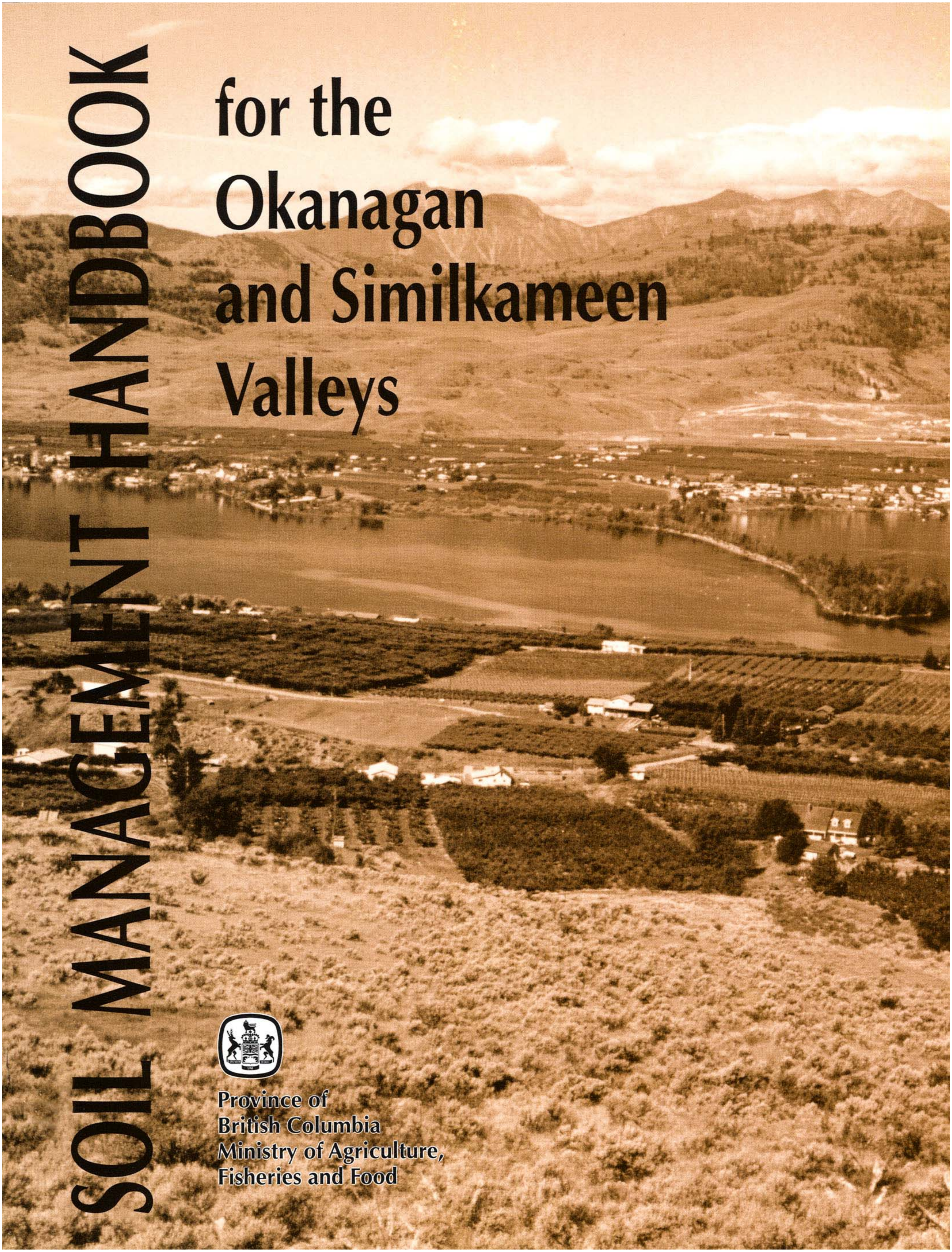
SOIL MANAGEMENT HANDBOOK for the Okanagan and Similkameen Valleys



Province of
British Columbia
Ministry of Agriculture,
Fisheries and Food

Soil Management Handbook For The Okanagan And Similkameen Valleys

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Preface

The Soil Management Handbook for the Okanagan and Similkameen Valleys has been prepared to facilitate the use of soil inventory maps and reports. The handbook provides information on the types of crops suited to the soils and climate of the Okanagan and Similkameen Valleys and the management inputs required to grow these crops. If more detailed information is required on soil management, contact an office of the B.C. Ministry of Agriculture, Fisheries and Food.

It should be noted that although the authors are specialists in soil management, general comments have been made in this publication on production economics, crop suitability and crop production. These are not intended to be expert comments, but to provide the reader with a general understanding of the suitability of various climatically adapted crops. For definite information on the economics of producing or marketing a specific crop, an expert in the appropriate field of agrology should be consulted.

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Table Of Contents

Page

Table of Contents Con't.

Page

Table of Contents Con't. Page

List Of Soil Series

*= indicates soils mapped in the North Okanagan only, but some map symbols are the same as in the South.
NOTE: Cameron Lake has two map symbols, CNA for the North and CN for the South.

List Of Soil Management Groups And Soils Which Comprise Each Group

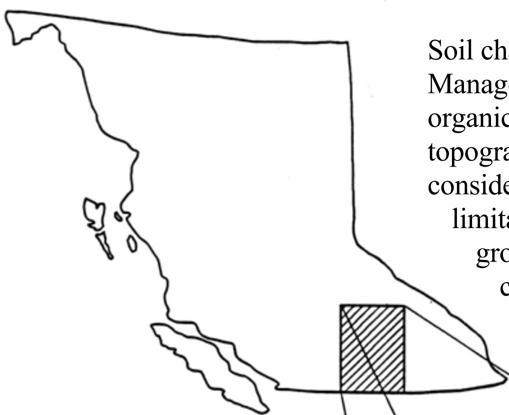
*= indicates soils mapped in the North Okanagan only, but some map symbols are the same as in the south
NOTE: Cameron Lake has two map symbols, CNA for the North and CN for the South.

List Of Figures

List Of Tables

Introduction And Use Of Handbook

One hundred forty-three soil series have been mapped in the Okanagan and Similkameen Valleys. Many characteristics which distinguish one soil from another must be considered if agricultural crops are to be grown, whereas, other characteristics have little relevance to crop production. In this Handbook, soils having similar agriculturally important characteristics are combined into "Soil Management Groups". Each group is comprised of soils with similar limitations to crop production and require similar types and levels of management inputs for successful crop production. Soils have mainly been grouped on the basis of parent material.



Soil characteristics considered agriculturally important and used in forming Soil Management Groups are: soil parent material, drainage, texture, surface soil organic matter level, depth to impervious or restricting layers, stoniness, topography and salinity. For each Soil Management Group, formed after consideration of the above parameters, the Handbook provides information on limitations for agriculture, suitability of crops and management inputs required to grow various crops. There are also sections on general soil management, climate and a listing of the soil series and locations of the Okanagan and Similkameen Valleys.

Proximity of the area covered in this handbook.

This Handbook is to be used in conjunction with the detailed (1:20,000) soil maps from the soil surveys entitled "Soils of the Okanagan and Similkameen Valleys" (Ministry of Environment Technical Report #18) and the "Soil Survey of the North Okanagan Valley". Included are valley bottoms and lower valley slopes from Deep Creek, northwest of Enderby, to the United States border in the Okanagan Valley, and from the Ashnola River to the United States border in the Similkameen Valley. There are several soil series that are included in the Soil Survey Report for the North Okanagan that have not been included in the mapped area. These series, therefore, will not be included in the Handbook.

To obtain information about the soils of a particular location, their management requirements and suited crops, the following steps should be used:

- Determine the soil names from the maps which accompany the above soil survey reports.

- Locate the pages where the soil series in question are discussed in the Handbook from the lists on pages viii and ix.

- Turn to the appropriate pages where information is provided on: general characteristics of the soil, dominant soil limitations for agriculture, suitability of climatically adapted crops and management inputs required to reach an acceptable level of productivity.

- Refer to pages 33 to 36 for more detailed of the physical nature of soils and on various soil management practices

- Appendix A provides details of the climate of the Okanagan and Similkameen Valleys.

- Appendix B is a detailed list of the location of the 143 soil series.

Issues of soil conservation and/or soil management often arise in agriculture. The following Table 1 is a guide cross reference to determine some of the potential management solutions that can be used to deal with a specific problem. In most instances, a general discussion of the management solutions provide in the table can be found in this Handbook.

Alternative Management Practices/Solutions

Areas of Concern	Problems	Contour Cropping	Crop Rotation	Cover Crops (Annual)	Cover Crops (Permanent)	Forages (Perennial)	Shelterbelts	Barrier Strips (Grass/Stubble)	Residue Management	Tolerant Crops	Animal Manure/Compost	Reduced Tillage	Alter Tillage Practices	Liming	Subsoiling	Timing of Field Operations	Water Erosion Control System	Grassed Waterway/Roadway	Subsurface or Surface Drainage	Reforestation/Grassland Revegetation	Mulching	Irrigation Practices	Dykes or Terraces	Fertilizer Practices	Stone Removal
Soil Conditions	Organic Matter		X	X	X	X			X		X	X	X							X	X				
	Fertility		X		X[1]	X			X	X	X			X[1]										X	
	Moisture Conservation	X	X		X		X	X	X		X	X	X		X	X	X[1]	X		X	X	X			
	Tilth/Structure		X	X	X[1]	X			X		X	X	X		X	X					X			X	X
	Compaction		X		X	X				X	X	X	X		X	X		X	X	X		X			
	Stoniness					X					X	X	X							X					X
	pH									X	X			X[1]										X	
	Salinity		X	X	X	X				X	X	X			X				X			X		X	
	Surface Puddling			X	X	X			X		X	X	X						X	X	X	X			
	Poor Drainage	X	X			X				X					X		X[1]		X[1]			X			
	Flooding									X						X	X[1]		X[1]	X[1]			X[1]		
Water Erosion	Rill	X	X	X	X	X			X		X	X	X			X	X	X		X	X	X	X		
	Gully	X	X	X	X											X	X	X[1]		X[1]			X[1]		
	Cliff Slump																		X[1]			X			
Wind	Erosion		X	X	X	X	X[1]	X	X		X	X	X		X	X		X		X	X	X			
	Speed						X	X								X				X					

NOTE: Some alternate management practices/solutions could be implemented at low cost or over a short time period. However, other practices/solutions could be more costly and take longer to implement, for example those marked X[1].

List of Definitions for Table 1

Contour Cropping: The production of crops in rows that follow the natural contour of the land and are at right angles to the direction of the slope.

Crop Rotation: Growing a variety of crops in reoccurring succession on the same land. (i.e., field vegetables followed by winter wheat, then forage grass).

Cover Crop: A crop of close-growing legumes, grasses or small grains grown primarily for the purpose of soil protection and improvement between periods of regular crop production.

> **Annual cover crops**, such a cereals or annual grasses, are usually allowed to die over the winter or is "killed" by the use of herbicides or tillage.

> **Permanent cover crops**, such as perennial grasses or legumes, are normally managed by mowing over the growing season. Permanent cover crops protect the soil from erosion, providing organic matter to the soil and may have benefits in terms of microclimate and insect management.

Forages (Perennial): Certain green crops (legumes or grasses) primarily grown and harvested to feed domestic livestock. These crops can aid in soil conservation or management of specific soil/site constraints such as stoniness or salinity.

Shelterbelts: An extended line(s) or "belt" of living trees and shrubs established and maintained to act as a shield protecting farmland from wind erosion and crops from wind damage.

Barrier Strips (Grass/Stubble): Consists of one or two rows of tall-growing grass or an annual cereal seeded every 15 to 24 metres at right angles to the prevailing wind. It may also be a strip of standing crop left taller than the adjacent crop residue. Barrier strips can protect sensitive young plants/crops from wind damage. Barrier strips may also be used to trap snow or reduce soil erosion during winter months.

Residue Management: A cropping system that maintains an adequate residue cover (min. 30% surface cover) for soil erosion control and protection of the soil surface from puddling and erosion.

Tolerant Crops: A crop able to grow under stressful growing conditions, such as high salinity or adverse soil physical conditions or wet sites.

Animal Manure/Compost: Livestock produce nutrient-enriched liquid and solid organic waste materials which can be distributed on soils to supply essential plant nutrients and improve soil physical conditions. They must only be used as a soil conditioner or plant nutrient. Composts, like animal manures, provide nutrients, they are also excellent soil conditioners, providing stable humic forms of organic matter. Compost contain nutrients which are less readily available so application rates can be higher. Compost can also be used as a mulch.

Reduced Tillage: A Tillage system where the number of field operations required for crop production are at minimum. Equipment types or modifications are used to minimize soil disturbance and maintain weed control. To delay or reduce the amount of tillage, herbicides are included in the system. For some forage production systems, tillage may be reduced to subsoiling, aeration and direct seeding.

Alter Tillage Practices: Changing tillage equipment type or operating speed, will reduce pulverization of the soil and the burial of crop residue. Avoid use of rotovators or implements which continuously work at the same depth. Use of power harrows, spaders or deep chisel cultivators may be beneficial.

Liming: The application of agricultural lime ($CaCO_3$) or other liming material required to raise the soil pH to a desired value under specific cropping conditions. Liming may also increase crop nutrient availability.

Subsoiling: Subsoiling is done in the fall (when soils are dry) to alleviate compaction, and to improve water infiltration and root penetration. Compaction may be the result of natural soil development or traffic/tillage on the soil.

Timing of Field Operations: The coordination and implementation of various field operations can improve or hinder existing soil conditions. (i.e., shift major tillage operations to drier periods or change crop type).

Water Erosion Control System: An erosion control system consists of a subsurface drainage system, which may include blind surface inlets and discharge structures coupled with cover, contour or continuous cropping practices.

Grassed Waterway/Roadway: A vegetated, natural or constructed broad, shallow channel designed to carry surface runoff across farmland with minimum water erosion. Grassed waterways or roads may provide better trafficability, reduce water erosion risk and can reduce wind erosion.

Subsurface or Surface Drainage: A conduit such as tile, pipe or tubing installed below the ground surface to lower watertables within a field and maintain unsaturated soil conditions.

