and extractable petroleum hydrocarbon soil analyses preformed by Cantest Laboratory for the Cedar Cottage brownfield site

Substance	Units	Agricultural Limit	Urban Park Limit	Cedar Cottage Garden
Antimony	ug/g	20	20	<10
Arsenic	ug/g	20	30	<10
Barium	ug/g	750	500	55
Beryllium	ug/g	4	4	<1
Boron	ug/g	2	No limit	<1
Cadmium	ug/g	3	5	0.6
Chromium	ug/g	750	250	29
Cobalt	ug/g	40	50	8
Copper	ug/g	150	100	26
Fluoride	ug/g	200	400	N.D.*
Lead	ug/g	375	500	19
Mercury	ug/g	0.8	2	0.04
Molybdenum	ug/g	5	10	<4
Nickel	ug/g	150	100	28
Selenium	ug/g	2	3	N.D.
Silver	ug/g	20	20	<2
Sulphur (elemental)	ug/g	500	-	N.D.
Thallium	ug/g	1	-	N.D.
Tin	ug/g	5	50	<5
Vanadium	ug/g	200	200	26
Zinc	ug/g	600	500	407
Total Polycyclic Aromatic Hydrocarbons	ug/g	1	1	N.D.
Light Extractable Petroleum Hydrocarbons	ug/g	1000	1000	<250
Heavy Extractable Petroleum Hydrocarbons	ug/g	1000	1000	<250

N.D. - No data

Table A. 8 Results of soil fertility analysis conducted by Pacific Soil Analysis Incorporated for the Cedar Cottage brownfield site

pH	C/N	E.C. (mmhos/cm)	O.M. %	Total N %	P	K	Ca	Mg
6.6	18.5	0.5	7.4	0.23	58	120	3150	75

Table A. 9 Results for strong acid soluble metal and extractable petroleum hydrocarbon soil analyses preformed by Cantest Laboratory for the 16 Oaks Garden brownfield site

Substance	Units	Agricultural Limit	Urban Park Limit	16 Oaks North	16 Oaks South
Antimony	ug/g	20	20	-	-
Arsenic	ug/g	20	30	17	-
Barium	ug/g	750	500	394	165
Beryllium	ug/g	4	4	N.D.	N.D.
Boron	ug/g	2	-	3*	2
Cadmium	ug/g	3	5	1.2	0.6
Chromium	ug/g	750	250	29	25
Cobalt	ug/g	40	50	8	10
Copper	ug/g	150	100	216*	27
Fluoride	ug/g	200	400	N.D.	N.D.
Lead	ug/g	375	500	365	246
Mercury	ug/g	0.8	2	0.38	0.22
Molybdenum	ug/g	5	10	N.D.	N.D.
Nickel	ug/g	150	100	17	16
Selenium	ug/g	2	3	N.D.	N.D.
Silver	ug/g	20	20	N.D.	N.D.
Sulphur (elemental)	ug/g	500	No limit	N.D.	N.D.
Thallium	ug/g	1	No limit	N.D.	N.D.
Tin	ug/g	5	50	17*	N.D.
Vanadium	ug/g	200	200	82	59
Zinc	ug/g	600	500	450	270
Total Polycyclic Aromatic Hydrocarbons	ug/g	1	1	N.D.	N.D.
Light Extractable Petroleum Hydrocarbons	ug/g	1000	1000	<250	<250
Heavy Extractable Petroleum Hydrocarbons	ug/g	1000	1000	<250	<250

***Value exceeds government-set standard limit for Urban Park or Agricultural land uses**

APPENDIX VII: INTERPRETIVE METHOD RESULTS

Table A. 10 Data obtained from soil quality interpretive methods applied to the Land and Food Systems Orchard Garden site, February 2009

Land and Food Systems Orchard Garden	
Interpretive Method	**Observation**
Puddling observation: severity, % area	Not applicable
Difficulty excavating soil pit	Easy – difficulty due to grass roots
Structure observation using diagram	Granular - lots of earthworms and roots
Rooting depth (if plants are present) – depth at which majority of roots end	25 cm
Thickness of un-compacted layer	Depth of pit – 50 cm
Depth until presence of human artifacts that form a restrictive layer	Human artifacts included plastic tubing and ceramic tiling. No artifacts formed a restrictive layer
Depth of penetrable soil	All soil was easily penetrable
Percentage of stones	5%-7% on a volumetric basis
Hand-texturing following a guide	Sandy loam
Colour observation (using Munsell guide)	10YR/3/2
Earthworm abundance	Abundant
pH reagent (from gardening supply store)	6-7

Table A. 11 Data obtained from soil quality interpretive methods applied to the House School Garden site, February 2009

York House School Garden	
Interpretive Method	**Observation**
Puddling observation: severity, % area	Not applicable
Difficulty excavating soil pit	Easy
Structure observation using diagram	Granular
Rooting depth (if plants are present) – depth at which majority of roots end	30 cm
Thickness of un-compacted layer	Depth of pit – 50 cm
Depth until presence of human artifacts that form a restrictive layer	Human artifacts included glass, and plastic figurines. A pipe was found approximately 20 cm below the surface, running down the center of the site, which decreased rooting volume in that area. No artifacts formed a restrictive layer.
Depth of penetrable soil	All soil was easily penetrable
Percentage of stones	1%-2% on a volumetric basis
Hand-texturing following a guide	Loamy sand
Colour observation (using Munsell guide)	10YR/2/2
Earthworm abundance	Abundant
pH reagent (from gardening supply store)	6-7

Table A. 12 Data obtained from soil quality interpretive methods applied to the Cedar Cottage Garden site, February 2009

Cedar Cottage Garden	
Interpretive Method	**Observation**
Puddling observation: severity, % area	Not applicable
Difficulty excavating soil pit	Easy
Structure observation using diagram	Granular
Rooting depth (if plants are present) – depth at which majority of roots end	No plants present
Thickness of un-compacted layer	50 cm
Depth until presence of human artifacts that form a restrictive layer	10 cm
Depth of penetrable soil	All soil was easily penetrable until a depth of 10cm. From a depth of 10 – 35cm, a layer containing several rocks was present. This layer greatly restricted the digging of the pit. After this layer the soil was largely sand, with fewer rocks.
Percentage of stones	10-15% on a volumetric basis based on the fill of the pit.
Hand-texturing following a guide	Layer 1: sandy clay loam Layer 2: loamy sand
Colour observation (using Munsell guide)	5YR/3/2
Earthworm abundance	Abundant
pH reagent (from gardening supply store)	8

APPENDIX VIII: CERTIFICATE OF APPROVAL GRANTED BY THE BEHAVIOURAL RESEARCH ETHICS BOARD

The University of British Columbia
Office of Research Services
Behavioural Research Ethics Board
Suite 102, 6190 Agronomy Road, Vancouver, B.C. V6T 1Z3

CERTIFICATE OF APPROVAL- MINIMAL RISK RENEWAL

PRINCIPAL INVESTIGATOR:	DEPARTMENT:	UBC BREB NUMBER:
Arthur A Bomke	UBC/Land and Food Systems/Agroecology	H07-01550

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT:

Institution	Site
N/A	N/A

Other locations where the research will be conducted:
In the field, on potential community garden sites. Possibly including: Victoria at the Hull divide, Keefer and Gore, Argyle and 57th, and the Means of Production garden

CO-INVESTIGATOR(S):

Melissa Iverson

SPONSORING AGENCIES:

City of Vancouver
Vancouver Coastal Health Authority

PROJECT TITLE:
Growing Food in a Growing City; Soil Quality and Microclimate Assessment of Urban Agricultural Land in the City of Vancouver

EXPIRY DATE OF THIS APPROVAL: August 18, 2009

APPROVAL DATE: August 18, 2008

The Annual Renewal for Study have been reviewed and the procedures were found to be acceptable on ethical grounds for research involving human subjects.

Approval is issued on behalf of the Behavioural Research Ethics Board and signed electronically by one of the following:

Dr. M. Judith Lynam, Chair
Dr. Ken Craig, Chair
Dr. Jim Rupert, Associate Chair
Dr. Laurie Ford, Associate Chair
Dr. Daniel Salhani, Associate Chair
Dr. Anita Ho, Associate Chair

Figure A. 8 Certificate of approval issued by the University of British Columbia behavioural research ethics board

APPENDIX IX: SITE ASSESSMENT GUIDE

Starting a Community Garden

A Site Assessment Guide for Communities

Melissa Ann Iverson M.Sc. (Soil Science)

2010

UNIVERSITY OF BRITISH COLUMBIA - FACULTY OF LAND AND FOOD SYSTEMS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Dedication

To the urban farmers, community organizers, and backyard gardeners who know the joy of placing their hands in the soil, and the satisfaction of observing a seed mature into a delicious fruit.

To future community gardeners, who aspire to create positive change in their communities. I hope this guide serves to help you achieve your goals, and realize the pleasure and potential that gardening can bring.

Though unassuming, the act of gardening is nothing less than an act of revolution.

INTRODUCTION – HOW TO USE THIS GUIDE

Have you ever walked by that vacant lot near your home, work, or school, and thought "I would love to make this place a garden!" If so, then this guide is for you!

The purpose of this guide is to help you answer some of the big questions about the environmental quality of your site. Questions like:

- How can I find out if the soil is contaminated?
- Is the soil deep enough for my plants to have healthy root systems?
- Are there enough nutrients in the soil?
- Is the site too shady for a garden?