Reforestation/Grassland Revegetation: The natural seeding or artificial replanting of trees, grasses or shrubs within an area that was previously under forest or grassland, which may be used as a wildlife habitat, reduce erosion hazard, or improve soil productivity on a long term basis.

Mulching: The application of straw or other coarse organic matter to reduce excessive water evaporation or the risk of soil erosion or surface structure degradation by wind and water.

Irrigation Practices: Excess applications of irrigation water can have significant impacts on soil/crop management (i.e., flooding or slumping of glaciolacustrine cliffs). Low application rates will reduce crop yield potential. Water conservation is impacted by irrigation system design and management.

Dykes or Terraces: Earthen berms constructed along river channels or canals to reduce the risk of flooding. Dyking is essential in some areas due to the spring freshet. Terracing, a long, low, earth embankment with a flat or graded channel constructed across the slope can be developed within fields on sloping land to control surface runoff or reduce water erosion.

Fertilizer Practices: Application of fertilizer or various types/methods of fertilizer application can be beneficial in various crop/soil/site conditions. Over-application can impact soil chemical parameters such as pH or electrical conductivity. Underapplication will reduce crop yield potential.

Stone Removal: Some soils contain stones near the surface that impact the suitability of a site for specific crops. Stones can be removed to reduce the impact on tillage, seeding and crop growth.

Management Inputs, Crops And Soil Management Groups

The climate (heat units, hours of sunshine, precipitation and freeze-free period) of an area region is the ultimate limit to the range of crops which are suitable for production and to the yield of each crop. Given a sufficient and appropriate level of management inputs, virtually all climatically suited crops can be produced on all soils within a climatic region with only minor differences in yield. For example, in a class 1 climatic region, most Canada Land Inventory class 1 to 6 lands can be managed such that all crops can be grown with similar yield potentials, but only if all limitations can be removed. Droughty land can be irrigated, wet lands drained; acid soils limed; sloped lands can be terraced, levelled or managed using appropriate conservation measures; stones can be removed from stony land; flooded lands protected by dykes; infertile soils fertilized; and so on.

However, it is recognized that some soils are better suited to production of a particular crop than are other soils. On the well suited soils, management inputs required to reach an acceptable level of productivity will be less than for a soil less well suited to the crop in question. To produce some crops on some soils, the level of management inputs required may not be justified or feasible using current technology and/or under current economic and market conditions. Economics have not been precluded as part of the discussion of suitability levels for any crop or crop group grown on a particular soil or site.

In the subsequent section on “Soil Management Groups”, the climatically adapted crops have been placed into one of three groups depending on the level of management required to achieve an acceptable level of production. These are as follows:

Well Suited Crops: a low to moderate level of management inputs are required to achieve an acceptable level of production.

Suited Crops: a moderate to high level of management inputs are required to achieve an acceptable level of production.

Unsuited Crops: crops that are not suited to the particular soil management group.

It is recognized that some crops require more intensive management in terms of labour, tillage, soil conservation, crop production, post harvest handling, etc., to achieve acceptable yields than do other crops grown on the same soil. The terms low, moderate and high level of inputs refer to the level of management required to produce a particular crop. That is, a low or moderate level of management inputs for a perennial forage crop on a wet site may be quite different from a low or moderate level for tree fruits. For example, to produce tree fruits, a high management input requirement indicates that it is more costly and difficult to achieve acceptable yields than where a low level of management inputs are required. Low management inputs may include liming or additions of organic matter. High management inputs many include drainage or stone removal.

When placing crops or crop groups into a particular suitability level within a soil management group, several site parameters are considered. In many cases, due to various levels of certain parameters being present, the “if – then” concept is used. For example: **if** a site has a range of stoniness classes from S_0 to S_3 and slopes that range up to 30%, **then** a crop such as sour cherries will be suited only to a site with stoniness up to S_1 and slopes less than 15%. In any soil management group where this type of situation occurs, the crop or crop group will only be listed once in the appropriate suitability class. It is assumed that the crop is then unsuited if the soil group parameters fall outside the stated range.

Following are some general consideration used to group crops according to their suitability for production within a particular soil management group.

Well Suited Crops

- All necessary management inputs can be made by the individual producer.

- An exceptional level of management expertise for the crop in question is not required.

- Technological inputs are low to moderate.

- There are no unusual annual costs which reduce the feasibility for production of the crop under consideration.

- Irrigation is required in most years for maximum economic yields of almost all crops listed as being climatically adapted to the Okanagan and Similkameen Valleys. Irrigation then is not considered an unusual cost. Although irrigation could be considered as a moderate to high level input, because it is considered to be essential for the production of any crop other than dryland grasses, this Handbook will treat it as a low level input. Therefore, other management inputs will dictate the suitability of soil groups to produce crops.

Suited Crops

- A moderate to high level of producer expertise is required. Improperly managed land could be seriously damaged; timeliness of cultivation, fertilization and other field operations are crucial to achieving acceptable crop growth.

- Technological inputs are moderate to high. For example, drainage, organic matter incorporation, subsoiling, conservation practices to reduce erosion and/or other inputs are required acceptable yields can be sustained.

- Land development costs (i.e., stone picking or land levelling) may be moderate to high.

- Economic inputs for land development and/or annual production may be moderate to high.

- Risk of crop failure or costs to reduce risk may be moderate to high.

- Irrigation is required for maximum economic yields; however, it is not considered an essential input for crop suitability.

Unsuited Crops

Crops placed in this category are considered to be not suitable for production on the soil management groups in question. It is, however, not to be concluded that a crop can not be grown on a particular soil. With a sufficient and appropriate level of management inputs, most crops can be grown on most soils. However, long-term commercial production of unsuited crops should be on soils that are well suited or suited to these crops. Some general considerations for considering crops to be unsuited are as follows:

- Risk of crop failure is high and the cost to reduce the risk to an acceptable level are very high.

- Level of management inputs required to achieve acceptable yields are probably not justifiable in terms of current economic and market conditions.

- An exceptional level of management expertise is required.

Management Inputs And Definitions

Cover Cropping: Cover crops are legumes, cereals, grasses, brassicas and mixtures grown for protection against soil erosion, amelioration of soil structure, enhancement of soil fertility and suppression of pests. Cover cropping is needed for water erosion control and to aid soil drainage by maintaining a porous soil surface or to reduce compaction, to alter the microclimate or to control pests in tree fruit or berry crops.

Erosion Control Practices: Practices employed to halt mass wasting, to reduce overland flow and/or sloughing and to reduce rainfall impact, includes: underdrains, blind surface inlets, grassed waterways and cover crops (see section 3.3).

Irrigation: is assumed to be a required input for the production of most crops in the Okanagan and Similkameen Valleys.

Organic Matter Incorporation: The use of manures, cover crops, mulches, composts and other organic inputs to improve soil structure and fertility and to reduce erosion. Additions of organic matter should follow the *"Code of Agricultural Practice"* and only be used as a soil amendment or as a fertilizer.

Stone Removal: Stone removal is required for seedbed enhancement and to prevent machinery damage. Stone removal may not be possible in all soils due to a low percent of non-coarse fragments in the soil.

Subsoiling: Subsoiling is done to increase infiltrability (air and water), to increase effective rooting depth and to improve soil structure. See Section 4.3.2 for details on which soils are suitable for subsoiling as a management practice.

Tillage Practices: Various practices that are used for soil structure improvement, seedbed preparation and organic matter incorporation or decomposition. See Section 4.2 for more information.

Water Management System: A system used to reduce overland flow, to reduce surface ponding/flooding and to lower the watertable (associate benefits). Includes underdrains, perimeter ditching, pumps, outlets, dyking and surface inlets. See Section 3 for more information.

Salinity/pH Adjustment: Salinity can be reduced by the installation of a drainage system and the application of irrigation water. pH can be raised or lowered through the addition of lime or sulphur compounds, respectively (refer to Section 3.7 for salinity and Sections 4.5.2.2 and 4.5.2.3 for pH). pH and salinity adjustments are not dealt with as a specific management input in any of the soil management groups. However, for many soil series in the Okanagan and Similkameen Valleys, due to topographic and soil parent material conditions, pH and salinity constraints exist. These soil phases may hve been unmapped. Shallow till overlying calcareous bedrock and shallow groundwater flow may result in high surface pH values and saline conditions respectively.

Definitions

The following definitions are included to explain some of the parameters used when designating management inputs.

Slope suitability classes range from 0 to 9%, 9 to 15%, 15 to 25% and 25% +, with 20% as a break for some crops. Slopes between 20 and 25% will require careful use of mechanical crop management techniques and mechanization on a large scale may require that slopes be less than 20%. Crops should be considered to be suited to sites from the steepest class break that they are mentioned under down to the shallowest slope class. (Slope suitability classes apply to all crops and crop groups.)

Drainage refers to the broad description of how well the whole soil profile drains, but does not necessarily refer to how well drained the soil is in relationship to its landscape position.

<u>Soil Depth</u> refers to the depth to either a seasonal high watertable or root restrictive layer such as bedrock or compact till layer. Each of these will affect plant growth in a different manner.

<u>Soil Texture</u> is a broad definition of the textural groups described in Table 6, Section 1.

<u>Stoniness Phases</u> stoniness generally refers to the soil surface condition. Stones are defined as rock fragments greater than 25 cm in diameter if rounded and greater than 38 cm along the greater axis if flat. Soils with a high stoniness class have a narrower range of crops which are suited. Stones will interfere with both cultivation and rooting even at a low percentage or if they are present in the surface layers of a soil. Where mentioned, the stoniness class is as follows (these classes apply to all crops and crop groups).

S_0 – Nonstony Phase, land having less than 0.01% of surface occupied by stones.

S_1 – Slightly Stony Phase, stones present offer slight to no hindrance to cultivation. Stones occupy 0.01 to 0.1% of surface.

S_2 – Moderately Stony Phase, enough stones are present to cause some interference with cultivation. Stones occupy 0.1 to 3% of surface.

S_3 – Very Stony Phase, there are sufficient stones to handicap cultivation seriously, some clearing is required. Stones occupy 3 to 15% of surface.

S_4 – Exceedingly Stony Phase, stones prevent cultivation until considerable clearing is done. Stones occupy 15 to 50% of surface.

S_5 – Excessively Stony Phase, the land surface is too stony to permit cultivation. Stones occupy more than 50% of surface.

Coarse Fragments: Coarse fragment content generally refers to the whole soil profile or a particular layer in the soil. In many soils in the Okanagan and Similkameen Valleys, coarse fragments are present, as defined by the *Canadian System of Soil Classification*, 1976. Coarse fragments are rock or mineral particles greater than 2.0 mm in diameter. The terms used to describe coarse fragments in soils are shown in Table 2.

For soils with a high coarse fragment percent (C.F. %), the range of crops which are suitable is relatively wide. C.F.'s do not generally interfere with root development. However, they reduce the usable soil volume which can be explored by crop roots.

Table 2
Coarse Fragments

Shape and Kind of Fragments	Size Range (All Shapes)		
	Up to 7.5 cm in diameter	7.5 to 25 cm in diameter	Over 25 cm in diameter
Rounded and subrounded fragments (All kinds of rock)	Gravelly	Cobbly	Stony
	Size Range (Flat fragments)		
	Up to 15 cm in length	15 to 38 cm in length	Over 38 cm in length
Thin flat fragments (Thin, flat sandstone, limeston and schist)	Channery	Flaggy	Stony

Crops Or Crop Groups

Alfalfa: alfalfa has a narrow range of moisture tolerance and generally requires “dry feet” and irrigation. Alfalfa is not suited on shallow soils or slopes greater than 15%. Artificially drained sites may have a higher suitability for alfalfa. Slopes between 9 and 15% may require special precautions for harvesting operations.

Annual Vegetable Crops: this crop group includes a wide range of crops. Root crop vegetables and annual leafy vegetables are separated from the larger group due to watertable restrictions. The group includes annual legumes (beans, fababeans, lentils, peas and soybeans), cucurbits (pumpkins, melons, cucumbers and squash), brassicas (broccoli, cabbage, cauliflower, brussels sprouts and kale) and tomatoes, peppers, onions and garlic. On slopes between 9 and 15%, drip irrigation practices are required to reduce water erosion. These crops are not generally suited on soils with a high coarse fragment percent (i.e., >50%) or on very stony soils (i.e., stones $>S_2$).

1) **Root Crop Vegetables:** crops include potatoes, carrots, beets, parsnips and turnips. These crops are not tolerant to shallow watertables, will require organic matter additions for longer term production on fine-textured soils and are restricted to slopes under 9% if mechanical harvesting is used. These crops should not be grown on soils with a stoniness class greater than S_1. On slopes greater than 9%, mechanical harvesting of root crops will become difficult.
2) **Annual Leafy Vegetables:** crops include spinach, lettuce, swiss chard, radish, celery and other ‘salad greens’. These crops are tolerant to shallow watertables during the growing season and the soil should have a stoniness class of S_1 or less.

Asparagus: a deep-rooted crop, asparagus should be planted only into fertile, well-drained loams and sandy loams which are free of perennial weeds.

Blueberries: blueberries are a shallow-rooted crop and needs a mulch on very coarse and very fine-textured soils. Blueberries generally prefer an acidic soil with a high organic matter percent or an organic soil, and have a relatively high moisture requirement, but do not like “wet feet”. Included with blueberries are *Ribes spp.* Currents and gooseberries can be grown on heavier, wetter soils.

Cereals: crops include barley, fall rye, oats, wheat and winter wheat. Oil seeds, such as canola, would be included in this crop group. Yields can be maximized when summer watertables are between 75 to 100 cm. Irrigation may not be economical on coarse-textured soils.

Corn: a deep-rooted crop, corn is suited to soils with a low coarse fragment percentage, and generally requires irrigation. Corn can be produced on slopes up to 15% if it is contour planted. Includes sweet and forage corn.

Forage Crops – drier sites: soils and landscapes are well drained, meaning these sites tend to be more arid. Irrigation may be required. Slopes under 15% are suitable for mechanical harvesting. Crops include orchard grass, ryegrass, timothy and barley (see slope comment for alfalfa).

Forage Crops – wetter sites: soils and landscapes are imperfect to poorly drained or soils have a high moisture-holding capacity. Irrigation is not generally required. Crops include reed canarygrass, creeping red fescue and meadow foxtail and most clovers (clovers may be suited to drier sites as well).