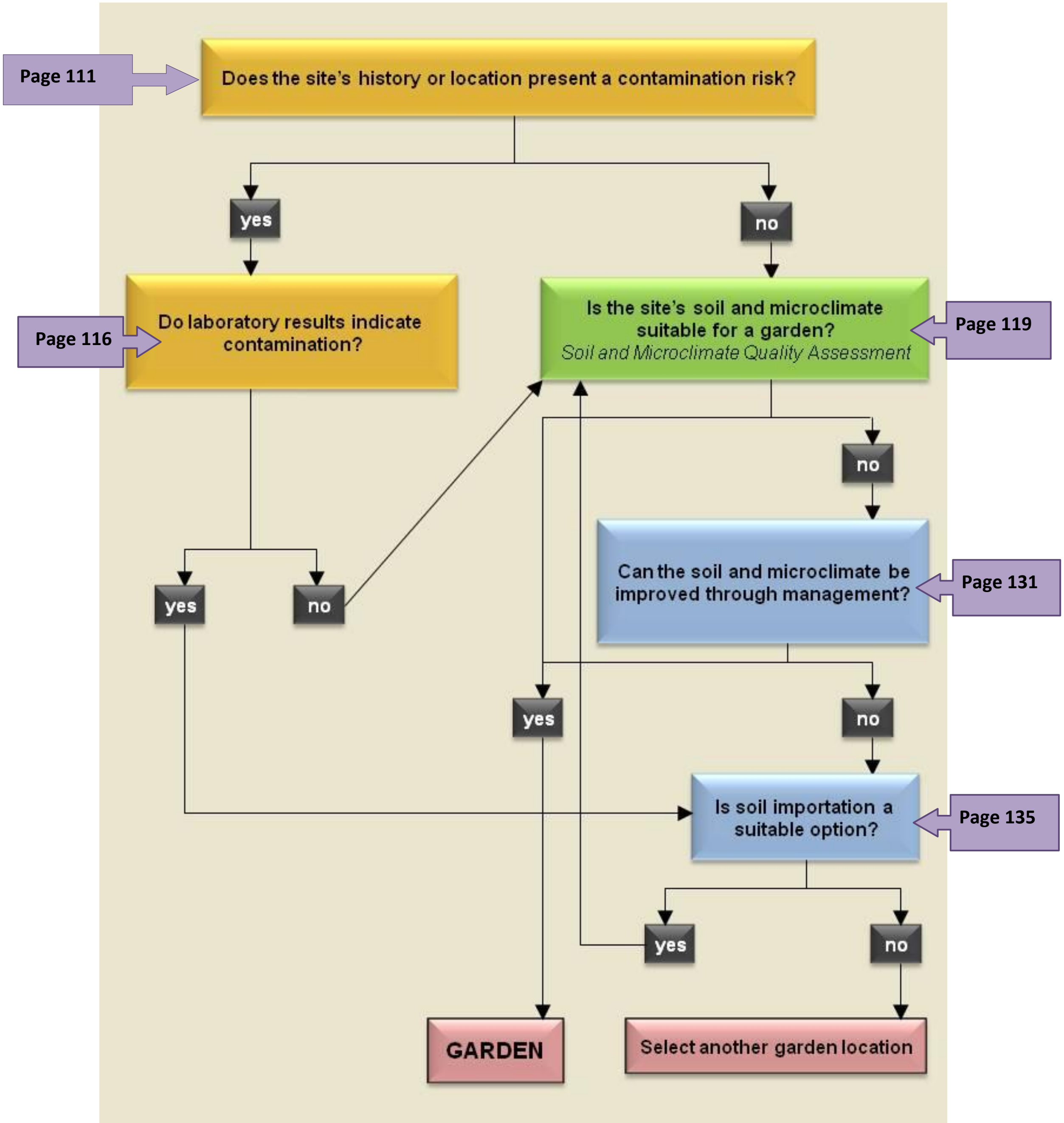
These are important questions to answer after issues regarding site tenure, community support, and liability insurance have been addressed.

To use this site, go to the decision tree diagram on the next page. Starting at the top of the "tree", with the box entitled: "Does the site's history or location present a contamination risk?" Go to the corresponding chapter heading and carry out the suggested activities. These activities should provide information to help determine a "yes" or "no" answer. Proceed down the decision tree, concluding with the boxes "Garden" or "Select another garden location."

All italicized terms are defined in the Glossary on page 136.

References for all books and resource materials are provided on page 141.

SITE ASSESSMENT DECISION TREE



DOES YOUR SITE HISTORY OR LOCATION PRESENT A CONTAMINATION RISK?

Determining if a site contains contaminated soil is the first action that should be taken when assessing a site for garden development. To ensure a site's soil is not contaminated, laboratory testing for contamination is required. These tests are expensive and not always financially accessible to community groups. Regardless of laboratory analysis, a site history should be conducted. Knowledge of a site's history provides an indication of the risk level associated with the site's soil, as well as probable contaminants that may be found on the site.

SITE HISTORY

There are four main ways to gather information on the current and past land uses of a particular brownfield: 1) contacting city officials, 2) accessing historical documentation, 3) talking with neighbours and locals, and 4) taking note of artifacts found onsite

1. CONTACTING CITY OFFICIALS

In the City of Vancouver, the Social Planning and Engineering Departments are able to provide the most information about the previous land uses of brownfield sites. The Director of Social Planning can provide information directly, or put you in contact with an appropriate person from the Department of Engineering.

2. HISTORICAL DOCUMENTATION

The Vancouver City Archives are another important source of historical information. The Vancouver Archives are open to visitors, and are located near the South side of the Burrard Street Bridge at 1150 Chestnut Street. Archivists and reference staff are available to help sort through past maps, architectural plans, City directories and other records of interest.

3. INTERVIEWS

Interviews with neighbours and people who have had contact with the site can provide the most relevant and useful information when conducting a site history. They can give indication of past, as well as present land uses. In one instance, a ***brownfield*** seemed to have low-risk land use history based on the information I received from the Social Planning Department and the City Archives. Upon speaking with a neighbour to the site I learned that another neighbour had been using the brownfield to dispose of the refuse oil from the oil changes he had been performing on his car. This key piece of information would not have been made available to me

FIGURE 1 LA COSECHA GARDEN - CLARK AVENUE AND BROADWAY
PHOTO CREDIT: MELISSA IVERSON

if I had not spoken with this neighbour. People who live, work, or frequently pass by brownfields have information about the kinds of activities that occur on the site that no government official or historical record can provide. In some cases, neighbours who have lived or worked in the area for a long time may be able to recount the history of the site, filling in some of the gaps in archival information.

4. Site Artifacts

Site artifacts consist of materials in or on top of the soil that have been abandoned or discarded onsite. These may include garbage, such as food containers or cigarette butts, or materials remaining from the site's prior use, such as rubble from demolished structures. These artifacts can be important clues to the activities that occurred on the site, including those activities that occurred after the site was left unoccupied.

In addition to compiling a site history, the site's surroundings may also provide clues regarding possible contaminants. For instance, close proximity to roadways or industrial facilities may suggest the presence of related contaminants.

Land uses that pose a risk

Once past land uses have been determined, compare results to Table 1: Past Land Uses and Associated Potential Contaminants and Table 2: Common Contaminants and their Sources. These tables are meant to serve as guidelines only. For a complete list and discussion of toxic effects see *Trace Elements in Soils and Plants* by Alina Kabata-Pendias and Henryk Pendias (2001).

TABLE 1 PAST LAND USES AND ASSOCIATED POTENTIAL CONTAMINANTS

Past Land Use	Potential Contaminants
Housing	Copper Lead Tin Zinc
Construction sites	Cadmium Copper Lead Nickel Tin Zinc Petroleum hydrocarbons
Park	Variable
Commercial (shops, restaurants, etc.)	Copper Lead Tin Zinc
Parking lots, gas stations, and site adjacent to busy roads	Cadmium Lead Petroleum hydrocarbons
Laundromat	Variable
Railway (adjacent to site)	Copper Zinc Petroleum hydrocarbons

TABLE 2 COMMON CONTAMINANTS AND THEIR SOURCES

Contaminant	Anthropogenic Sources
Cadmium	Coal ash Fossil fuel combustion Batteries Pigments, Metal coatings Plastics Manufacture and application of phosphate fertilizers Waste incineration and disposal *Can be atmospherically deposited onsite*
Copper	Anti-fouling paint Wires and electrical conductors Plumbing fixtures and pipes Coins and cooking utensils Wood, leather and fabric preservatives Pesticides and fungicides Sheet metal
Lead	Batteries and battery oxides Coal residues Municipal refuse incineration and wastewaters Older paints, ceramic products, caulking, and pipe solder Lead can persist in the soil from car emissions emitted before the practice of leading gas had ceased. *Can be atmospherically deposited onsite*
Mercury	Municipal waste incineration; Sewage and hospital waste incineration; Coal and other fossil fuel combustion; Cement manufacturing Thermometers and barometers Dental fillings Antiseptic creams, ointments, and skin lighteners Electrical products (e.g., dry-cell batteries, fluorescent lamps, and electrical switches) Production of chlorine gas and caustic soda
Nickel	Used in the chemical and food-processing industries and in the medical profession Shipbuilding Plating and catalysis Valves and heat exchangers Electrodes Smelting and alloy-producing processes Employed in electrolyte solution Plating Batteries *Can be atmospherically deposited onsite*

Tin	Glass coatings Base for the formulation of colors Food additives dyes Perfumes Soaps Polyvinyl chloride (PVC) heat stabilizers Paints and anti-fouling paints Pesticides and pest repellants Can linings for food, beverages, and aerosols. Toothpaste Plastics (e.g., food packages, plastic pipes) *Can be atmospherically deposited onsite*
Zinc	White paints and ceramics Rubber Wood preservatives Manufacturing and dyeing fabrics Major ingredient in smoke from smoke bombs Used by the drug industry (e.g., vitamin supplements, sun blocks, diaper rash ointments, deodorants, athlete's foot preparations, acne and poison ivy preparations, and anti-dandruff shampoos) Coatings to prevent rust Dry cell batteries
Petroleum hydrocarbons	Gasoline Oil Lubricants

DO LABORATORY RESULTS INDICATE CONTAMINATION?

SENDING SOIL SAMPLES TO THE LABORATORY FOR CONTAMINATION ANALYSIS

If the site's history, location, or onsite artifacts reveal a possibility of contamination risk, laboratory analysis should be conducted. Determine what to test for based on the tables above. Commonly, people choose to test for metals, such as lead, copper and cadmium (referred to as ***strong acid soluble metals*** by testing laboratories) and petroleum products such as oils, gasoline, and lubricants (referred to as ***extractable petroleum hydrocarbons***). Contact information for the local laboratory used to conduct contamination analysis for this research is provided below. There are other testing laboratories in the Vancouver-area and mention of this particular laboratory does not indicate preference or endorsement. Before sampling, contact the laboratory of your preference to find out price listings, their particular sampling requirements, and methods of analysis. Some laboratories provide glass jars and coolers with ice packs for sampling.

Maxxam Analytics (formerly Cantest Laboratory) 4606 Canada Way Burnaby, BC Canada V5G 1K5 Tel: (604) 734-7276 Toll-free: 1-800-665-8566

TABLE 3 CONTAMINATION ANALYSIS LABORATORY CONTACT INFORMATION

SAMPLING PROTOCOLS FOR CONTAMINATION ANALYSIS

When soil sampling, you will need: a shovel, a metal and/or plastic trowels, a metal and/or plastic bucket, glass jars, and a cooler with ice packs.

To take a sample:

1) Dig a soil pit approximately 30 cm deep
2) Place trowel 2-3 cm from the edge of the pit and remove a portion on the soil pit wall (Figure 2)
3) Cut a rectangle of soil from the centre of the trowel to keep as the sample. Discard soil on either side of the trowel (Figure 3). This will ensure an equal representation of soil from all depths.

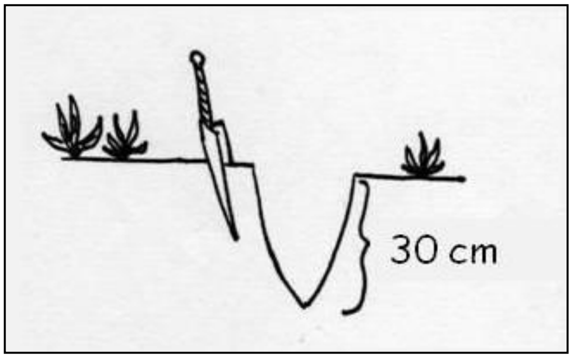


FIGURE 2 TAKING A SOIL SAMPLE (A)

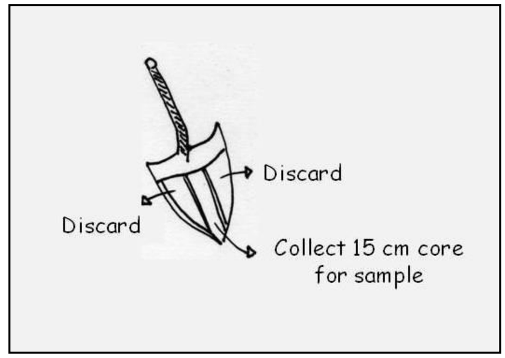


FIGURE 3 TAKING A SOIL SAMPLE (B)

If contaminants of concern are metals or metalloids, do not use a metal trowel or metal bucket. If contaminants of concern are organic compounds, such as petroleum-based contaminants (i.e. gasoline, oil, etc.), do not use plastic trowels, buckets, bags or containers. Store samples in glass containers and keep cool (under 10° C) until analyzed. Clean sampling devices between each sample.

FIGURE 4 LABELING EACH SOIL SAMPLE FOR IDENTIFICATION
PHOTO CREDIT: MELISSA IVERSON

One cost-effective sampling technique is composite sampling. This is when you mix together soil samples taken from similar areas of the site to get an average among those similar areas. Soil samples taken from areas with differing vegetation, soil textures, compaction levels, or elevations (down-slope or up-slope) should **not** be mixed into the same composite sample.

Always record in your notes the areas you have sampled, and give your soil samples names that clearly reflect where they were taken from.

The British Columbia Ministry of Agriculture and Lands published a detailed factsheet on soil sampling (Hughes-Games and Schmidt 2005). A copy of this 4-page factsheet is provided in the appendix (pg 144).

Interpreting Your Results

When results return from the lab, compare them to the table below. Values at or under the government-set limits (provided in the right-hand column) indicate soils that are a safe for growing plants.

TABLE 4 GOVERNMENT LIMITS FOR METALS

Substance	Unit	Government Limit
Antimony	ug/g	20
Arsenic	ug/g	20
Barium	ug/g	500
Beryllium	ug/g	4
Boron	ug/g	2
Cadmium	ug/g	3
Chromium	ug/g	250
Cobalt	ug/g	40
Copper	ug/g	100
Fluoride	ug/g	200
Lead	ug/g	375
Mercury	ug/g	0.8
Molybdenum	ug/g	5
Nickel	ug/g	100
Selenium	ug/g	2
Silver	ug/g	20
Sulphur (elemental)	ug/g	500
Thallium	ug/g	1
Tin	ug/g	5
Vanadium	ug/g	200
Zinc	ug/g	500

It is important to note that government contamination limits are provided in ***total values***, and not ***plant- or bio-available values***. This means that the metal concentrations provided by the laboratory are in the soil, but plants are not necessarily able to take them up. Because of this, it is important to determine the naturally occurring background metal levels for the location. In Vancouver, British Columbia, elevated levels of iron and aluminum are to be expected due to the ***iron- and aluminum-oxides*** characteristic of the region's ***Podzolic soils***. This iron and aluminum is not toxic to plants or humans.

IS YOUR SITE'S SOIL AND MICROCLIMATE SUITABLE FOR A GARDEN?

VANCOUVER'S NATIVE SOILS

This section contains descriptions of Vancouver's ***native soils***. These soils may be entirely present, partially present, or absent at the predicted locations. If entirely or partially present, this section will help identify characteristics and management practices for each soil. If absent, this section will help characterize the type, and extent of alterations that have occurred on a site.

The City of Vancouver possesses three main soil management groups, though others are present to a lesser extent. These predominant soil management groups are: Bose-Heron, Whatcom-Scat, and Langley-Cloverdale. Each group is located in a particular elevation range, making identification possible. Elevations greater than 65 meters above sea level (MASL) indicate Bose-Heron soils; elevations between 35 and 65 MASL indicate Whatcom-Scat soils, and; elevations below 35 MASL indicate Langley-Cloverdale soils (see Figure 5). Within each of these management groups, soils differ in terms of ***internal soil drainage***, based on ***topography***. Descriptions for the soil series constituting each management group were taken from (Luttmerding 1984), following the model used in the Soil Management Handbook for the Lower Fraser Valley (Bertrand et al. 1991), which can be found at:

www.agf.gov.bc.ca/resmgmt/publist/600Series/6100001_Soil_Mgmt_Handbook_FraserValley.pdf

Minor inclusions of other soil series (Boosey in Bose-Heron, and Berry in Whatcom-Scat and Langley-Cloverdale) were omitted from management group descriptions due to limited presence. Descriptions for Boosey and Berry soils can be found in (Luttmerding 1984).

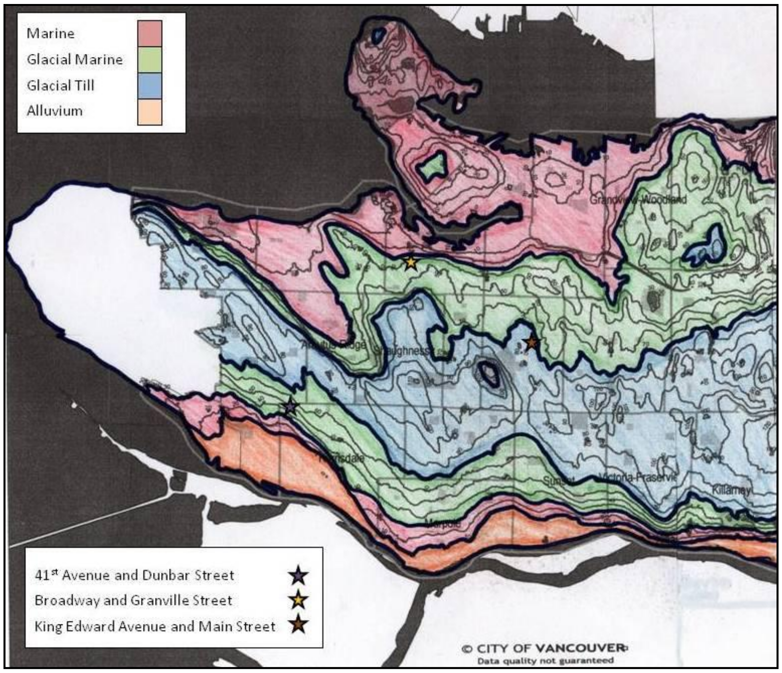


FIGURE 5 THE DIFFERENT SOIL MANAGEMENT GROUPS OF VANCOUVER, BRITISH COLUMBIA

Bose-Heron Management Group

Bose-Heron Soils, found above 65 MASL, range from moderately-well to well-drained in higher landscape positions, to poorly drained in depressions. They consist of a gravelly sandy loam or loamy sand texture near the surface and are approximately a meter thick. They lie on top of impervious ***glacial till parent material***. Soils in this management group will have a low water-holding capacity and ***cation exchange capacity***. For gardening, these properties can be improved with the addition of organic matter. These soils also possess a high ***coarse fraction*** content that can be remedied through rock-picking. Low-lying areas (Heron Series) may have high ***water tables*** that can impact soil rooting depth. In the absence of surface drains or ditches, additional soil (in raised beds, etc.) should be supplemented in such cases.