Ginseng: is suited to a well defined soil which has a loam to silt loam texture with a workable soil depth of 30 cm and a whole depth of 60 cm, low coarse fragment percent less than 15%, good water retention and moderate organic matter content. It is advisable to avoid gravels, shale and clay. The slopes should be less than 15%. Where slopes are >5%, there is a risk of water running on the shad cloth causing erosion or “wet spots” under the cloth. Where slopes are >9%, mechanical digging is affected.

Grapes: grape suitability is strongly dependent on variety and microclimate. Grapes will not tolerate a water-logged soil and perform better on a well drained soil. Site selection should have suitable soil drainage, and good water-holding capacity, and some sites may require organic matter additions and cover cropping practices. Slopes to 20% are suited, to 25% are less suited and greater than 25% are unsuited. Refer to the *Atlas of Suitable Grape Growing Locations in the Okanagan and Similkameen Valleys of British Columbia* for more information.

Grasslands: sites which are suited to the grassland crop group many not have a high animal unit month (AUM) carrying capacity. They are best suited to “grass species”. Grasslands are defined as lands where native vegetation, including grasses, forbs, sedges, shrubs and trees, and cultivated species, i.e., crested wheatgrass or reed canarygrass, grow well. They may have been revegetated to include tame forages, however, intensive forage production, irrigation, drainage or fertilization is not normal. If harvested, they are normally harvested by grazing due to steepness and/or stoniness. Areas are designated to this crop group when slopes are 15% and up, stoniness greater than S3 and depth of the soil less than 50 cm over compact till or bedrock. Some lowland, wetter sites or soils have also been given this crop group designation. This is a result of several soil limitations which do not allow for use of soil management inputs at an economic level. These lands may be Crown or privately owned. Grassland sites may or may not be used for grazing, outdoor recreation or may be held as ecological reserves.

Nursery and Christmas Trees: this crop group refers to in-ground rather than container production of nursery stock. These crops generally will not tolerate shallow watertables, but are suited to shallow soils. Christmas trees may be grown on steeper slopes (greater than 15%) and on soils with a higher coarse fragment percent (i.e., >75%).

Raspberries: included with raspberries are blackberries and loganberries. Raspberries are well suited on slopes to 9% due to erosion risk and suited up to 15%. Cover cropping on an annual basis is recommended.

Strawberries: all varieties. Strawberries may be considered to be well suited only on slopes to 9% or less because of the risk or erosion.

Tree Fruits: this is the largest crop group grown in the Okanagan and Similkameen Valleys other than perennial forages and rangeland. Due to their economic importance and variability in management, Table 3 has been developed to distinguish the differences between species and rootstocks. This table is modeled after the “Tree Fruit Suitability Mapping Project” of the Okanagan Valley Tree Fruit Authority (OVTFA). Depth to watertable, texture and slope are the most critical soil characteristics for tree fruits. The OVTFA system also uses pH to 30 cm (if pH >9.0) and salinity to 50 cm. This handbook considers pH and salinity to be parameters which can be dealt with through various management inputs. Depth of soil and drainage class are used in this Handbook to describe the depth to watertable and depth to root restrictive layer. Site suitability may include other parameters not dealt with by this Handbook or the OVTFA project. Climate and microclimate factors are also important, however, they are not covered in detail in this Handbook.

Table 3

Criteria For Tree Fruit Suitability

	Slopes	Drainage	Soil Depth	Soil Texture
Well Suited				
Apples (Antanovka)*	up to 20%	well	>100 cm	med.-mod. coarse, <50% c.f.
Apples (M9/M26/M4)*	up to 15%	well	>100 cm	medium
Pears*	up to 20%	well-mod. well	>75 cm	med.-mod. fine
Sweet Cherries	up to 20%	well	>100 cm	med.-mod. coarse
Sour Cherries	up to 9%	well	>100 cm	med. fine-mod. coarse
Peaches, apricots, plums, prunes & nectarines	up to 20%	well	>100 cm	med.-mod. fine
Suited				
Apples (Antanovka)*	20 to 25%	moderate	50-75 cm	mod. fine-coarse
Apples (M9/M26/M4)*	15 to 20% (less suited 20 to 25%)	moderate	50-75 cm	mod. fine-coarse
Pears*	20 to 25%	mod.-poor	>50 cm	mod. fine-mod. coarse
Sweet Cherries	20 to 25%	moderate	>75 cm	mod. fine-coarse
Sour Cherries	9 to 15% (less suited 15 to 20%)	moderate	>75 cm	fine-coarse
Peaches, apricots, plums, prunes & nectarines	20 to 25%	moderate	>75 cm	fine-mod. coarse
Unsuited				
Apples (Antanovka)*	>25%	poor	<50 cm	very heavy clay, >75% c.f.
Apples (M9/M26/M4)*	>25%	poor	<50 cm	very heavy clay, >75% c.f.
Pears*	>25%	very poor	<50 cm	very heavy clay
Sweet Cherries	>25%	poor	<50 cm	very heavy clay
Sour Cherries	>20%	poor	<50 cm	very coarse >75% c.f.
Peaches, apricots, plums, prunes & nectarines	>25%	poor	<50 cm	fine

NOTE: All tree fruits are generally considered to be unsuited on sites with >S_3 stoniness, however, some sites with a high level of management and/or intensive production system may be suited to tree fruits.
c.f. = coarse fragment content

***Rootstocks used as examples:**

Apples	Malling 4, 9 and 26 (moderately hardy) Antanovka (hardy)
Pear	Bartlett

Soil Management Groups

This section of the Handbook contains information about each of the Soil Management Groups. Due to the need for irrigation on most sites, the following **A**vailable **W**ater **S**torage **C**apacity information is provided. AWSC data is calculated based on a 90 cm soil depth except where the soils are less than 90 cm (see * below) and these are based on the actual soil depth given in the soil data files. The following ranges indicate the approximate AWSC for the soil series: >165 high, 165 to 90 moderate and <90 low. However, to be more accurate, AWSC should be determined on a site specific basis using recommended AWSC measurement procedures.

Soil Series	AWSC	Soil Series	AWSC	Soil Series	AWSC	Soil Series	AWSC
Acland Creek	97	Gardom	186	Lumby	99	Ratnip	123
Agar Lake	102	Gartrell	113	Manery	76	Reiswig	117
Armstrong	169	Gellatly	169	Maynard	140	Roy Creek	102
Bessette	106	Giants Head	117	McDougall	136	Rumohr	195
Bluespring	108	Gillanders	161	McKinley	124	Rutland	83
Boucherie	172	Glenemma	103	Mission Creek	189	Seaton	86
Broadview	143	Glenfir	102	Moffat	191	Shannon	162
Bullock	87	Glenmore	185	Monashee	53*	Shuswap	87
Burnell Lake	98	Grandview	111	Munson	189	Similkameen	162
Cameron Lake	92	Greata	143	Nahun	103	Skaha	92
Canyonview	78	Grizzly Hill	132	Naramata	124	Snehumpton	104
Carlin	163	Guisachan	161	Nighthawk	59*	Solly	75
Cawston	151	Harrland	112	Nisconlith	165	Spallumcheen	177
Chapman	189	Hayman	132	Nkwala	111	Stemwinder	113
Cherryville	115	Haynes	84	Okanagan	225	Stepney	92
Chopaka	181	Higgin	151	O"Keefe	80	Strutt	154
Coldstream	155	Hullcar	189	Olalla	146	Summerland	171
Corporation	101	Hupel	83	Olhausen	153	Susap	94
Coulthard	90	Iltcoola	82	Osoyoos	80	Swanson	145
Darke Lake	225	Inkaneep	171	Oyama	107	Tanaka	117
Dartmouth	88	Kalamalka	108	Pandozy	82	Tappen	167
Debeck	82*	Kalamoir	113	Paradise	93*	Tomlin	104
Dub Lake	79	Kaleden	142	Pari	90	Trepanier	160
Duteau	148	Kelowna	112	Parkill	102	Trewitt	84
Eaneas	96*	Kendall	225	Peachland	110	Trout Creek	102
Ellison	83	Keremeos	183	Penticton	189	Twin Lakes	98
Enderby	182	Kinney	122	Plaster	174	Valley Creek	118
Equesis	97*	Kloag Pass	93	Ponderosa	114	Waby	206
Faulder	143	Knox Mountain	151	Postill	81	Westbank	166
Fowler	160	Lambly	166	Priest Creek	181	Winslow	109
Gammil	84						

Chopaka Soil Management Group

<u>Soil Series</u>: Bessette (BT), Chopaka (CK), Duteau (D), Gillanders (GS), Nisconlith (N) (N:ca), Priest Creek (PT) and Strutt (ST)

<u>General Characteristics</u>: These soils have developed on recent alluvial floodplain deposits and on fluvial fan deposits. The floodplain soils of this group consist of stone-free, medium to moderately fine-textured overlays which vary in depth from less than 50 cm to 100 cm or more in thickness. These deposits are underlain by coarse-textured sandy and gravelly deposits. The alluvial fan soil – Priest Creek (PT) – is moderately coarse to medium-textured in the surface and subsurface and can be slightly stony (S_1). Gravels occur quite deep in the subsoil. Soils developed from both parent materials are calcareous. They have topographies that range from nearly level (0.5%) to very gentle (5%) and drainage that is poor to very poor.

<u>Dominant Soil Limitations</u>:

- The soils in this group are subject to flooding in the spring.
- These soils are poorly to very poorly drained and are subject to a high groundwater table.
- This group has varying levels of salinity, ranging from none to moderately saline.

<u>Well Suited Crops</u>: Forage crops – wetter sites and grasslands.

<u>Suited Crops</u>: When soils are drained, annual vegetable crops, blueberries, cereals, corn, forage crops – drier sites, nursery stock and Christmas trees and strawberries. Where drainage or flooding protection is provided and salinity can be controlled through irrigation, some sites may be suited to tree fruits.

Management Inputs:
Water Management System: Drainage is required to lower the groundwater table and to remove salts that have been leached by irrigation. The suggested drain spacing is 16 to 18 m at a 1.2 m depth.

<u>Unsuited Crops</u>: Alfalfa, asparagus, ginseng, grapes, raspberries and tree fruits.

Reasons: Because of the normally deep-rooting habit of these crops, minimum watertable levels required for maximum yields could be achieved only at very high costs.

Gammil Soil Management Group

Soil Series: Debeck (DE), Ellison (EN), Gammil (GM), Glenemma (G), Nahun (H) (H:db), Peachland (PA), Rutland (R) and Seaton (SE)

General Characteristics: These soils have developed in gravelly, cobbly and stony, coarse to moderately coarse soil overlays which vary in depth from 10 to 70 cm. The surface stoniness varies from nonstony (S_0) to exceedingly stony (S_4). These veneers are underlain by gravelly, cobbly and stony, coarse and very coarse-textured glaciofluvial deposits. The arable topography varies from nearly level to moderate slopes (9 to 15%). Non-arable topography exists and have slopes that range from 15 to 45%. These soils are rapidly to well drained, have a low water storage capacity and have a low to very low nutrient-holding capacity.

Dominant Soil Limitations:

- Adverse topography occurs where the slopes are in excess of 20%. Tractor operation is difficult on these slopes and the soils are susceptible to erosion by water.
- Variable stoniness hinders cultivation and planting in various parts of the land parcels.
- Coarse-textured soils are very susceptible to soil acidification after several years of irrigation and fertilizer additions.
- Soils are low in available water storage capacity, natural fertility and organic matter content.

Well Suited Crops: On sites where the slopes are up to 9%, surface stoniness is S_0 and soil depth is greater than 50 cm, all climatically adapted crops are well suited.

Suited Crops: On slopes up to 15%, soil overlay >50 cm and stoniness is S_0 to S_1, blueberries, cereals, corn, raspberries, sour cherries and strawberries. On slopes to 20%, forage crops - drier sites and M9 and M26 apple rootstocks. Where slopes are less than 25%, surface stoniness classes range from no stones (S_0) to very stony (S_3), soil surface textures are sandy loam to gravelly sandy loam, then Christmas trees, grapes and all tree fruits (except M9 and M26 apple rootstocks and sour cherries) can produce acceptable yields. Generally, sites with S_4 stoniness would limit the suitability of tree fruits.

Management Inputs:

Stone Removal: These soils have a very shallow veneer of coarse soils over stones and stone removal is required in stoniness classes S_2 (moderately stony) and S_3 (very stony). Areas with fewer stones, in the surface soils, are still root restricting for all crops and need to be closely monitored with regards to water and nutrient movement.

Organic Matter Incorporation: Incorporation of organic matter is required for moisture conservation.

Unsuited Crops: Alfalfa, annual vegetable crops, asparagus, forage crops - wetter sites, ginseng, nursery stock and root crop vegetables on S_4 soils.

Reasons: Surface and subsurface stones in a very high percentage of these soils would prevent acceptable yields due to harvesting difficulties and the need for high levels of irrigation.

Glenmore Soil Management Group

<u>Soil Series</u>: Boucherie (BE), Broadview (B), Glenmore (GL) (GL:dg), Plaster (PLA), Spallumcheen (S) (S:gl) (S:gl,ca), Tappen (T) and Westbank (WK)

<u>General Characteristics</u>: These soils have developed on moderately well drained, moderately fine to fine-textured silty and clayey glaciolacustrine sediments. The soils are slowly pervious, have a high water storage capacity and a high available nutrient-holding capacity. The topographies of the soils in this group range from very gentle and gentle (2 to 9%) to strong (15 to 30%).

<u>Dominant Soil Limitations</u>:

- These fine to very fine-textured soils have a high potential to be eroded.
- The compact clayey subsoils will restrict the proper rooting depth of some crops.
- Soils are very weakly to weakly saline below 60 cm.
- Organic matter content of the surface horizons is low.

<u>Well Suited Crops</u>: Alfalfa, annual vegetables (except root crop vegetables), cereals and forage crops - wetter sites are well suited on slopes up to 9%.

Management Inputs:

Tillage Practices: Careful cultivation practices provide a good seedbed and minimize compaction.

Organic Matter Incorporation: Incorporation of organic matter in the cultivation layer will improve the soil structure and decrease surface crusting.

Subsoiling: Periodic subsoiling opens up the fine-textured dense subsoil.