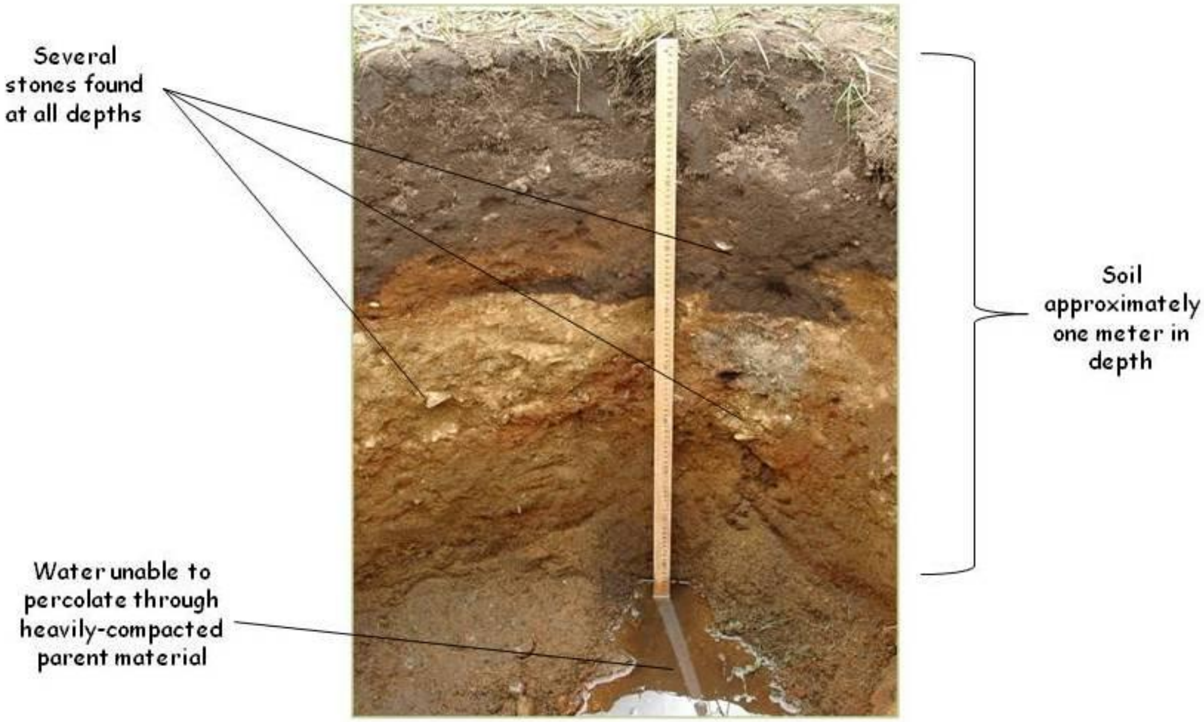


FIGURE 6 BOSE-HERON SOIL MANAGEMENT GROUP
PHOTO CREDIT: RACHEL STRIVELLI

WHATCOM-SCAT MANAGEMENT GROUP

Whatcom-Scat soils are found from 35 MASL to 65 MASL. They are moderately-well to well-drained in higher landscape positions and poorly drained in depressions. Possessing a finer texture than their Bose-Heron counterparts, Whatcom-Scat soils consist mainly of silt loam and silty clay loam. They overlie ***glacial marine material***. This parent material is not impervious, like the glacial till underlying Bose-Heron soils, but does not rapidly drain. Limited rooting depth caused by a high water table in the wintertime, and poor drainage are the limiting factors for gardening in these soils. Installing subsurface drainage or importing additional soil (to increase the soil depth) can correct for these shortcomings in order for ***perennial crops*** to be grown. The finer texture of this soil management group leads to increased water-holding capacity and cation exchange capacity. Fewer rocks are present in these soils than in the Bose-Heron management group. Existing rocks can be removed through rock-picking. Overall, these soils possess a high urban-agricultural capability and should be retained in place and improved. These soils are often mistakenly removed from landscaped sites and replaced with inferior human-made growing media.

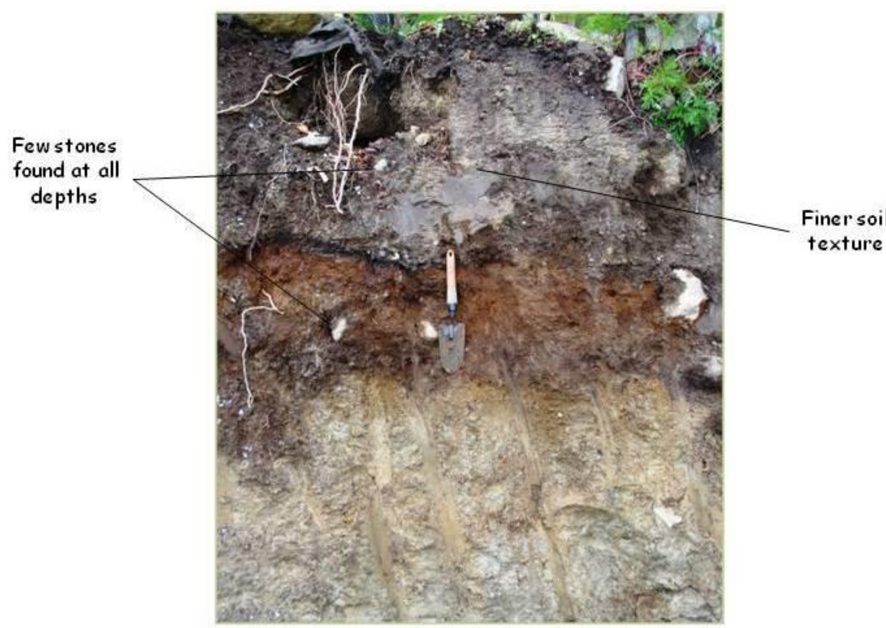


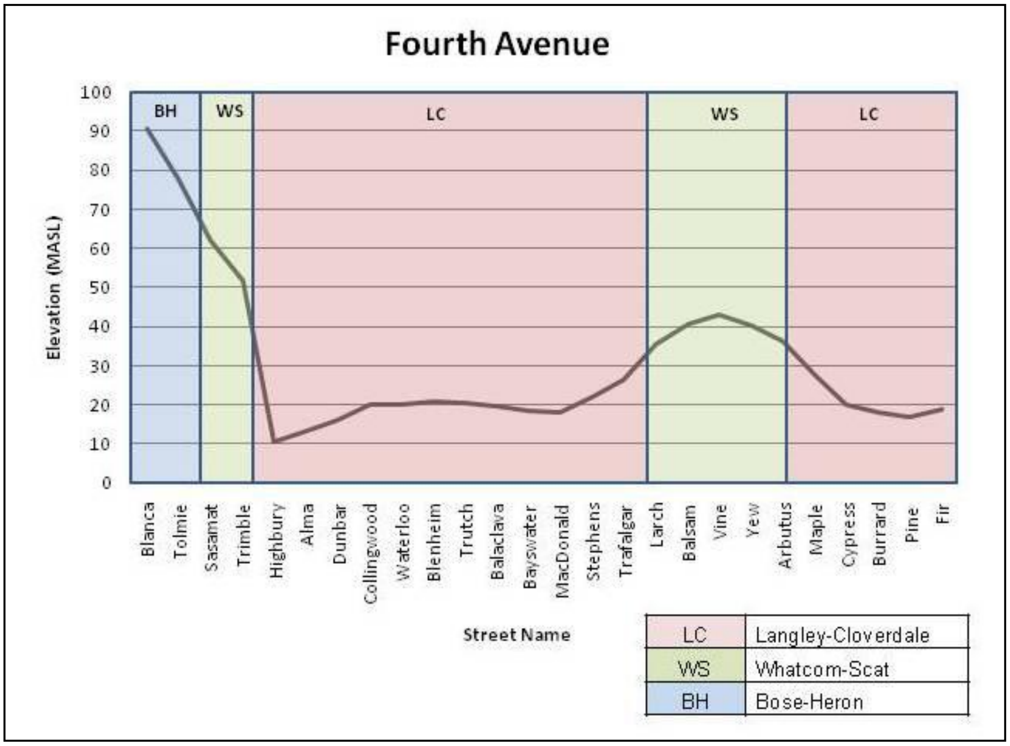
FIGURE 7 WHATCOM-SCAT SOIL MANAGEMENT GROUP
PHOTO CREDIT: MELISSA IVERSON

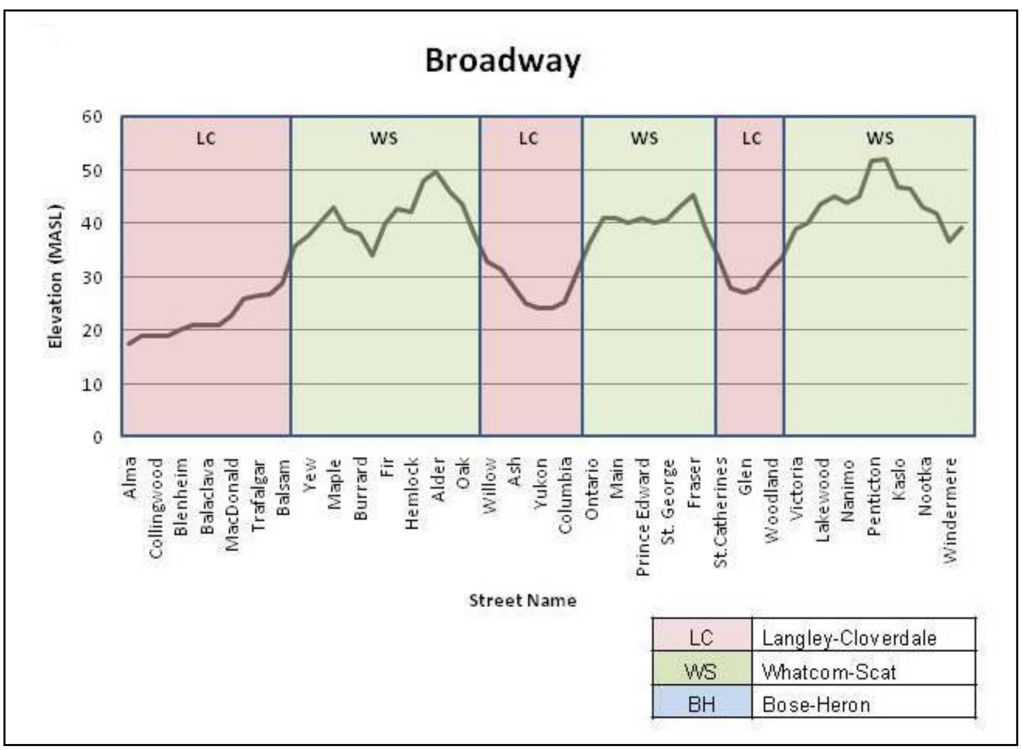
Langley-Cloverdale Management Group

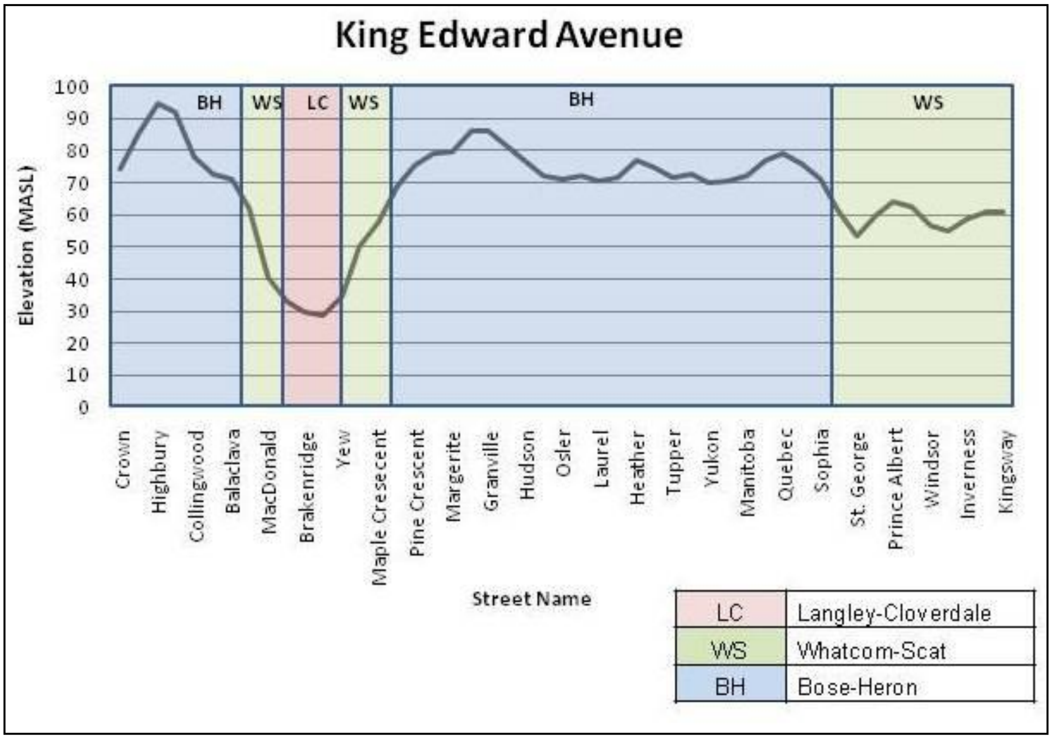
Langley-Cloverdale soils are found below 35 MASL. They are moderately-poor to poorly-drained, have a fine texture, silty clay loam, or clay loam, and tend to be stone-free. They have developed on top of ***marine parent material***. These soils may benefit from the addition of organic matter in order to increase soil aeration. Similar to the Whatcom-Scat management group, these soils can suffer from poor drainage and high ***perched water tables*** in the wintertime. For perennial crops, additional soil or subsurface drainage is needed. Limit traffic on these soils in the wetter months, as they are easily compacted when wet. Raised beds may be a useful management option.

FIGURE 8 LANGLEY-CLOVERDALE SOIL MANAGEMENT GROUP
PHOTO CREDIT: MELISSA IVERSON

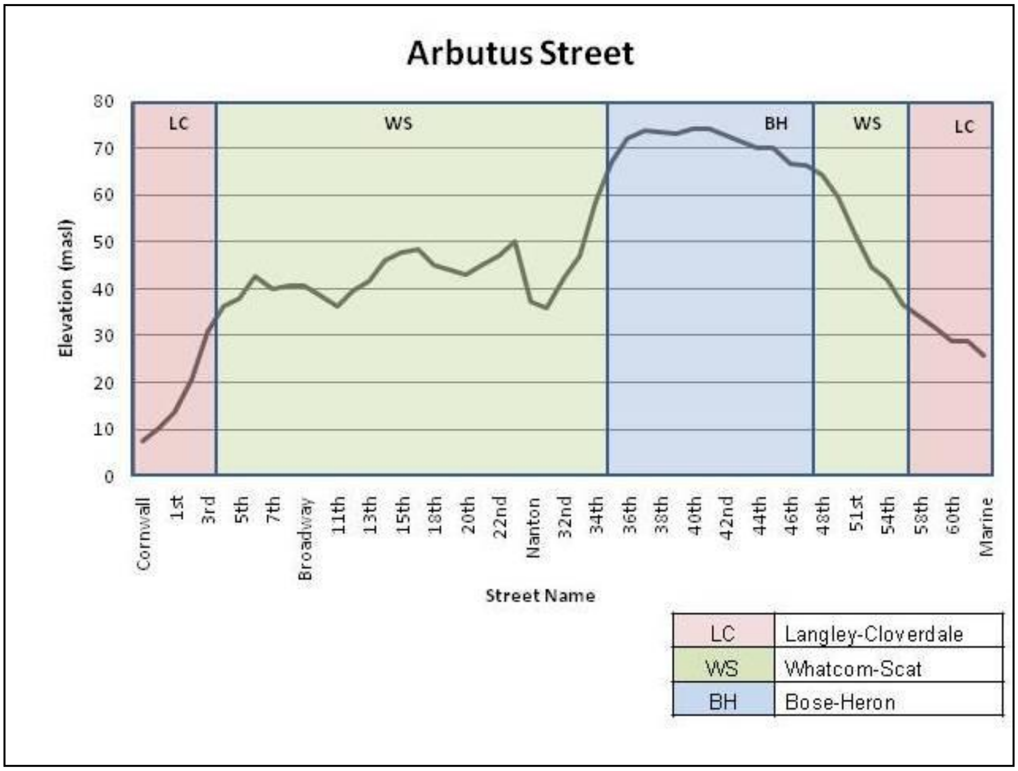
Identification of soil management groups along six of Vancouver's major thoroughfares, Fourth Avenue, Broadway, King Edward Avenue, 41st Avenue, Arbutus/West Boulevard, and Main Street, are provided on the following pages.



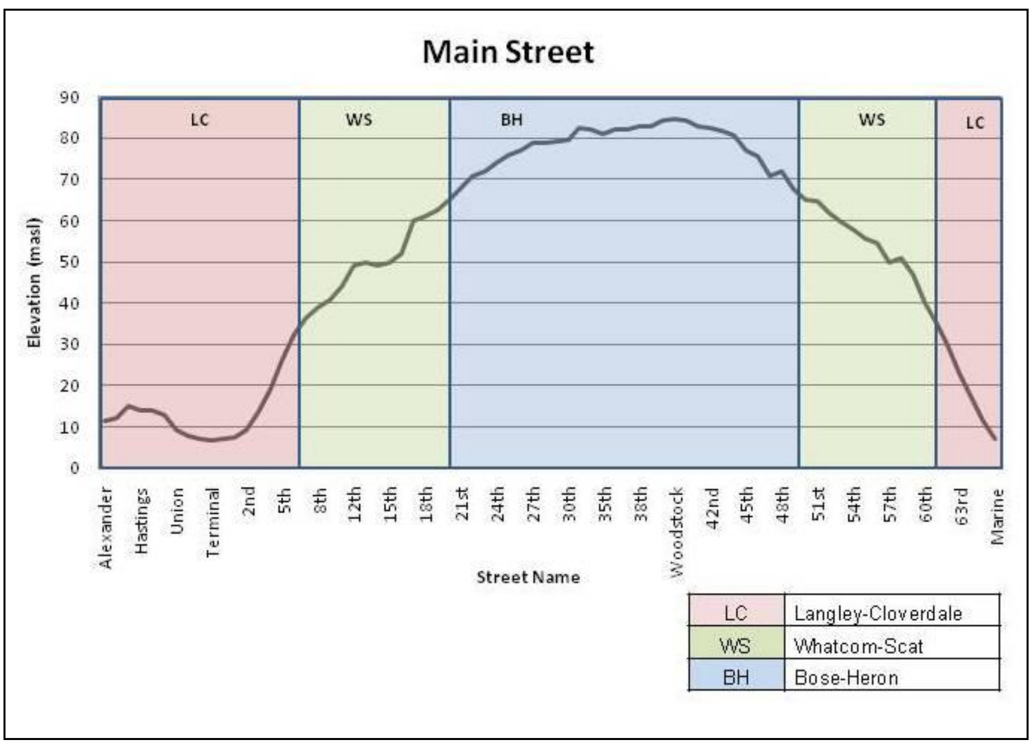



King Edward Avenue
Elevation (MASL)
100
90
80
70
60
50
40
30
20
10
0
BH
WS
LC
WS
BH
WS
Crown
Highbury
Collingwood
Balaclava
MacDonald
Brakenridge
Yew
Maple Cresecent
Pine Crescent
Margerite
Granville
Hudson
Osler
Laurel
Heather
Tupper
Yukon
Manitoba
Quebec
Sophia
St. George
Prince Albert
Windsor
Inverness
Kingsway
Street Name
LC Langley-Cloverdale
WS Whatcom-Scat
BH Bose-Heron


41st Avenue
Elevation (MASL)
120
110
100
90
80
70
60
50
40
30
20
10
0
LC
WS
BH
Camosun
Wallace
Alma
Blenheim
MacKenzie
Larch
Yew
Cypress
Churchill
Hudson
Oak
Heather
Cambie
Columbia
Quebec
Prince Edward
Prince Albert
Ross
Culloden
Dumfries
Bruce
Victoria
Clarondon
Earles
Rupert
McKinnon
Street Name
LC Langley-Cloverdale
WS Whatcom-Scat
BH Bose-Heron



Arbutus Street
Elevation (masl)
80
70
60
50
40
30
20
10
0
LC
WS
BH
WS
LC
Cornwall
1st
3rd
5th
7th
Broadway
11th
13th
15th
18th
20th
22nd
Nanton
32nd
34th
36th
38th
40th
42nd
44th
46th
48th
51st
54th
58th
60th
Marine
Street Name
LC Langley-Cloverdale
WS Whatcom-Scat
BH Bose-Heron



Main Street
Elevation (masl)
90
80
70
60
50
40
30
20
10
0
LC
WS
BH
WS
LC
Alexander
Hastings
Union
Terminal
2nd
5th
8th
12th
15th
18th
21st
24th
27th
30th
35th
38th
Woodstock
42nd
45th
48th
51st
54th
57th
60th
63rd
Marine
Street Name
LC Langley-Cloverdale
WS Whatcom-Scat
BH Bose-Heron

Soil and Microclimate Assessment

To determine the quality of the site's soil and microclimate, please complete the 11-step Soil and Microclimate Assessment on the following pages.

To complete the Assessment, you will need:

- A shovel,
- A trowel,
- A compass,
- The soil texture guide found in the Appendix
- Plastic bags,
- Masking tape and pen (to label the samples),
- A pick ax if the soil is compacted, and
- A pen/pencil to write down your observations.

FIGURE 9 SOIL AND MICROCLIMATE ASSESSMENT IN ACTION

PHOTO CREDIT: CHRIS THOREAU

The Assessment should be completed in multiple areas around your site since conditions can differ within small areas.

Soil and Microclimate Assessment in 11 Steps

1

Looking over the entire garden site, do you observe features (large stones, concrete slabs, pooling water, etc.) that would detract from a garden site?

A site free of extraneous material, that allows water to infiltrate and not puddle, is ideal.

2

Is the site covered in vegetation? If so, does it appear healthy?

Presence of healthy, abundant vegetation is a good indication that soil conditions are conducive to plant growth.

3

Dig a pit 50 cm deep

While digging, take note of the level of difficulty required to excavate the soil at different depths.
Determine whether difficulties are due to dense plant cover, compaction, or the presence of rocks or human artifacts.

A productive soil will have ample rooting volume that is not restricted by several stones or human artifacts, a rooting depth of 20 cm, and uncompacted soil to a depth of 50 cm to allow for adequate drainage is recommended.