<u>Suited Crops</u>: Corn, nursery and Christmas trees and root crop vegetables, are suited on slopes that are less than 9%. Where slopes are 9 to 15%, blueberries, forage crops - drier sites, grapes, raspberries, strawberries and tree fruits, can produce acceptable yields.

Management Inputs:

Tillage Practices: Proper timing of land preparation is important for the reduction of soil compaction.

Organic Matter Incorporation: Incorporation of organic matter in the cultivated layer will improve the soil structure and decrease surface crusting, especially for blueberries.

Erosion Control Practices: Soil conservation practices should be carried out on slopes in excess of 9% to prevent erosion by water.

Subsoiling: Periodic subsoiling will be necessary for the opening of dense subsoils to improve rooting of annual crops.

Cover Cropping: Tree fruits should have a perennial cover crop and grapes, blueberries and raspberries should have some form of cover crop during the August to March period to reduce soil erosion.

Water Management System: Where drainage is required, the suggested drain spacing is 10 to 12 m at a 0.8 m depth.

<u>Unsuited Crops</u>: Asparagus and ginseng.

Reasons: Even with subsoiling, these crops would produce yields that are likely to be low.

Greata Soil Management Group

Soil Series: Greata (GT) (GT:bl), McKinley (MK) and Valley Creek (VW)

General Characteristics: These soils have developed in well drained, gravelly and stony, coarse-textured fluvioglacial overlays which vary from 30 to 100 cm in thickness. The surface stoniness varies from nonstony (S_0) to very stony (S_3). These soils are underlain by medium to moderately fine-textured silty and clayey glaciolacustrine sediments. Drainage of these soils to a specified depth range from rapid to slow depending on the thickness of the overlay. The topography of these soils vary from gentle (6 to 9%) to very strong slopes (30 to 45%). There are also minor areas with slopes that are greater than 70%.

Dominant Soil Limitations:

- Adverse topography occurs where slopes are greater than 25%.
- Surface and subsurface stoniness varies from nonstony (S_0) to very stony (S_3).
- Compact subsoils are present below the sandy and gravelly fluvioglacial overlays.
- Very weakly to moderately saline subsoils occur.
- Increased soil acidification is expected after several years of irrigation and fertilizer additions.
- Organic matter content of surface horizons varies from moderate to very low.

Well Suited Crops: None

Suited Crops: These sites are best suited to the grassland crop, however, where slopes are less than 15%, surface textures are gravelly sandy loam to gravelly loamy sand in the top 50 cm over glaciolacustrine deposits, surfaces are nonstony (S_0) to moderately stony (S_2), suited crops are: alfalfa, annual vegetable crops (except root crop vegetables), blueberries, cereals, corn, forage crops -drier sites, ginseng, grapes, nursery and Christmas trees, raspberries, strawberries and tree fruits. In areas that are less well drained, forage crops - wetter sites are suited. Slopes that are 15 to 25%, but have other soil conditions as listed above, are suited to grapes and tree fruits (except sour cherries, M9 and M26 apple rootstocks on slopes up to 20%) only.

Management Inputs:

Stone Removal: Stone removal will be required for moderately stony soils (S_2) when crops other than tree fruits and grapes are grown.

Erosion Control Practices: Crops to be grown on slopes greater than 9% will require conservation practices to prevent soil erosion.

Water Management System: Where drainage is required, the suggested drain spacing is 16 to 18 m at a 1.2 m depth.

Unsuited Crops: Asparagus and root crop vegetables on any slopes due to the shallowness and stoniness of the surface soil. All crops are unsuited where slopes are greater than 25%, except grasslands.

Reasons: Soil erosion susceptibility of these slopes is extreme. Machinery has great difficulty negotiating these slopes and excess stoniness limits cultivation.

Guisachan Soil Management Group

Soil Series: Guisachan (GN), Tanaka (TA) and Winslow (WW)

General Characteristics: These soils have developed on gravel free and stone-free veneer, which overlies moderately coarse to medium-textured fluvial lower fan deposits. Surface and subsurface textures range from sandy loam to silty clay loam, while subsoils are gravels and sands at approximately 50 cm and greater in some profiles. The soils are predominantly poorly to very poorly drained with minor inclusions of imperfectly drained soils on slightly elevated locations. The topography varies from level and gently undulating (0 to 0.5%), to very gently sloping (0.5 to 2%).

Dominant Soil Limitations:

- A fluctuating high groundwater table is present and some areas are subject to flooding in the spring.
- Tanaka soils are weakly saline.

Well Suited Crops: Forage crops - wetter sites.

Suited Crops: When soils are drained, alfalfa, annual vegetable crops, blueberries, cereals, corn, forage crops - drier sites, nursery and Christmas trees, pears, raspberries and strawberries. Apples are suited on better drained or artificially drained sites.

Management Inputs:
Water Management System: Drainage is required to lower the groundwater table. Leached salts will need to be carried out by drainage water. The suggested drain spacing is 18 m at a 1.2 m depth.

Unsuited Crops: Asparagus, ginseng, grapes and tree fruits (other than apples and pears). On very poorly drained sites, apples and pears will be unsuited as well.

Reasons: Very costly drainage systems would be required to lower the watertable levels deep enough so that these deep-rooted crops could produce acceptable yields.

Kelowna Soil Management Group

Soil Series: Armstrong (A) (A:sw) (A:sw,cb), Bluespring (BP), Cherryville (CY), Giants Head (GH), Grizzly Hill (GH), Harrland (HD), Hayman (HN), Kelowna (KE), McDougall (ML) and Reiswig (RS)

General Characteristics: These soils have developed in deep, medium to moderately coarse-textured glacial till deposits which are usually capped with sandy to loamy, wind-blown surface deposits that vary from 10 to 30 cm in thickness. This surface layer may be up to 100 cm in the McDougall soils. These soils are well drained. The arable topography ranges from very gentle (2%) to moderate (15%) slopes. Non-arable topographies (25 to 70% slopes) also occur on these soils. The surface stoniness of these soils ranges from nonstony (S_0) to exceedingly stony (S_4).

Dominant Soil Limitations:

- Adverse topography occurs where slopes are greater than 25%.
- Subsoils are dense and compact and may limit root penetration of some crops.
- Organic matter content of surface layers is low to very low.
- Variable surface stoniness exists and would require, in some cases, stone removal for crop production.

Well Suited Crops: Where surface soils are stone free and deeper than 50 cm over glacial till, have slopes that are less than 9% and soil surface textures that are loam to loamy sand, all climatically adapted crops can produce maximum economic yields.

Management Inputs:
Organic Matter Incorporation: Incorporation of organic matter is required for moisture conservation when soils are cultivated.

Suited Crops: Where surface soils are slightly stony (S_1) to moderately stony (S_2), have depths that are 25 to 50 cm over glacial till, consist of slopes that are less than 9% and comprised of textures that are loam to loamy sand, the following crops have the potential to produce maximum yields: alfalfa, annual vegetable crops (except root crop vegetables), blueberries, corn, cereals, forage crops - drier sites, ginseng, grapes, nursery and Christmas trees, raspberries, strawberries and tree fruits. Where soil conditions are similar to the ones given above, but the slopes range from 9 to 15%, the suited crops are the same as listed above except ginseng, nursery and Christmas trees and strawberries, if they are clean cultivated. Slopes that are 15 to 25% are suited to grapes, forage crops - drier sites and tree fruits (except sour cherries). On slopes 20 to 25%, M9 and M26 apple rootstocks and forage are not suited.

Management Inputs:
Stone Removal: Stone removal will be required for moderately stony soils (S_2) when crops other than tree fruits and grapes are grown.

Erosion Control Practices: Crops grown on slopes greater than 9% will require conservation practices to prevent soil erosion.

Cover Cropping: Cover crops are required to supply organic matter to the soil.

Unsuited Crops: All climatically adapted crops are unsuited where slopes are greater than 25% and where the stoniness class is S_4 (exceedingly stony), except grasslands.

Reasons: Tractor operation is risky where slopes are greater than 25% and where stoniness class is S_4. Stone removal for crop production is likely to be uneconomic.

Keremeos Soil Management Group

Soil Series: Cawston (CA), Coulthard (CD), Keremeos (K), Nighthawk (NG) and Snehumpton (SN)

General Characteristics: These soils have developed on fluvial floodplain terraces and consist of stone-free medium to coarse-textured overlays which vary in depth from less than 25 cm to about 100 cm in thickness. These deposits are underlain by very coarse-textured sandy and gravelly deposits. The soils are well to moderately-well drained. The topography ranges from nearly level (0 to 0.5%) to very gentle slopes (0.5 to 2.0%).

Dominant Soil Limitations:

- Spring flooding can occur during higher than normal runoff in areas that are not dyked.
- A short duration fluctuating groundwater table can occur in sandy and gravelly subsoils during the spring freshet.
- Fluctuating watertables on Nighthawk and Snehumpton soils may pose specific problems to deeper rooting crops. These fluctuating watertables may be associated with old channels or proximity to current river channels.

Well Suited Crops: Where spring flooding does not occur and surface soils are deeper than 60 cm over gravels, all climatically adapted crops, except asparagus and ginseng.

Suited Crops: Where surface soil depths range between 30 to 60 cm over gravels - Nighthawk and Snehumpton soils - all climatically adapted crops, except asparagus and root crop vegetables, are capable of producing high yields. The limitation to asparagus and root crop vegetables is the shallow depth of the surface soils to gravels. Ginseng suitability may be limited due to the possibility of temporary high watertables.

Management Inputs:

Organic Matter Incorporation: Incorporation of organic matter is required to improve the water-holding capacity and nutrient-holding capacity of these soils.

Cover Cropping: Cover crops are required for grapes and tree fruits.

Water Management System: Dyking is required for some locations along the Similkameen River.

Unsuited Crops: Asparagus and root crop vegetables are not suited on Nighthawk and some areas of Snehumpton soils.

Reasons: The natural rooting habit of these crops would be severely restricted, and therefore, maximum yields might not be achieved. Corrective measures are not feasible.

NOTE: Cawston soils mapped in the Okanagan River Floodplain, north of Osoyoos Lake, are poorer drained than Cawston soils in the Similkameen Valley. This may be related to historic soil development or their proximity to the Okanagan River channel and its associated flood control structures.

Munson Soil Management Group

<u>Soil Series</u>: Carlin (CN), Chapman (CH), Enderby (EY), Gellatly (GY), Higgin (HG), Hullcar (HR), Kalamoir (KR), Knox Mountain (KN), Lambly (LY), Mission Creek (MC), Munson (MU), Naramata (NM), Olhausen (ØH) and Penticton (P)

<u>General Characteristics</u>: These soils have developed in one of the following, gravel free and stone free soil deposits: **(a)** silty, medium to moderately fine-textured stratified glaciolacustrine sediments (Carlin, Chapman, Enderby, Hullcar, Munson and Penticton soils); **(b)** sandy and loamy textured eolian or fluvioglacial overlays which vary from 20 to 100 cm in thickness. These materials are underlain by silty, medium to moderately fine-textured, stratified glaciolacustrine deposits (Gellatly, Kalamoir, Knox Mountain, Mission Creek, Naramata and Olhausen soils); **(c)** silty, medium-textured glaciolacustrine overlays between 30 to 80 cm thick. These materials overlie sandy fluvioglacial deposits (Lambly soil); **(d)** silty, medium to moderately coarse-textured fan deposits that have eroded from silty textured glaciolacustrine sediments (Higgin soil). The soils of this group are well drained. The most frequently found topography ranges between nearly level (0.5%) and strongly sloping (15%). Three soils -- Lambly, Olhausen and Munson -- have slopes that range from very gentle to very steeply sloping (30%) or extremely sloping (70%).

<u>Dominant Soil Limitations</u>:

- Adverse topography occurs where slopes are greater than 25%.
- Soils developed in eolian overlays and lacustrine deposits are susceptible to water erosion where their surface slopes exceed 9%.
- Very weakly to moderately saline subsoils exist.
- Organic matter content of the surface layers is low to moderate.

<u>Well Suited Crops</u>: Where the topography is less than 9%, all climatically adapted crops.

Management Inputs:
Organic Matter Incorporation: Incorporation of organic matter is required for soil moisture conservation and soil structure stabilization.

Erosion Control Practices: Due to fine-textured surface soils, soil conservation practices are required to control soil erosion.

<u>Suited Crops</u>: Where topography ranges between 9 and 15%, alfalfa, annual vegetable crops (except root crop vegetables), asparagus, cereals, corn, forage crops - drier sites, grapes, nursery and Christmas trees and tree fruits are suited. Slopes that are 15 to 25% are suited to grapes, Christmas trees and tree fruits only. Sour cherries are more economically produced on slopes that are <15% as harvesting machines do not operate effectively on steeper slopes. Forage crops - drier sites up to a 20% slope.

Management Inputs:
Erosion Control Practices: Soil conservation practices should be carried out on these slopes to prevent soil erosion by water.

Cover cropping: Tree fruits and grapes should have a perennial cover crop established between the rows.

<u>Unsuited Crops</u>: All crops, except grasslands, are unsuited where slopes are greater than 25%.

Reasons: Tractors have difficulty negotiating these slopes and erosion potential is great even with soil conservation measures in place.

WARNING - Excessive or poor irrigation and/or water management practices on these soils could result in mass wasting or slumping of glaciolacustrine cliffs.

Osoyoos Soil Management Group

Soil Series: Glenfir (GF), Grandview (GR) (GR:dg), Haynes (HA), Kaleden (KA), Moffat (MT), O'Keefe (ØK), Osoyoos (Ø), Oyama (ØY), Parkill (PR), Shuswap (SH), Stepney (SY), Trepanier (TR) and Trewitt (TW)

General Characteristics: These soils have developed in deep gravel-free and stone-free sandy, coarse-textured fluvioglacial deposits and minor fluvial fan deposits. The soils are well to rapidly drained. The arable soil surfaces vary from nearly level (0.5%) to steeply sloping (30%). A considerable inclusion of non-arable topography also occurs and ranges from very steeply sloping (30%) to extremely sloping (70%).

Dominant Soil Limitations:

- Adverse topography occurs wherever slopes are greater than 25%.
- Slopes greater than 9% are susceptible to soil erosion.
- Coarse-textured soils have a high potential for increased acidity after several years of irrigation and fertilizer additions.
- Organic matter content of surface soils is low.