4

Does the soil near the surface appear to be dark brown or black?

Organic matter is important as a source of nutrients, water-holding capacity, aeration, and nutrient holding capability can usually be recognized for its rich dark colour.

5

Are earthworms abundant in your soil (are they easily spotted when digging)?

There should be an abundance of earthworms near the surface under moist conditions.

6

Observe the pile of soil you excavated from the pit. What percentage of the soil is made up of stones larger than 2 cm in diameter?

If several stones are present, they may restrict the rooting volume of your plants and hinder their growth.

7

Take a handful of the soil you excavated from the pit. From this soil determine the texture of your soil, following the hand-texturing guide provided.

A texture that demonstrates characteristics of all three textural classes (loamy) is preferred. Sandy or clayey soils can be augmented with organic matter to improve soil physical properties.

8

Take a handful of the soil you excavated from the pit. Do the soil particles clump together to form *aggregates*?

Good structure is characterized by the presence of aggregates, or clumps of soil particles.

9

Is the site located on a slope? If so, which direction is the slope facing (*aspect*)?

A slightly sloping site with a south-facing aspect provides the most access to sunlight.

10

Are there any objects on or adjacent to the site that block access to sunlight?

The fewer restrictions on sunlight the better, though most plants require a minimum of 6-8 hours of sunlight a day.

11

Are important nutrients such as nitrogen, phosphorus and potassium found in adequate levels in your soil?

Laboratory analysis is required to determine these levels. Collect samples for analysis. Information on sampling and result interpretation is provided below.

NUTRIENT ANALYSIS

Compile a composite sample, representing the entire area of your site, for laboratory nutrient analysis. If one area of the site seems different than the rest, do not include it in this sample. For useful information and instructions, please refer to the soil sampling factsheet found in the appendix (pg 142) and instructions and figures provided in the section titled Sampling Protocols for Contamination Analysis (pg. 116).

Nutrient analysis is important because it provides information on possible nutrient deficiencies, ***pH*** and possible ***lime*** requirements, as well as total organic matter and nitrogen. Early diagnosis of nutrient deficiencies and lime requirements allows time for management remedies, helping ensure the success of the garden. Knowledge of organic matter amounts is also important as a long term indicator of soil quality.

Contact information for a laboratory in the Vancouver area that runs soil nutrient assessments is provided below. We are not aware of other local laboratories that analyze soil samples for available nutrients. The laboratory listed below was used while conducting this research.

Pacific Soil Analysis Inc. #5 - 11720 Voyageur Way Richmond, BC V6X 3G9 Tel: 604-273-8226

TABLE 5 SOIL FERTILITY LABORATORY CONTACT INFORMATION

Different soil laboratories use different testing methods. These methods may be comparable in terms of reliability, but values resulting from different methods should not be compared. Therefore, once you decide on a testing laboratory, it is beneficial to return to the same laboratory for testing in subsequent years. This ensures an accurate comparison of nutrient values over the years.

Can soil and microclimatic quality issues be resolved through management?

After identifying possible soil and microclimate quality issues, use the management solutions table and the nutrient analysis interpretation information in this section to select an appropriate course of action.

Management Solutions

The table below provides a list of barriers to soil and microclimate quality and corresponding management solutions.

TABLE 6 GARDEN SITE QUALITY ISSUES AND CORRESPONDING MANAGEMENT SOLUTIONS

Soil Attribute	Barrier to Garden Development	Management Options
1. Compaction	Compacted soil	Rototill or aerate the soil with hand tools In severe cases, uses a backhoe to break up the soil Install raised beds with subsurface drainage Add organic matter
2. Soil depth	Depth under one meter	Import soil, install raised beds
3. Stoniness	% coarse fragments	Remove stones
4. Texture	Coarse or fine texture (high % sand or %clay)	Add organic matter
5. Soil organic matter	Low organic matter percentage	Add compost Plant green manure crops such as crimson clover or hairy vetch
6. Soil reaction	pH under 5.5 or over 7	Low pH – add lime High pH – If plants seem healthy, no remediation is needed. If not, add iron- or aluminum-sulfate, or organic matter with pine needles or oak leaves
7. Nutrients	Lower than recommend amounts	Fertilize the soil using organic-approved materials Institute a garden composting system
8. Topography/aspect	Steep slope north-facing aspect	Site design (terracing, leveling) Plant selection (plants with low light requirements*)
9. Sun exposure	Sunlight blocked by on- or off-site structures	Site design (shade avoidance) Plant selection (plants with low light requirements*)

***IN GENERAL, LEAFY VEGETABLES (I.E. SPINACH, LETTUCE, CHARD, ARUGULA, ETC.) ARE THE MOST SHADE-TOLERANT VEGETABLES. ROOTING VEGETABLES (I.E. POTATOES, BEETS, CARROTS, AND TURNIPS) AND VEGETABLES IN THE BRASSICA FAMILY (I.E. BROCCOLI, KALE, KOHLRABI, CABBAGE, ETC.) REQUIRE AN INTERMEDIATE AMOUNT OF SUN EXPOSURE (AT LEAST A HALF DAY OF FULL SUN). FRUITING VEGETABLES, SUCH AS TOMATOES, PEPPERS, SQUASH, EGGPLANTS, REQUIRE THE MOST SUN EXPOSURE.**

Recommended Nutrient Amounts

After receiving laboratory results for nutrient analysis, compare the concentrations with recommended amounts provided in the Table below. Laboratory methods and units of measurements used by the laboratory need to be the same as those used in the interpretation guide in order to effectively compare results.

TABLE 7 RECOMMENDED NUTRIENT AMOUNTS*

Soil Property	Recommended Amount	Excessive Amount	Method[‡]
pH	6-7.5	-	Potentiometrically determined using 1:1 soil to distilled water slurry and radiometer conductivity cell (Thomas 1996)
Organic matter	>10%	-	Walkley-Black wet oxidation method (Nelson and Sommers 1996)
Total Nitrogen	>0.2%	-	Colourimetrically determined using a Technicon Autoanalyzer – semi micro Kjeldahl digest (Bremner 1996)
Phosphorus	40-100 ppm	>100 ppm	Colourimetrically determined using ascorbic acid colour development method on a 1:10 soil: Bray 0.03 M NH_4F in 0.025 M HCl extract (Bray P1) (Kuo 1996)
Potassium	250-800 ppm	>800 ppm	Determined by Perkin-Elmer Atomic Absorption Spectrophotometer on a 1:5 soil to ammonium acetate extract (Helmke and Sparks 1996; Suarez 1996)
Calcium	1000-2000 ppm	-	
Magnesium	180 ppm	-	
Boron	1-2 ppm	-	Colourimetrically determined on a hot water soluble extract using the azomethine-H method (Keren 1996)
Sulfate-sulfur	>10 ppm	-	Hi-Bismuth reducible method on a 1:2 soil to calcium chloride extract (Tabatabai 1996)

*RECOMMENDED RANGE FOR VANCOUVER'S SOILS

†PPM, OR PARTS PER MILLION, IS EQUAL TO UG/G, OR MICROGRAMS PER GRAM

‡METHODS LISTED FOR THESE INTERPRETATIONS ARE THE SAME AS THOSE USED BY COMMERCIAL LABORATORY PSAI

In addition to the table provided above, there are two helpful soil test interpretation guides for Northwest soils. The first (Marx, Hart, and Stevens 1999), published in affiliation with Oregon State University can be found at:

http://www.koin.com/Sites/KOIN/pdfs/2008_watershed/soil_test_interpretation.pdf

Another useful soil interpretation guide is titled *Soil Testing Methods and Interpretations* (Neufeld 1980). Unfortunately, it is not available online at this time.

When using either of these interpretation guides, ensure the laboratory methods used are the same as those specified by the interpretation guide. Each guide provides different ranges for each nutrient (high, medium low or excessive, high, deficient). Concentrations falling under the "high" designation are recommended for Vancouver's soils because of their high coarse fraction (particles larger than 2 mm in diameter) percentage.

IS SOIL IMPORTATION A SUITABLE OPTION?

The use of native soil is preferred if they are suitable for garden use. If shallow soil depth or contamination is identified through the assessment process, soil importation may be a good option.

Sources for imported soil include opportunistic obtainment, donation, or purchase. Soil excavations that occur in conjunction with construction are one opportunist source of soil, and can be learned about through the City's Engineering Department. Check source site history to ensure that it is non-contaminated. A Yard-Trimmings Compost and sand mixture can be donated by the City of Vancouver Transfer and Landfill Operations, Delta, following a brief application process. Garden and landscaping stores sell soils that vary in terms of ingredients, source location, and quality. Do not assume that the imported soil will immediately support plant growth without fertilization or liming. Despite having a dark colour and appearing fertile, most imported soils supply inadequate available nitrogen and should be sampled and tested to determine of other nutrients or lime are needed. This may be true even if the imported soil has a high percentage of organic matter.

FIGURE 10 ADDING AN IMPORTED SOIL MIX TO RAISED GARDEN BEDS AT THE CEDAR COTTAGE GARDEN

PHOTO CREDIT: MELISSA IVERSON

When importing soil, consider the following:

- How much soil is needed?
- How will the soil be delivered to the site?
- If it is delivered by a large truck, how will the vehicle access the site?
- Where should the soil be dumped on the site?

Make sure you are not importing contaminated or nutrient deficient soil to your site. Depending on where you source your material from, you may be able to request the results of nutrient and/or contamination analyses. If contamination analysis has not been conducted, return to the Site Assessment Decision Tree on page 110 of this guide, and carry out the suggested activities to the imported soil.

Glossary

Aggregates – Many soil particles held together in a single mass or cluster. Soil aggregates form different shapes, such as crumb, block-like, or prismatic.

Annual crops – A plant that experiences its complete lifecycle in one year, ending in death. Lettuce, peas, and corn are examples of annual vegetable crops.

Aspect – The direction a slope is facing – north, east, south, west, or a combination thereof.

Bio-available values – The amount of an element – nutrient or non-essential metal – in a form that is available for plant uptake.

Brownfield – A neglected, abandoned, derelict site, commonly found in urban centres.

Cation exchange capacity – Plant nutrients exist in the soil as cations, or positively charged ions. Cation exchange capacity (CEC) is the sum total of exchangeable cations that a soil can adsorb. Therefore CEC represents the amount of nutrients a soil is able to hold.

Coarse fraction content – The percentage of soil particles larger than 2 mm in diameter. These large soil particles include gravel and stones that take up rooting volume and don't effectively hold nutrients.