Well Suited Crops: Where slopes are less than 9%, all climatically adapted crops are well suited.

***Management Inputs**:*

Organic Matter Incorporation: Incorporation of organic matter is required for moisture conservation when the soils are cultivated.

Suited Crops: Where the topography ranges from 9 to 15%, the suited crops are: alfalfa, annual vegetable crops (except root crop vegetables), asparagus, blueberries, cereals, corn, forage crops - drier sites, ginseng, grapes, nursery and Christmas trees, raspberries, strawberries and tree fruits. Slopes between 15% and 25% are only suited to Christmas trees, grapes and tree fruits (except sour cherries and M9 or M26 apple rootstocks).

***Management Inputs**:*

Erosion Control Practices: Soil conservation practices will be required on these slopes in order to prevent soil erosion.

Cover Cropping: A perennial cover crop should be established in orchards and vineyards.

Unsuited Crops: Forage crops - wetter sites. All crops, except grasslands, are unsuited where slopes are greater than 25%.

Reasons: Tractor operation is risky on these slopes and even with conservation measures, erosion potential is very great.

Postill Soil Management Group

<u>Soil Series</u>: Eaneas (ES), Equesis (ES), Faulder (FR), Fowler (FR), Nkwala (NK), Pari (PAR) and Postill (PL)

<u>General Characteristics</u>: These soils have developed in moderately coarse to coarse-textured colluvium and/or glacial till deposits, which vary from about 10 to 100 cm or more in thickness and overlie bedrock. Surface and subsurface stoniness ranges from nonstony (S_0) to very stony (S_3). These soils are well drained. Soil surfaces range from moderately sloping (9%) to extremely sloping (70%).

<u>Dominant Soil Limitations</u>:

- Adverse topography exists above 25% slopes.
- Shallow soils over bedrock and stoniness of the surface and subsoil prevent adequate plant rooting.
- Organic matter content of surface soils is low to moderate.

<u>Well Suited Crops</u>: None

<u>Suited Crops</u>: These sites are best suited to the grassland crop, however, Christmas trees, forage crops - drier sites, grapes and tree fruits (except pears and sour cherries) may be suited on sites where slopes are less than 25%, stoniness is less than S_4 and depth to restrictive layer (bedrock) is >50 cm.

***Management Inputs*:**

Stone Removal: Stone removal will be required on some soils.

Cover Cropping: Perennial grasses should be planted between rows.

Organic Matter Incorporation: Organic matter additions may be required.

<u>Unsuited Crops</u>: Alfalfa, annual vegetable crops, asparagus, blueberries, cereal, corn, forage crops - wetter sites, ginseng, nursery stock, pears and sour cherries, raspberries and strawberries.

Reasons: Corrections of stoniness, topography and shallowness of the soil are not economically feasible.

Roy Creek Soil Management Group

Soil Series: Cameron Lake (CNA) (CN), Inkaneep (IK) and Roy Creek (RY)

General Characteristics: This group of soils has developed on moderately coarse to medium-textured fluvial fan deposits. Gravels usually occur quite deep in the subsoil. Surface and subsurface stoniness varies from nonstony (S_0) to slightly stony (S_1). The soils are imperfectly drained with inclusions of moderately well drained sites. The slopes of these soils vary from nearly level (0.5%) to moderately sloping (9%).

Dominant Soil Limitations:

- These soils may have fluctuating watertables that can occur to within 50 cm of their surfaces.
- Excess subsoil moisture exists for some crops in the early part of the growing season.
- Organic matter content of surface layers is low.

Well Suited Crops: Annual leafy vegetables, forage crops - wetter sites and grasslands.

Management Inputs:
Organic Matter Incorporation: Incorporation of organic matter is required for moisture conservation when the soils are cultivated.

Suited Crops: Alfalfa, cereals, corn, forage crops - drier sites, ginseng, grapes, nursery and Christmas trees, raspberries, root crop vegetables, strawberries and tree fruits are suited. Blueberries may be suitable if organic matter is incorporated and a mulch is used. Drainage is recommended where watertables fluctuate to within 50 cm of the soil surface.

Management Inputs:
Water Management System: Drainage is required to lower the groundwater table in some locations during the early part of the growing season. Where drainage is required, the suggested drain spacing is 16 m at a 1.2 m depth.

Organic Matter Incorporation: Incorporation of organic matter is required to improve the water-holding capacity, nutrient-holding capacity and to decrease the effects of compaction.

Unsuited Crops: Asparagus.

Reasons: The normally deep-rooted habit of this crop would necessitate more intensive drainage systems than required for the other crops. The costs versus returns might make the exercise unprofitable.

NOTE: The Cameron Lake soil series is mapped in both the North and the Okanagan and Similkameen Valleys. The CNA symbol is used in the North and the CN symbol in the Okanagan and Similkameen.

Rumohr Soil Management Group

Soil Series: Darke Lake (DL), Gardom (GMA), Kendall (KD), Nisconlith (N:p), Okanagan (Ø), Rumohr (RH) and Waby (WY:m)

General Characteristics: These soils have developed in semi-decomposed organic deposits which vary in depth from approximately 20 to 160 cm or more. The organic deposits are mainly underlain by coarse to moderately coarse-textured fluvial deposits. In some locations, the organic deposits are underlain or intermixed with marl deposits. These soils are very poorly drained. Slopes vary from depressional (0.5%) to gentle (5%).

Dominant Soil Limitations:
- These soils are subject to a high groundwater table.
- These soils require drainage for maximum crop production.

Well Suited Crops: Forage crops - wetter sites may be produced as pasture or single cut hay without drainage.

Suited Crops: Where drainage has been implemented, all climatically adapted crops, except alfalfa, asparagus, ginseng, grapes, nursery and Christmas trees, raspberries, strawberries and tree fruits can produce acceptable yields.

Management Inputs:
Water Management System: Drainage is required to control the high groundwater table for most crops. The suggested drain spacing is 14 m at a 1.2 m depth.

Unsuited Crops: Alfalfa, asparagus, ginseng, grapes, nursery and Christmas trees, raspberries, strawberries and tree fruits.

Reasons: Maintaining watertable levels that would not impair crop growth would be difficult and costly.

Similkameen Soil Management Group

Soil Series: Coldstream (CS) (CS:wd) (CS:wd,ca), Kalamalka (K) (K:dg) (K:l), Olalla (OL), Shannon (SA) and Similkameen (SM)

General Characteristics: These soils have developed in medium to moderately fine-textured fluvial fan deposits. Surface and subsurface stoniness varies from nonstony (S_0) to moderately stony (S_2). The soils are moderately pervious, have a high available water storage capacity and a medium to high nutrient-holding capacity. These soils are practically all arable with slopes that vary from nearly level (0.5%) to moderately sloping (9%). The soils are either well or moderately well drained.

Dominant Soil Limitations:

- Variable surface and subsurface stoniness which requires minor stone removal for crop production.
- Organic matter content of the surface horizons is low.

Well Suited Crops: Where soils are nonstony (S_0) or only slightly stony (S_1), all climatically adapted crops.

Management Inputs:

Organic Matter Incorporation: Incorporation of organic matter is required for moisture conservation.

Stone Removal: Minor stone removal may be required on some soils.

Suited Crops: Where soils are moderately stony (S_2), these sites are better suited to all climatically adapted crops except annual vegetables and ginseng.

Unsuited Crops: None

Skaha Soil Management Group

Soil Series: Acland Creek (AC), Agar Lake (AA), Dartmouth (DH), Paradise (PE), Skaha (SK) and Trout Creek (TC)

General Characteristics: These soils have developed in moderately coarse to medium-textured, gravel free overlays that vary in depth from about 25 to 100 cm. The overlays are underlain by gravelly, to very gravelly and stony glaciofluvial deposits. The surface stoniness varies from practically none (S_0) to slightly stony (S_1). These soils are rapidly to well drained. Arable topography varies from nearly level (0.5%) to strong slopes (15%). Inclusions of non-arable topography having steep (25%) to very steep slopes (70%) and are usually associated with steep terrace escarpment slopes and kettle holes which sometimes occur within the deposits.

Dominant Soil Limitations:

- Adverse topography occurs whenever slopes are greater than 25%.
- Slopes greater than 9% are susceptible to erosion by water.
- Variable surface stoniness may be a slight hindrance to cultivation in some locations.
- The gravelly subsoils have a low water-holding capacity.
- Coarse-textured soils have a high potential for increased acidity after years of irrigation and fertilizer additions.
- Organic matter content of surface layers is low.

Well Suited Crops: Where surface soils are stone free and deeper than 50 cm over gravels, have slopes that are less than 9% and soil surface textures that are loam to loamy sand, all climatically adapted crops can produce very good yields.

Management Inputs:
Organic Matter Incorporation: Incorporation of organic matter is required for moisture conservation.

Suited Crops: Where surface soils are slightly stony (S_1), have depths that are 25 to 50 cm over gravels, consist of slopes that range from 9 to 15% and contain textures that are loam to loamy sand, suited crops are: alfalfa, annual vegetable crops (except root crop vegetables), blueberries, cereals, Christmas trees, forage crops - drier sites, grapes, grasslands, raspberries, strawberries and tree fruits (except sour cherries).Where slopes are 15 to 20%, Christmas trees, forage crops - drier sites, grapes, tree fruits (except sour cherries). Where slopes are 20 to 25%, Christmas trees, grapes and tree fruits (except M9 and M26). Where soils are <25 cm deep, Christmas trees, forage crops - drier sites, grapes and tree fruits (except pears and sour cherries) are suited.

Management Inputs:
Erosion Control Practices: Crops recommended on slopes greater than 9% will require conservation practices to control soil erosion.

Cover Cropping: Cover crops are required to supply organic matter to these sandy soils which will improve the water-holding capacity and decrease the effects of compaction.

Unsuited Crops: All crops are unsuited where slopes are greater than 25%, except forage crops - wetter sites and grasslands.

Reasons: Soil erosion potential is great even when a cover crop is grown and tractor operation on these slopes is dangerous.

Stemwinder Soil Management Group

Soil Series: Burnell Lake (BL), Canyonview (CY), Hupel (HU), Lumby (LY) (LY:gl), Manery (MY), Pandozy (PY), Ponderosa (PØ), Ratnip (RN), Stemwinder (SW), Tomlin (TM) and Twin Lakes (TL)

General Characteristics: The soils within this group have developed in gravelly, cobbly, stony and bouldery coarse to medium-textured fluvial fan deposits. Surface and subsurface stoniness varies from nonstony (S_0) to excessively stony (S_5). The aprons of the fans tend to be less stony than the apexes. The soils are well to rapidly drained. Arable topography ranges from very gentle (2%) to strong slopes (15%). Slopes greater than 25% are considered to be non-arable and these can be found on the Twin Lakes soil.

Dominant Soil Limitations:

- Adverse topography occurs where slopes are greater than 25%.
- Surface and subsurface stoniness varies from arable nonstony phases (S_0) to non-arable excessively stony phases (S_5).
- These coarse-textured soils are very susceptible to soil acidification after several years of irrigation and fertilization.

Well Suited Crops: None

Suited Crops: These sites are best suited to the grassland crop, however, where surface soils are nonstony (S_0) to slightly stony (S_1), have depths that are 30 to 50 cm over gravels, cobbles and stones, consist of slopes that are less than 9% and are comprised of textures that are sandy loam to gravelly loamy sand, suited crops are: alfalfa, annual vegetable crops (except root crop vegetables), blueberries (mulched), cereals, Christmas trees, forage crops - drier sites, ginseng, grapes, raspberries, strawberries and tree fruits. Where surface soils are moderately stony (S_2) to very stony (S_3), have depths that are 30 to 50 cm over gravels, cobbles and stones, consist of slopes that are 9 to 15% and comprise of textures that are sandy loam to gravelly loam sand, then suited crops are: Christmas trees, forage crops - drier sites, grapes and tree fruits (except pears and sour cherries).

Management Inputs:

Stone Removal: Stone removal will be required for moderately stony (S_2) and very stony (S_3) soils when crops other than tree fruits and grapes are grown.

Erosion Control Practices: Crops grown on slopes greater than 9% will require conservation practices to prevent soil erosion.

Organic Matter Incorporation: Incorporation of organic matter is required to improve the water-holding capacity and nutrient-holding capacity of these soils.

Unsuited Crops: All climatically adapted crops are unsuited where surface soils have stoniness that is classed as exceedingly and excessively stony (S_4 and S_5 respectively). Soils within these classes generally occur on slopes which are more than 15%. Some high density, highly managed tree fruit blocks may be moderately suited to S_4 or S_5. Also, where stones are picked and managed, forage may be suited on some S_4 to S_5.

Reason: There is insufficient soil of medium textures amongst the stones and cobbles to retain the required water and nutrients for good crop growth.

Summerland Soil Management Group

Soil Series: Gartrell (GR), Summerland (SR) and Swanson (SN) (SN:vp)

General Characteristics: The Gartrell soils have developed in a moderately coarse to medium-textured, relatively stone-free glaciofluvial overlay, which varies in depth from about 60 to 100 cm. These deposits are underlain by sands and gravels. The Summerland and Swanson soils have developed in silt loam to clay glaciolacustrine deposits. The soils are imperfectly to poorly drained and have high watertables that are generally within 75 cm of the surface throughout the year. The slopes vary from depressional (0.5%) to gentle (5%).

Dominant Soil Limitations:

- These soils are poorly drained and have fluctuating, high groundwater tables.
- The soils are calcareous and have a variable level of salinity which ranges from very weak to moderately saline.
- Some areas mapped to these soils may be too narrow to farm.

Well Suited Crops: Forage crops - wetter sites.

Management Inputs:
Water Management System: Drainage is required to control the fluctuating groundwater table.

Suited Crops: Annual vegetable crops, blueberries, cereals, corn, forage crops - drier sites, pears and strawberries are suited where soils have been drained.

Management Inputs:
Water Management System: Drainage is required to control the fluctuating groundwater table if yields are to be maximized. The suggested drain spacing is 16 m at a 1.2 m depth.

Unsuited Crops: Alfalfa, asparagus, ginseng, grapes, nursery and Christmas trees, raspberries and tree fruits (other than pears), would be low yielding.

Reason: Establishing effective drainage for these deep-rooted crops is likely to be unprofitable.

Susap Soil Management Group

Soil Series: Bullock (BK), Kinney (KY), Monashee (MØ) and Susap (SU)

General Characteristics: All soils have as their parent materials recent fluvial floodplain deposits. Bullock, Kinney and Susap consist of stone-free, medium, moderately coarse and coarse-textured overlays that vary in depth from 25 to 100 cm or more in thickness. These overlays are underlain by coarse-textured sandy and gravelly deposits. The Monashee soils vary from nonstony (S_0) to very stony (S_3) in the surface 25 cm. The surface soil is underlain by a cobbly subsoil. The soils of this group are imperfectly drained and have fluctuating groundwater tables that are within 0 to 25 cm of the surface at times. Soil surfaces vary from near level (0.5%) to gently sloping (5%).

Dominant Soil Limitations:

- The soils have fluctuating groundwater tables.
- The soils are susceptible to flooding in undyked areas along the Similkameen River.
- The soils (especially Kinney) may be susceptible to high watertables in some areas along the Okanagan River Channel.
- Kinney soils may have moderate levels of salinity.

Well Suited Crops: Forage crops - wetter sites.

Suited Crops: Where drainage and dyking have been installed, suited crops are: annual vegetable crops, blueberries, cereals, corn, forage crops - drier sites, grapes, nursery and Christmas trees, raspberries and strawberries. Tree fruits may be suited on sites that have drainage provided by dykes or micro-topographic features.

Management Inputs:

Water Management System: Drainage is required for all soils to lower the groundwater table and dyking is necessary for some soils to prevent flooding. The suggested drain spacing is 16 m at a 1.2 m depth.

Organic Matter Incorporation: Incorporation of organic matter is required to improve the water-holding capacity and nutrient-holding capacity of these soils.

Unsuited Crops: Alfalfa, asparagus and ginseng. Tree fruits are not suited in undrained areas or where seepage from a river or channel saturates the subsoil.

Reasons: Cost of providing effective drainage for these deep-rooted crops is likely to be uneconomical.

Miscellaneous Soils

Soil Series: Armstrong (A:er), Corporation (CP), Dub Lake (DU), Enderby (EY:er) (EY:li), Glenemma (G:er), Iltcoola (IL), Kloag Pass (KG), Maynard (MD), Nahun (H:er), Rutland (R:er) and Solly (SØ)

General Characteristics: Corporation, Dub Lake, Kloag Pass and Solly soils have developed in sandy and gravelly coarse-textured fluvioglacial or lacustrine deposits, Iltcoola soils in coarse-textured sandy and gravelly fluvial deposits and Maynard soils in medium-textured glaciolacustrine material that is very calcareous and weakly to moderately saline. Armstrong soil, eroded phase, has developed in coarse-textured glacial till deposits and have a shallow sandy eolian surface cap. Nahun, Rutland and Glenemma soils, eroded phases, have developed on gravelly, cobbly, coarse to moderately-coarse glaciofluvial deposits. Enderby soils have developed on a stone-free, medium to moderately fine-textured stratified glaciolacustrine sediments. The eroded phase has a soil depth of less than 50 cm. The lithic phase has a bedrock contact within 75 cm of the surface. The topography of Corporation soils ranges from strong to extreme, 15 to 70% and Dub Lake soils from very strongly to extreme, 30 to 70%; both soils have a stoniness class of S_0. Kloag Pass soils have slopes that range from very gentle to gentle, 2 to 9% and a stoniness class of S_1 to S_2. Solly soils have surfaces that vary from nearly level to gentle slopes, 0.5 to 9% and a stoniness class of S_2. Iltcoola soil surfaces vary from nearly level to very gentle slopes, 0.5 to 9% and a stoniness class of S_0 to S_4. Flooding risk is a limitation of this soil. Maynard soils range from gentle to extreme slopes, 5 to 70% and have a stoniness class of S_0. Armstrong, eroded phase, slope is greater than 30% and stoniness class is S_1 to S_3. Nahun, Rutland and Glenemma, eroded phases, have a stoniness class up to S_4 and are very strongly to extremely sloping (30 to 70%). The Enderby eroded phase has slopes greater than 15% and the lithic phase has slopes that range from 5 to 30%.

- **Armstrong A:er** is a poorly developed, shallow soil found on very strongly sloping sites which are not suited to agriculture.
- **Corporation** soils are severely constrained for agricultural uses because of steep topography and potential slope instability.
- **Dub Lake** soils are not suitable for agricultural uses because of excessive slopes and instability and erosion hazards if the thin natural vegetation cover is disturbed.
- **Enderby EY:er** eroded phase, **Enderby EY:li** lithic phase, these soils are generally too shallow to support the growth of agricultural crops.
- **Glenemma G:er, Nahun (H:er) and Rutland (R:er)** are poorly developed, shallow soils with a high percent of stones or coarse fragments in relation to the soil matrix. There is insufficient soil to support crop production.
- **Iltcoola** soils are generally unsuited for agricultural uses due to coarse, stony-textures and the danger of flooding. Forage crops - wetter sites may be poorly suited to some sites. These soils have a low suitability to a narrow range of crops, but tree fruits are being grown on some.
- **Kloag Pass** soils are uncommon and are not suited to agricultural uses. No crops are recommended on these soils.
- **Maynard** soils are generally not suited for agricultural uses. Adverse topography, high susceptibility to erosion, slow subsoil permeability, low bearing strengths and high salinity are all major restrictions.
- **Solly** soils are poorly suited for agricultural uses and only a few areas have been developed for pasture (forage crops - drier sites).

Miscellaneous Land Types

There are seven miscellaneous land types that consist of naturally occurring or man-made components of the landscape, and are not considered to be 'soil' as defined in this Handbook. The seven miscellaneous land types are as follows:

MLA: Gravel and Sand Pits: consists of active and inactive areas of granular material extraction sufficiently large enough to be mapped.

MLB: Landfill, Cut and Fill or Levelled Areas: consists of man-made features or areas that have been so severely modified that the original has been destroyed.

MLC: Bedrock Outcrop: consists of exposed bedrock or bedrock areas with less than 10 cm of soil on the rock surface.

MLD: Dykes: these occur along portions of the Okanagan and Similkameen rivers.

MLE: Dry River Channels: consists of gravel bars and similar deposits exposed during low water in the Similkameen and Okanagan rivers.

MLF*: Ponds and open water.

MLG*: Deep marl deposits.

*indicates the North Okanagan only.

Soil Management Guide

This section of the handbook contains basic information about the nature and properties of soils, and how soil properties are affected by management practices. Soils differ greatly in their composition and in the way they change under the influence of management practices, therefore, this handbook describes important features common to all soils, and shows in principle, how management practices affect soil conditions and crop growth.

Soils are a dynamic natural body, a thin mantle on the surface of the earth with supports plant life, and in turn, the life of all land animals. The soil plays a major role in the ecological balance of the whole environment, with an important influence on the quantity and quality of ground and surface waters. The soil itself is alive with countless plant and animal life forms adapted to live in the soil environment, and to promote soil fertility.

In nature, soils change and develop very slowly. When brought under cultivation, they undergo very rapid changes which affect their physical, chemical and biological properties. The objective of soil management is to maintain soils in a physical, chemical and biological condition favourable for crop growth. Whatever is done to the soil affects it in some way, and all practices must be considered as part of soil management.

1. The Physical Nature Of Soils

1.1 Soil Composition and Soil Properties

Soils are found in a wide variety of forms. Most commonly, soils are composed of mineral materials derived from rock, with some accumulation of organic matter or humus and a large population of soil organisms. Table 4 shows the four main soil types.

Whatever their composition, all soils have air spaces or pores which may hold air and water. The composition of a typical silt loam soil is shown in Figure 1.

Table 4
The Four Main Soil Types

Soil Type	Characteristics
Mineral Soils	Dominantly mineral matter. Various proportions of gravel, sand, silt and clay, containing less than 15% organic matter in topsoil layers.
Organic Soils	Over 30% organic matter in all layers of the soil profile. Organic matter may be completely decomposed, as muck, or only partially decomposed as in peat soils. Many organic soils are locally called muck soils.
Muck Soils	Organic soil mainly composed of highly decomposed organic materials and may contain mineral matter.
Peat Soils	Organic soil composed of slightly decomposed organic materials.

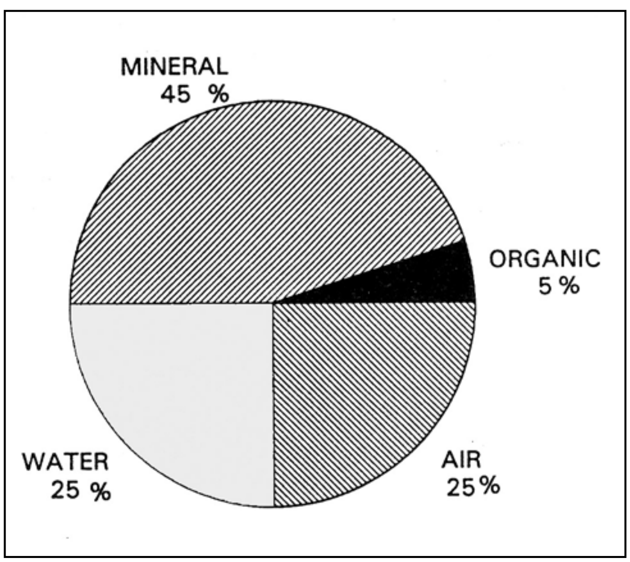


Figure 1

Volume composition of a silt loam surface soil in good condition for plant growth

The physical properties of the mineral and organic matter making up the solid portion of the soil have a marked influence on the size and number of pore spaces that may exist in the soil under different conditions. This in turn affects the soil's water-holding capacity, aeration, internal drainage, the ease of tillage and root growth, soil temperature and the availability of plant nutrients.

In addition to these effects, the physical nature of soil materials also determines such properties as soil consistence and strength. Some knowledge of the physical properties of soils is required in understanding the effects of agricultural practices on the soil, and how management can improve soil properties for agricultural purposes. The physical properties important in soil management are described in the following sections.

1.2 Soil Texture

The mineral materials in soils are simply small fragments of rock or mineral materials derived from

Table 5

Soil Particle Size and Characteristics

Particle	Diameter	Properties
Gravel	2 mm – 7.5 cm	Rounded, coarse rock fragments. Single grained and loose.
Sand	0.05 mm – 2.0 mm	Somewhat rounded, single grained and loose. Can be felt as grit.
Silt	0.002 mm – 0.05 mm	Rounded, generally forms clods, easily broken, floury when dry, soapy or buttery, but not sticky when moist or wet.
Clay	Less than 0.002 mm	Flat particles, forms hard clods when dry, sticky and plastic when moist or wet.

rock, but which have been altered by water and chemical reactions in the soil. Soil particles are grouped into four particle sizes as outlined in Table 5.

In describing soils, texture refers to the relative percentages of sand, silt and clay sized particles in the soil material. Soil textures are shown in Figure 2.

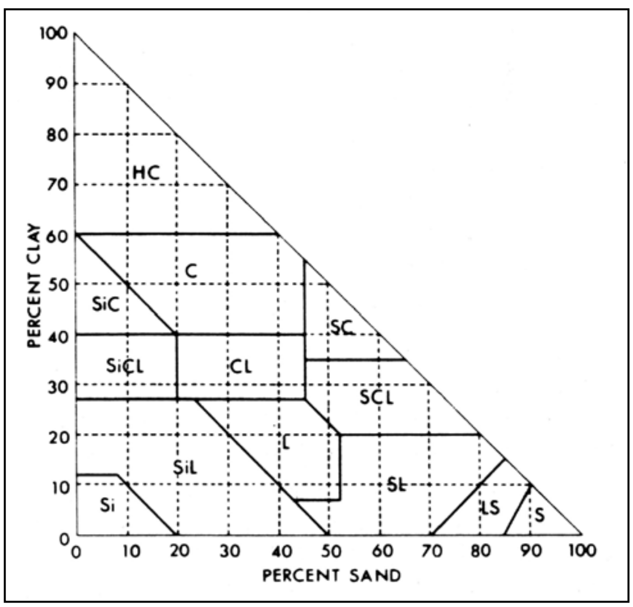


Figure 2

Soil texture classes. Percentages of clay and sandy in the main textural classes of soil; the remainder of each class is silt.

Soil texture may be further described using modifiers which indicate a dominant or additional feature of the soil. In the Okanagan and Similkameen Valleys, soils are often described as gravelly or very gravelly. These refer to 20 to 50% and 50 to 90% by volume of gravel size coarse fragments, respectively. Other modifiers could be mucky silt loam or sandy clay loam. Refer to the section on Management Inputs and Definitions (page 7) for more detail on stoniness and coarse fragment definitions.

It is convenient to place soil textures into four main groups and describe the important properties common to each group, as in Table 6.

Soil texture is a permanent characteristic. Texture will not change unless a large quantity of soil material of another texture is added to it, such as might occur during land clearing or very deep plowing into the subsoil which is of a different texture.

1.3 Soil Structure

In soils, individual sand, silt and clay particles become more closely packed and bonded together to form larger particles called aggregates. Soil structure refers to the type and arrangement of aggregates found in soils. Aggregates occur in almost all soils, but their strength, size and shape varies considerably among soil types. Figure 3 illustrates well-structured and poorly-structured soils.