Compaction – The amount of soil porosity (pores are the places where air and water is stored in a soil). A compact soil will have little room for water and air pores, and will also be difficult to dig.

Composite (samples, sampling) – A sampling method where soil samples from similar areas of a site are combined in order to reduce laboratory costs or time spent conducting analysis.

Extractable petroleum hydrocarbons – A group of common contaminants in urban soils made up of petroleum products such as oils, gasoline, and lubricants.

Glacial marine (parent material) – A parent material created in a marine environment influenced by glacial activity.

Glacial till (parent material) – A parent material consisting of a mixture of clay, silt, sand, and boulders, deposited and compacted by a glacier.

Internal soil drainage – the downward movement of water through a soil.

Lime – A soil amendment used to raise soil pH. Chemically, lime is composed of calcium carbonate.

Marine (parent material) – Parent materials formed in a marine environment, predominantly influenced by the ocean.

Metalloid – A non-metallic element that has some properties of a metal, such as arsenic.

Microclimate – Those climates in close proximity to the soil, in the realm of plant and animal life.

Native soil – Soil formed and developed in situ, and not imported from offsite.

Parent material – mineral or organic material, on top of bedrock, from which soil is developed.

Perched water table – A zone of saturated soil held above the main body of groundwater by an impermeable layer and a dry zone. Impermeable layers, or "hardpans" can be caused by glacial till parent material, or human-introduced materials (such as buried slabs of asphalt) under the soils surface.

Perennial crops – Plants that live for longer than two years. Asparagus, leeks, and eggplant are examples of perennial vegetable crops.

pH – The concentration of hydrogen ions in the soil. The lower the pH, the more acidic the soil - the higher the pH, the more alkaline the soil (on a scale of 1-14). A pH between 6-7.5 is suitable for most plants, though some plants prefer soils that are more acidic or more alkaline.

Plant-available values - See "bio-available values"

Podzolic soil – one of the ten soil orders of Canada (a classification system for soil identification). Podzolic soils are prominent in the Vancouver region, and are acidic and coarse-textured. They are commonly identified by a reddish B-Horizon (the second soil layer from the surface).

Rooting depth – The depth of soil that is available for plant roots without physical restriction. Also referred to as the rooting zone.

Soil structure – The combination or arrangement of soil particles to form aggregates (see "aggregates").

Soil texture – the relative proportion of particle sizes ranging from fine- to –coarse textured. These particle sizes include: clay (less than 0.002 mm), silt (0.002-0.005 mm), and sand (0.005-0.02 mm). An example of a fine-textured soil is silty clay. An example of a coarse-textured soil is loamy sand.

Strong acid soluble metals – Metals such as lead, copper, and cadmium, which are made soluble when extracted with a mixture of nitric and hydrochloric acids by testing laboratories.

Structure – See "soil structure".

Texture - See "soil texture".

Topography – The physical features of the earth's surface, such as elevation and slope.

Total values – The amount of an element – nutrient or non-essential metal – in a form that may or may not be accessible to uptake by plants

Water table – The upper level of groundwater, or the level below which the soil is saturated with water

Acknowledgements

I would like to thank Dr. Art Bomke for sharing his tremendous ideas, valuable insights, and tireless passion for building healthy communities. Art's guidance, patience, and knowledge, provided at every stage of this project, made the completion of this guide possible.

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Thank you to David Tracey of the Vancouver Community Agriculture Network, and Samantha Charlton of the Environmental Youth Alliance for sharing their knowledge, support, and experiences with me on an ongoing basis. I am deeply grateful for the valuable community connections they provided, which were critical in the shaping of this project.

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About the Author

Born in Chicago, Illinois and raised in Portland, Oregon, Melissa Iverson has spent her entire adult life in one of Canada's most beautiful cities; Vancouver, British Columbia.

Melissa began her love affair with urban agriculture at the tail-end of her undergraduate degree from UBC's faculty of Land and Food Systems, as she became increasingly aware of the costs the current food system imposes on human and ecological health. A curiosity and fascination with soil, one of our most precious (and all-too-often neglected) resources, brought Melissa back to UBC in 2006, where she began a Master's degree in soil science. Since that time, Melissa has been working with communities in Vancouver to find accessible and accurate ways of assessing urban brownfields, neglected and derelict lots, for community gardens. Through these adventures in Vancouver's urban agriculture scene, Melissa has participated in the creation of seven community gardens, witnessing the struggles and triumphs of folks that wish to create spaces to grow their own food, connect with their neighbours, or simply just get their hands in the dirt. This Site Assessment Guide is the product of these experiences and research.

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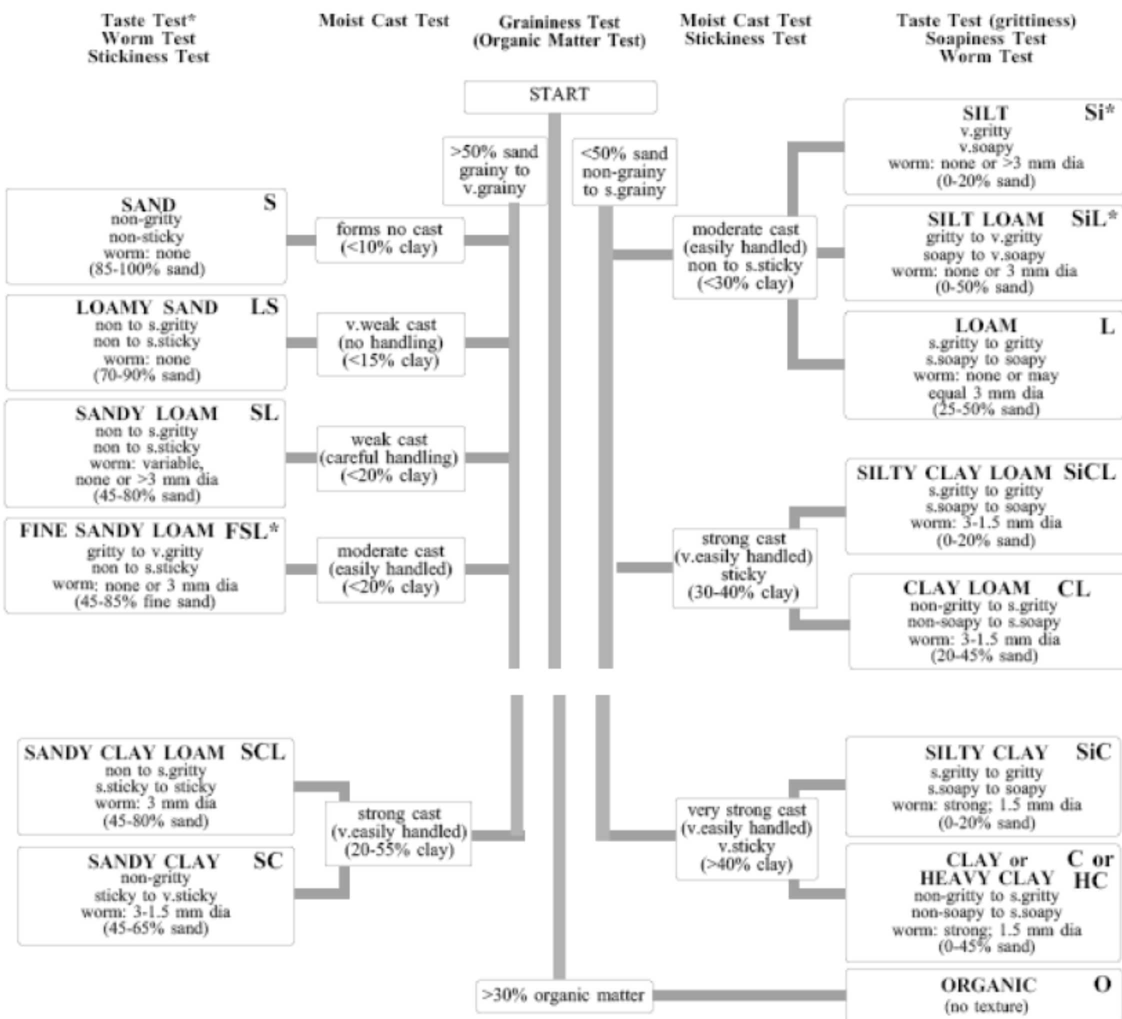
APPENDIX

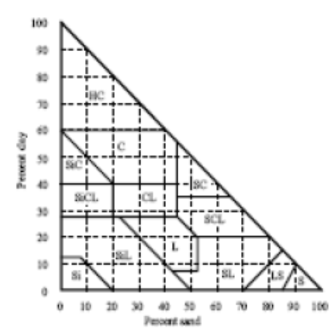
HAND TEXTURING GUIDE



* Silt feels slippery or soapy when wet; fine sand feels stiffer, like grinding compound or fine sandpaper.

Key to Abbreviations	Measurement Conversions
s = slightly	3.0 mm = 1/8"
v = very	1.5 mm = 1/16"
dia = diameter	

Fine Fraction	(particle diameter)
SAND -------------- (S)	2 - .05 mm
SILT --------------- (Si)	.05 - .002 mm
CLAY -------------- (C)	<.002 mm



Nutrient Management FACTSHEET

BRITISH COLUMBIA
Ministry of Agriculture and Lands

Nutrient Management Factsheet - No. 1 in Series

Order No. 631.500-1
October 2005

SOIL SAMPLING FOR NUTRIENT MANAGEMENT

In Nutrient Management Planning, soil sampling is done to collect a soil sample for lab analysis that represents the variability in the soil of the field being sampled. To do this many small samples will be collected and mixed together to make one composite sample for each field. The results are used to determine what level of additional nutrients, if any, are required for the crop(s) being grown.

There are a number of steps to follow as outlined below to ensure that a representative sample is collected. There are qualified professional agrologists throughout the province who will do soil sampling; contact the closest BCMAL office or the BC Institute of Agrologists (1-604-855-9291) for a list in your area. Factsheet 631.500-7 ***B.C. Agricultural Testing Laboratories*** contains a list of BC labs that do agricultural soil analyses.

When to Collect Soil Samples

Check with the chosen lab as to their turnaround time for soil analysis. Samples may need to be collected 2-3 weeks before the intended time of manure application to give the lab enough time to complete the required analyses. Annual sampling should occur at approximately the same time each year.

South Coastal BC: Soil samples should be collected in late spring, as close as possible to the start of field work provided there is enough time for the lab analyses.

Interior BC: Fall or spring sampling is acceptable in Interior areas. There is minimal loss of soil nitrate-N over winter so a fall soil sample will be as accurate for estimating the soil nitrate-N level as a spring sample. Sample after crop growth has stopped in late September or October, depending on the farm location. If manure has been applied in fall, particularly dairy manure on corn land, a spring soil test which includes ammonia-nitrogen should be done.

Sampling Frequency

Annually cropped fields should be sampled once per year, in late spring just prior to manure application. Fields in perennial forage should be sampled before they are reseeded and thereafter once every 3 years until they are reseeded.

Sampling Strategy

Before beginning soil sampling, consider the variability within each field on the farm. Fields up to 10 ha (25 acres) in size that are fairly level, have a similar soil type throughout and have been farmed for several years as a single unit can be sampled as one unit.

Fields that have significant variability in them should be subdivided into similar units. Variability may be due to topography, eroded areas, sandy vs. clay-rich areas, or sections of a field that have previously been farmed separately and may have received different amounts of manure or fertilizer over the years. Divide such fields into similar units, and sketch the boundaries on a permanent map that is kept with the soil analysis records. Assign a number or name to each field unit. Fields that are otherwise similar but that are greater than 10 ha in size should be subdivided into sampling units of 10 ha in size. Once fields have been subdivided, always sample them in this configuration.

Sampling Pattern

For most agricultural fields that are relatively uniform, samples should be collected from throughout the field using a zig-zag or Z pattern. Avoid areas that are not cropped such as wet spots, or areas that might skew the analysis such as old manure stockpile sites or fertilizer spills. **Figure 1** shows an example of a random soil-sampling pattern (shown in yellow) and areas to avoid (shown in red).

Non-uniform fields should be subdivided into similar units and samples collected from each sampling unit using the same zig-zag or Z pattern as described above. If fields are greater than 10 ha in size, subdivide and sample from each 10 ha piece. Once a pattern has been chosen, always sample using the same pattern.

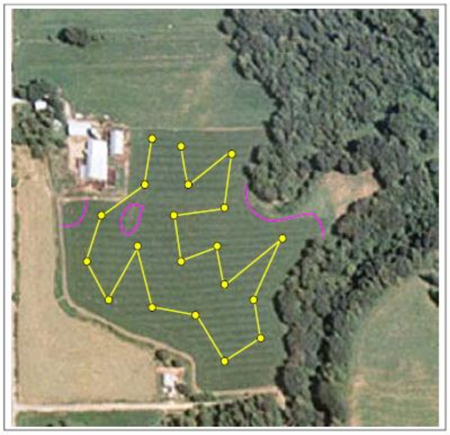


Figure 1 Random Soil Sampling Pattern

side of the hole to 15-20 cm (6-8 inches), and trim the slice to form a 2-3 cm (1 inch) wide core (**Figure 3**). Lift out the soil slice and place it into the sample bucket. If sampling for micro-nutrients or metals, ensure that the sampling equipment is clean, and has no rust on it as metals from the equipment itself can contaminate the sample. Wear rubber gloves for micronutrient and metal sampling

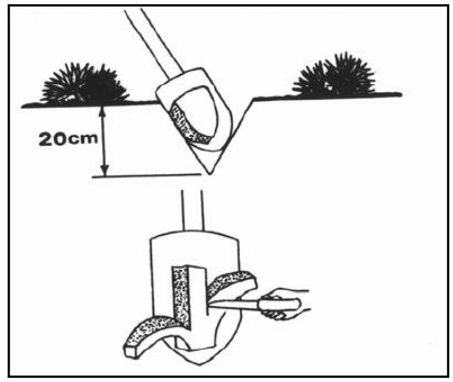


Figure 3 Shovel Method of Soil Sampling

Sampling Equipment

Samples can be collected using a soil sampling tube, an auger or a trowel. A soil sampling tube or soil probe (**Figure 2**) works best in well cultivated soils without rocks but is difficult to use in rocky, very dry or very wet soil. An auger or trowel is better for less well cultivated or rocky soils.

Figure 2 Soil Sampling Equipment

When sampling with a tube or auger, follow manufacturers' directions. When sampling with a trowel, make a V-shaped hole where the sample is to be taken. Take a 2-3 cm (1 inch) thick slice down one side of the hole to 15-20 cm (6-8 inches), and trim the slice to form a 2-3 cm (1 inch) wide core.

Sampling Depth

For routine nutrient analysis, and metal or micronutrient determination, collect samples to 15 cm deep (6 inches). Most manure and fertilizer nutrients will remain in the top 15 cm (6 inches) of soil. If sampling soil in the fall to monitor soil nitrate-N level, sample at two deeper increments, 15-30 cm (6-8 inches) and 30-60 cm (1-2 feet) if soil conditions permit as excess soil nitrate will move below the top 15 cm (6 inches) with fall rain. When sampling below 15 cm (6 inches), collect separate samples from each additional depth, and composite these separately.

For a further discussion of "report card" or post-harvest soil nitrate testing, see reference below.

> ***Post-harvest Soil Nitrate Testing for Manured Cropping Systems in Western Oregon and Washington***: available on the **Integrated Soil Nutrient and Pest Education** website at http://cropandsoil.oregonstate.edu/nm/

Tips for Sample Collection: Soil samples collected in perennial forage crops will have a layer of sod on top of the soil. Discard the top layer of dead leaves and roots above the mineral soil but not the roots that extend into the soil. When sampling in newly worked bare land, gently press down the soil with your boot before sampling to more accurately mimic the settled soil depth.

Making a Composite Sample

Collect 5 soil samples per ha for small fields or 15 to 20 samples per 10 ha (25 acres) field to make up the composite sample for each field. Each soil sample should be approximately the same size or weight. Place all samples in a clean plastic pail and mix well.

From the mixed samples, take out a small amount of soil (1/2 kg or 1 lb) and place into a heavy plastic bag or clean plastic container. This is the composite sample that will be used for lab analysis. It is very important that it be well mixed as the lab will use only a few grams of soil, and that small amount must represent equally all the cores that were initially placed in the pail.

If the soil is very wet at the time of sampling, it may mix more easily if it is air dried for a day. Use a trowel to break up lumps.

Sample Handling and Containers

Composite samples should be placed in plastic freezer bags or ½ to 1 litre clean plastic containers with screw top lids. Close samples tightly in bag or container. If samples are not to be taken to the lab immediately, place them on ice or freeze until transported to the lab. If shipping samples, ensure they reach the lab as quickly as possible.

Labeling

Clearly label samples with date, field or site identification, sampling depth (0-15 cm or other) and your name or the farm name. Bagged samples should be double bagged and a paper label placed between the two bags. Do not put paper labels in with soil as moisture may destroy label. Do not rely solely on information written on the outside of a plastic bag as it can easily rub off.

What Analyses are Required ?

To complete the nutrient management planning process, the following soil test information is required:

- available phosphorus (P) [Bray P1 or Kelowna]
- available potassium (K) [ammonium acetate or Kelowna]
- nitrate-nitrogen (NO_3-N)
- for spring soil tests in the Interior, ammonia-nitrogen (NH_4-N)

Other information may be included with the soil test report, such as soil concentrations of secondary and micro-nutrients, and metals, bulk density, pH and % organic matter. This is important information, and should be kept on record.

Laboratory Analysis Methods

The following section discusses various analytical methods used in BC to analyze soils for available phosphorus, potassium, and nitrate nitrogen.

Available Phosphorus

This lab method extracts a portion of the total phosphorus in a soil sample. The extracted portion or 'available phosphorus' mimics the amount of phosphorus that is plant-available at the time of sampling (the majority of soil phosphorus is bound up the soil and not immediately plant-available). There are several different extractants used to determine available phosphorus, but the standard analyses used in BC are the Bray P1 and the Kelowna extract.

The Bray P1 is a good predictor of plant-available phosphorus in acidic soils, and is used most frequently on soils from South Coastal BC. It is not considered suitable for high pH soils. The Kelowna extract was developed at the former Provincial Soil Test Lab in Kelowna from the Bray P1, and is the standard extractant used on high pH soils throughout BC and in the western Prairie provinces. It is also considered suitable for acidic soils. It is generally considered that the Kelowna method extracts slightly more phosphorus from soils than the Bray P1 method.

Available Potassium

This lab method extracts a portion of the total potassium in a soil sample. The extracted portion, or 'available potassium' mimics the amount of soil potassium that is plant-available at the time of sampling. In BC, two different extractants are used to determine available potassium, the Kelowna extractant (acetic acid and ammonium fluoride) and ammonium acetate, and each soil lab has its preferred method. It is generally agreed that the Kelowna method extracts about 20% less potassium than the ammonium acetate method.

Nitrate-Nitrogen

This lab method measures the amount of crop-available nitrate in the soil at the time of sampling. The nitrate present at the time of sampling is available for crop uptake over the growing season, but is only a portion of nitrogen that will be crop-available over the season. Nitrogen is released through the summer months by decomposition of organic matter, and adds to the pool of available nitrate in the soil. Unlike the available phosphorus and potassium, a spring soil nitrate test is not an indication of the amount of nitrogen available for that growing season.

Interpreting Lab Results for Nutrient Management Planning

To develop a Nutrient Management Plan, the following information is required from the soil test reports for each field:

- available phosphorus in ppm, ug/mL or mg/L (all are equivalent)
- available potassium in ppm, ug/mL, or mg/L
- nitrate-nitrogen in kg/ha (multiply value in ppm by 1.5)

On the soil lab report, the section where this information is found may be called soil test results, available nutrients, nutrient analysis or another similar term. The fertilizer recommendations are not required other than as a comparison with the recommendation generated by the nutrient management plan.

Converting from "parts per million" (ppm) to "kilograms/hectare" (kg/ha)

To do this conversion correctly requires knowledge of the soil bulk density (in kg/m^3) and the depth of the soil layer being sampled (in metres). If unknown, the suggested defaults are 1000 kg/m3 and 0.15 m (15 cm).

The sample calculation is:

Value in kg/ha = Value in ppm * 10,000 m^2/ha * 0.15 m / 1000 kg/m^3

OR Value in kg/ha = Value in ppm *1.5

Many labs rate the level of each nutrient in the soil as low, medium, high or very high, or deficient, marginal, optimum or excess to indicate how well the soil in each field is supplied with each nutrient. The soil nutrient rating scales for phosphorus and potassium used in the nutrient management planning process are close to those used by most commercial labs.

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