Some of these aggregates may persist in stable forms which are not easily broken down by water or

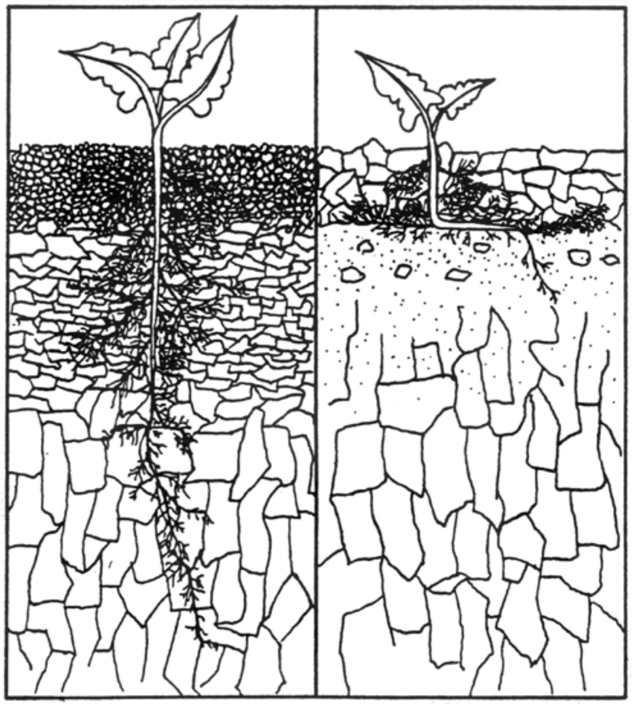


Figure 3

Schematic drawing of root growth in well-structured (left) and poorly-structured soil (right)

physical forces. In soils under cultivation, most aggregates at the surface tend to break down under the forces of rainfall, tillage and traffic.

Soil structure also influences the internal drainage of the soil, affects its water-holding capacity, temperature and resistance to the growth of plant roots and the emergence of seedlings. The formation of soil structure and factors which influence its breakdown are discussed in Section 2.1.

1.4 Porosity

The porosity, or % pore space, in soils is the portion of the soil mass occupied by air and water. Porosity is determined by both soil texture and structure, and therefore, porosity is influenced by practices which alter soil structure.

The size and distribution of pores in the soil is very important in determining the rates of air and water movement in soils, as well as influencing root growth. Plant roots require a balance of air and water for optimum growth.

Very small (micro) pores tend to restrict air and water movement while large (macro) pores promote good air and water movement.

Sandy soils have a low porosity (35 to 50% by volume), but the pores are relatively large. As a result of this, sandy soils tend to drain rapidly, to retain little water and to be well-aerated.

Medium and fine-textured soils have higher porosity (40 to 60% by volume), and a high proportion of the pores are small. These soils tend to retain more water, to drain more slowly and to be less well-aerated.

In finer-textured clay soils, those approaching 60% porosity with a predominance of small pores; structure and porosity, restrict air and water movement. In these soils, it is desirable to create larger pores by promoting a granular structure.

In addition to the effects of texture and structure on soil porosity, the activities of soil organisms is of equal importance. The burrowing activities of worms and soil insects result in the formation of larger pores which are beneficial to most soils. Practices which encourage the activity of soil organisms are of some practical significance in the management of finer-textured soils.

Table 6

Physical Characteristics of Soil Textural Groups

Soil Textural Group	Soil Textures and Types	Characteristics
Coarse to Moderately Coarse	Gravel Sand Loamy Sand Sandy loam Fine Sandy Loam	Loose and friable when moist or wet. Loose to soft when dry. Very high proportion of large pores. Low water-holding capacity. Good bearing strength and trafficability when wet. Tends to form weak clods when cultivated. Easy to maintain good tilth.
Medium	Very Fine Sandy Loam Loam Silty Loam Silt	Slightly sticky and plastic when wet. Friable to firm when moist, soft to slightly hard when dry. Moderately easy to maintain good tilth. Moderately good trafficability and bearing strength when wet. Tends to form small to medium, slightly firm clods when cultivated. High proportion of medium to small pores, high water-holding capacity and available water.
Moderately Fine to Fine and Very Fine	Sandy Clay Loam Clay Loam Silty Clay Loam Sandy Clay Clay Silty Clay Heavy Clay	Sticky and plastic when wet. Friable to firm when moist, hard to very hard when dry. High proportion of small pores. Moderately difficult to maintain good tilth. Poor trafficability when wet. Tends to form large, firm clods when cultivated. High water-holding capacity, but less available water than medium-textured soils.
Organic Soils	Muck and Peat	Variably sticky, usually non-plastic, friable, slightly firm when dry. Very high water-holding capacity. Poor trafficability when wet. Tends to form small to medium clods when cultivated. Easy to maintain good tilth.

2. Maintaining Soil Structure And Fertility

Soil structure is the most important soil characteristic that must be considered when managing soils, because it is structure which is most affected by management practices. In turn, soil structure is one of the most important factors in crop growth. Therefore, the main objective in soil management is to promote and maintain good soil structure which will be favourable to crop growth.

Most aspects of soil management are concerned with the structure or tilth of the soil within the cultivated or plow layer. Here, the upper 10 to 30 cm or more of the surface soil is subject to the influence of repeated tillage operations, cropping sequences and frequent additions of soil amendments. Below the plow layer, soil structure can be affected by traffic and tillage causing deep compaction. Soil compaction at the bottom of the plow layer, or deeper in the soil profile, can occur in the soils of the Okanagan and Similkameen Valleys. This compaction is the result of both natural soil processes and farming activities. Soil structure improvements below the plow layer can be achieved over a long period by the use of deep tillage, subsoiling, drainage and the growth of deep-rooted perennial crops. If the compacted or degraded soil structure is just below the plow layer, it is more readily reversed through the use of crop rotations, drainage and variation of tillage implement and tillage depth.

As a general rule, the plow layer in most soils has a granular structure, and it is this type of structure which provides the best tilth for seeding, germination and crop growth. Granular structure provides a balanced supply of air and water as well as a friable medium through which roots can penetrate. Over cultivation, particularly with power driven tillage implements, has degraded the surface soil structure in many soils in the region.

Massive, crusted or lumpy structure are adverse conditions which will reduce or even prevent plant growth by creating poor aeration and drainage. This structure will also physically restrict growth of roots or emergence of seedlings.

Perennial forage crops, annual cover cropping, additions of organic residues, such as manure or compost, and reduced tillage will help to reverse the soil structure degradation and return the soil to a granular structure.

2.1 The Formation of Soil Structure

Aggregates and structural pores in the soil are formed by a number of means, including the growth of plant roots, activities of soil organisms, wetting and drying, freezing and thawing, and tillage (tillage is discussed in Section 4.2, Tillage and Tillage Implements).

2.1.1 Plant Roots

The growth of plant roots is one of the most important agents in the formation of aggregates and pores. Growing roots expand and force individual soil particles closer together; they extract water from the soil, causing the mass to shrink and cracks to develop. Dead roots leave numerous pores and channels. The result of this process is the development of many aggregates and pores. The most favourable and stable soil structure is developed under a perennial (minimum 3 to 4 years) grass or grass-legume crop. See Figure 4. Plant roots excrete simple sugars and resins that bind soil particles.

2.1.2 Soil Organisms and Organic Matter

Soil aggregate stability is proportional to its organic matter content. As a general rule, when soil organic matter levels are high, there are more stable aggregates than in soils with low organic matter levels.

By their movement through the soil, the larger soil organisms, such as earthworms and soil insects, leave small channels and promote good soil structure. When soil organisms decompose organic matter, cementing agents such as sugars and gums are formed. These substances serve to bind soil particles together as aggregates, but in time these substances are themselves decomposed by other soil organisms. Therefore, in order to maintain a constant supply of cementing agents to promote soil structure, soils must have a continuous replenishing of organic matter; otherwise, the original structure will deteriorate.

In soils under cultivation for annual crops, the structure deteriorates faster than it can be built up by plant roots and organic matter. The effect of crops on the formation of stable aggregates is shown in Figure 4. Note that the addition of manure also increases the formation of aggregates.

2.1.3 Soil Texture - Clay

Clay particles are an important agent in soil aggregate formation. In sandy soils, a small percentage of clay may be the chief agent binding sand particles together. In soils which are dominantly clay, aggregates may tend to be larger than desirable for the preparation of a seedbed. In such soils, the addition of generous amounts of organic matter tends to promote smaller aggregates. Sand may be used in conjunction with organic matter additions.

2.1.4 Soil Water - Wetting and Drying - Freezing and Thawing

Prolonged saturation of the soil will eventually weaken and 'dissolve' soil aggregates and cause pores to be filled with finer particles. After drainage, the soil may become very compact, retarding water and air movement and restricting root growth. The watertable in perennially wet soils must be controlled by artificial drainage before good structure can be achieved.

In drained soils, alternate wetting and drying and freezing and thawing of the soil mass has a very important effect on structure. When soils freeze, water in the pores expands, forcing aggregates apart. Moist or dry soil aggregates break down into smaller particles when they are wetted, unless the wetting is very gradual. As wet aggregates dry out, they shrink and crack, breaking down into smaller aggregates. When soil aggregates are large, several centimetres in diameter, this process may be desirable. In soils with small or very weak aggregates, these processes may destroy most of the structure.

Tillage implements, operating in wet soils, can also rapidly destroy structure simply by mechanical forces acting upon soil aggregates. Even on a weakly structured dry soil, tillage can have a detrimental effect on the soil structure.

2.2 Soil Structure, Degradation and Plant Growth

The air and water relationships within the soil are markedly influenced by soil structure. Optimum plant growth depends upon an adequate, but not excessive, supply of water and air, as well as a loose, friable medium through which roots and shoots can penetrate. Such a favourable structure is usually found in the plow layer of most cultivated soils,

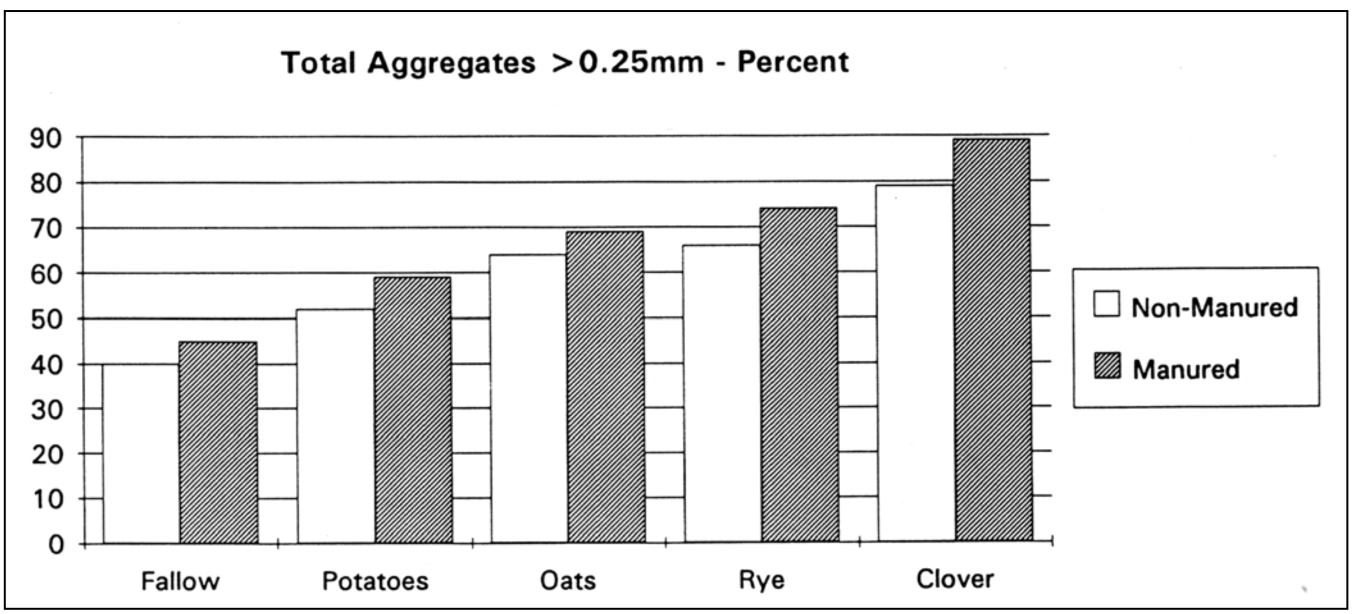


Figure 4

Effects of cropping practices on soil aggregation where the common structure is described as granular or crumb-like.

The plow layer is subject to many agents or forces which break down or build up soil structure. Some structural conditions, unfavourable to plant growth, commonly occur in soils. These are outlined in the following sections.

2.2.1 Crusting and Puddling

By the action of water or mechanical forces, the granular or crumb structure in the plow layer may become completely broken down into a solid mass with no large pores. Such a soil is said to be puddled. When the puddled surface dries out, a hard crust forms. This crust may prevent seedlings from emerging, and tend to seal off the soil surface, preventing the infiltration of air and water.

2.2.2 Soil Compaction

Soil compaction refers to the disruption and reduction of the large pores within the soil. The presence of excess soil moisture at the time of any field operation is the main factor leading to soil compaction. Once a soil is compacted, the bulk density and the strength of the soil are increased. For construction purposes, a compacted soil is ideal, but under normal crop production, a compacted soil can be a serious problem. Penetration into the soil by tillage implements and crop roots is restricted. The movement of air and water through the soil is hampered, causing the soil to remain wet and cool long into the growing season

Many areas in British Columbia suffer from this debilitating condition, which can be the main obstacle to good crop production. Because compaction is such a serious threat, a closer look should be taken at ways to reduce or reverse its effects. However, section 2.2.2 will only deal with the recognition and effects of soil compaction.

2.2.2.1 How to recognize a compacted soil.

Soil compaction occurs when a force compresses the larger soil pores and reduces the air volume of the soil. (See Figure 5.) The continuity of the pores from the surface of the soil to deeper depths is disrupted, and thus, the transmission of water through the soil, and gases between the crop's roots and atmosphere is reduced. (See Figure 6.)

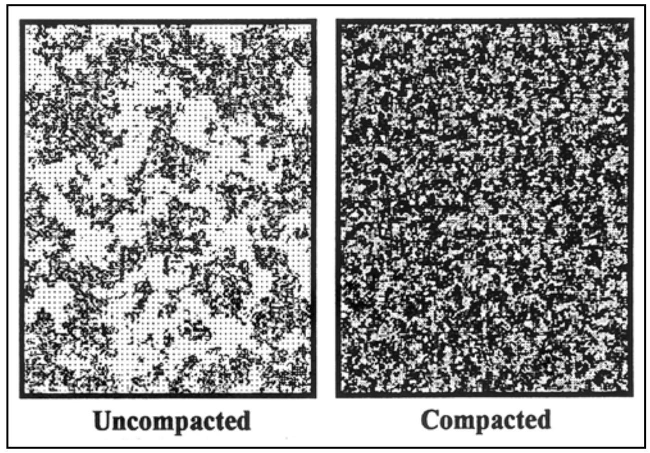


Figure 5

The effect of compaction on pore space

Measurements of compaction damage to agricultural soils can be based on changes in density, strength or visual estimates of structure.

a) Bulk Density

The measurement of a soil's bulk density provides a relative value of soil compaction. The porosity of a soil can be related to the bulk density measurement, with further laboratory procedures.

Bulk density is expressed as weight per volume of soil (usually in terms of grams per cubic centimetre). Variation in bulk density can occur on a year to year basis, as freezing and thawing, wetting and drying cycles, and cultivation can alter the basic structure of a soil.

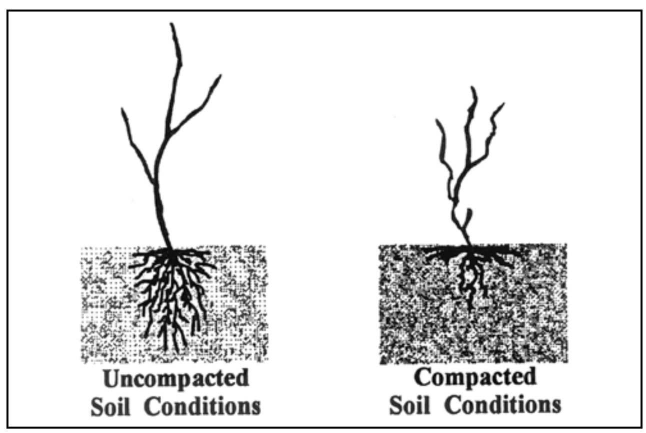


Figure 6

The effect of compaction on crop root growth

The bulk density of high organic mineral soils and peats is much lower than that of mineral soils. Table 7 gives some examples of soil bulk density measurements.

Table 7

Examples of Average Mineral Soil Bulk Densities

	(g/cm^3)*
Well structured high organic loam soil	0.9
Silt loam	1.1
Medium to fine-textured loam	1.3
Sand	1.5
Compacted soil or clay subsoil	1.3-1.6

*1 g/cm^3 = 62.43 pounds per cubic foot

b) Penetrometer Method

Another method of measuring soil compaction is using a penetrometer. Penetrometers can give quick results in the field, and many measurements can be taken in a short time. However, the use of penetrometers and interpretation of the results requires considerable skill, especially if soils are in the initial stages of compaction. Penetrometers are useful in finding hard layers that will obviously obstruct root development or water flow through a soil.

Penetrometers measure soil strength and their movement through the soil has been related to the soil's resistance to root penetration. Plant roots, however, grow around obstacles and can exert tremendous local pressure on soil pores, so that penetrometers can only provide a relative root resistance value.

Factors which affect penetration resistance as measured by penetrometers are cone angle, cone diameter (surface area), and rate of soil penetration; soil factors which affect soil strength or resistance are water content, structure and bulk density.

The effects of compaction are dependent on the amount of root zone that is compacted, continuity of the compacted zone and susceptibility of crops to compaction.

Table 8 is a rough guide to penetrometer resistance values (in megapascals - MPa) and soil compaction through the rooting zone.

These penetrometer readings are averages and were obtained using a penetrometer with a 60 degree cone angle.

Although using penetrometers is much easier and quicker in the field, the number of factors that come into play in interpreting their results makes them as difficult to use as the bulk density method. If proper sampling techniques are used, the bulk density method may give a more accurate result for any particular site in the field. Because both technical methods have limitations, the visual method may be the quickest and best alternative.

c) Visual Method

Often the best method of determining soil compaction is visual observation of both the soil and crops. Cloddy seedbeds, increased surface water ponding,

Table 8

Impact of Soil Resistance Values on Crop Yield

Effect of Compaction on Crop Yield	**Soil Resistance Value (MPa)***
Low	1.0
Medium	1.0-1.5
Severe	2.0-3.0

*1MPa = 145.0 pounds pressure per square inch

*1KPa = 0.1450 psi

loss of granular soil structure and reduced pore spaces through the soil are good visual indicators of compaction. Digging an observation hole in the field and observing rooting depths and patterns helps to determine if the crop is exploring the total soil volume or is restricted. Probing soil layers with a knife can indicate compacted zones and help determine where rooting or water flow has been curtailed.

Depressed crops, stunted or contorted root systems, a tendency to show yellow colouring, especially during or after large rainfalls (poor aeration), indicate compacted soils. Shifts in weed population are also good indicators. In addition, root rot diseases may increase with surface compaction.

2.2.2.2 Effect of Soil Compaction on Crops

A reduction in yield or yield potential is the most significant effect that soil compaction has on crops. The inability of roots to penetrate compacted soil layers will result in decreased yield. With less root penetration into the soil, root mass is reduced and a plant's ability to take up nutrients is reduced. As a result of surface soil layers having lower water storage capacities, plant roots remain closer to the surface and are, therefore, more susceptible to drought during periods of peak evapotranspiration. Compacted soils often have higher subsurface soil moisture contents because soil water is unable to drain away freely and air movement in the soil is restricted. This reduction in internal drainage generally leads to surface ponding which may drown the crop when evapotranspiration is low.

As a result of the reduction in the size and number of macropores in the soil and the subsequent reduction in aeration, microbial activity is reduced. Soil microbes play an important role in the breakdown of organic matter and fertilizer into usable plant nutrients, so soil fertility may be reduced. Poor quality, low fertility organic matter accumulates on the soil surface because soil microbes are not present to breakdown crop residues. Well decomposed organic matter (humus) levels in the upper soil layers will decline with a reduction in microbial activity. With this loss of humus, soil aggregate stability is reduced.

Mechanical pressure and manipulation from equipment and loss of aggregate stability lead to further degradation of the soil structure. Compacted soils also tend to warm more slowly, resulting in slower crop growth and higher moisture contents. Compacted soils remain cool and wet into the growing season resulting in conditions that favour the growth of soilborne pathogens such as Pythium or Rhizoctonia root rot. Plants under stress are also much more susceptible to root rots and other diseases.

If compacted layers are present in the soil, the risk of soil erosion is increased. The movement of water into and through the soil is reduced resulting in greater overland flow and subsequent surface erosion. Increased erosion will result in lower crop yields.

2.2.2.3 Factors Influencing Compaction

The potential of any soil to compact is dependent upon its physical properties, water content and the nature of the force applied. The physical properties influencing compaction include the original bulk density and structure as well as the texture and organic matter content. In general, soils with fine textures (silt and clay), low organic matter contents, high porosities and weakly aggregated structures, are more susceptible to serious compaction. From a soil management stand point, all soils should be considered as capable of being compacted.

The two major management factors that influence the soil's ability to compact are the soil moisture content at the time of any field operation and the contact pressure exerted by the implement or vehicle involved in that operation.

2.2.2.4 The Causes Of Soil Compaction

a) Natural

Compaction is the result of either natural soil formation processes and/or cultural practices. Natural compaction, resulting from soil formation processes, is found in many areas. This compaction is usually related to chemical transformations below the surface of the soil. It may also be related to the texture of the subsurface material and how it was deposited. Natural compaction may take the form of hardpans or cemented subsoils. Because some natural compaction continues as the soil formation processes continue, there is little or nothing that can be done to prevent its occurrence. Cemented layers or shallow natural hardpans may be disturbed by deep cultivation.

Other management practices, such as drainage, may reduce the effects of the hardpans or reverse the soil formation processes that lead to cemented layers.

b) Cultural Practices

Most soils in their undisturbed state have porous surface layers, but after years of cropping this porosity is often significantly reduced. This reduction in pore space and size is the result of several cultural practices performed either alone or together. Some cultural practices that cause reduction in porosity and compaction are untimely or excessive tillage, repeated tillage at the same depth, pulverizing of soil aggregates by tillage equipment and excessive or untimely access to field by farm vehicles. The process of deformation of randomly placed soil particles into a dense layered mass is known as puddling. A 'puddled' soil has a greatly reduced infiltration rate. (See Figure 7.) The term 'Ks', refers to the steady state water infiltration rate of a soil.

c) Drainage

The presence of excess soil moisture is the main cause of soil compaction. The cultural practice with the greatest potential to reduce soil compaction in much of the humid areas of British Columbia is the use of subsurface drainage. The whole soil is more easily deformed and soil particles can be forced together when subjected to external pressure when they are wet. In saturated soils, the soil particles are dislodged and subsequently redeposited in a dense, layered form.

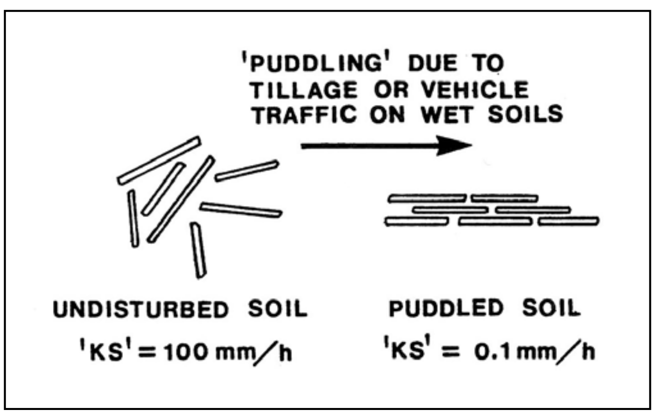


Figure 7

Puddling of soil particles

Wheel ruts and tillage pans formed in soft wet soils can be seen to have an effect on crop growth long after any excess soil moisture is gone. Drainage systems can be designed to prevent saturated soil conditions thereby greatly reducing soil compaction problems. (See Figure 8.)

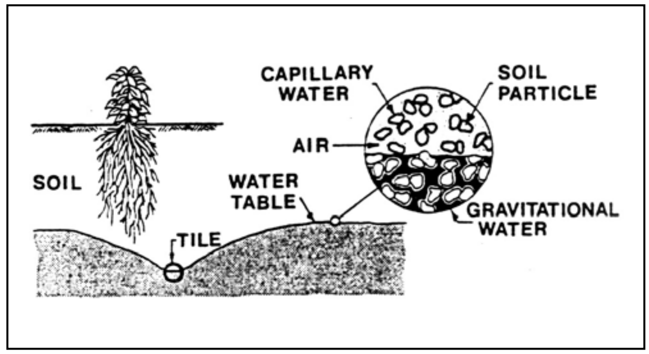


Figure 8

Effects of drainage on soil moisture

d) Traffic

Traffic from vehicles such as forage wagons, farm trucks or manure vacuum tankers exerts force on the soil. (See Figure 9.) The degree of compaction caused by vehicle traffic is dependent on two main factors that can be controlled by the crop producer. The first is the contact pressure of the vehicle which is determined by the overall weight of the vehicle and the foot print of the vehicle tires or tracks. The greater the contact pressure and/or the more frequently the vehicle passes over a particular area in the field, the greater and deeper will be the resulting compaction. (See Figure 10.) The second factor is the soil moisture content at the time the vehicle is in the field. The greatest amount of compaction occurs when the soil is wet. It has been estimated that up to 80% of the soil surface of a field can be exposed to wheel traffic at least once in any field season; this is particularly true in the case of fields used for forage production.

e) Tillage

Tillage breaks apart soil aggregates, permitting soil particles to move apart or be forced closer together. Exposure of the soil particles to air also causes more rapid decomposition of soil organic matter which is

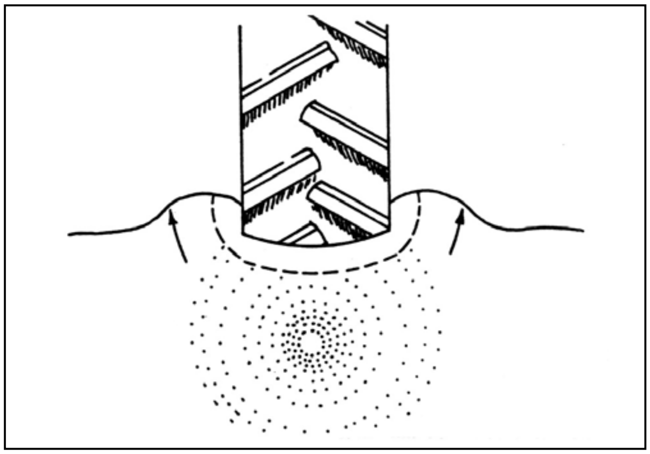


Figure 9

Effects of wheel traffic on soil (dotted and dashed lines indicate zones of compaction)

important for soil aggregate stability. In wet soils, tillage does not break apart soil particles, but rather smears the particles together to form clods. Tillage,

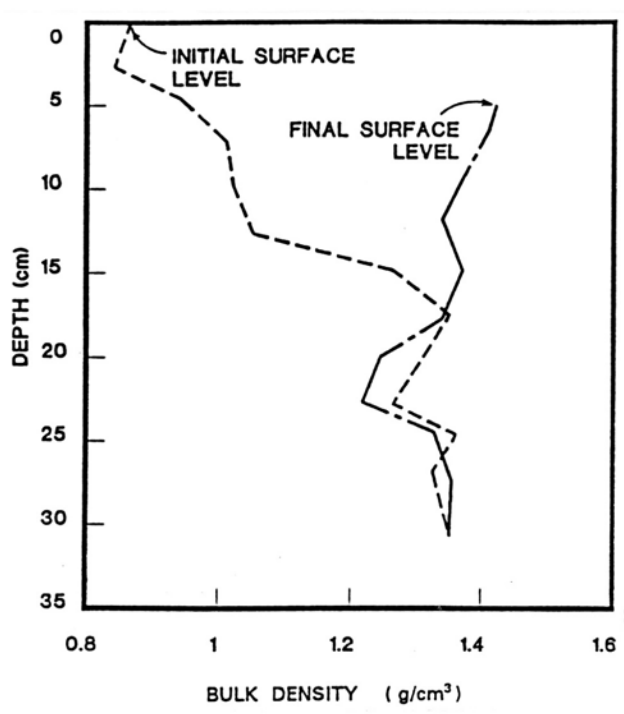


Figure 10

Bulk density profiles before and after tractor wheel passage

depending on the implement used, also exerts downward pressure on the soil layers below the surface leading to deep compaction and the formation of "plow pans". Thin layer smearing by implements such as mouldboard plows or rotovators, plus the compaction on the bottom of the furrow slice resulting from the contact pressure or any slippage of the tractor wheel cause deep tillage related compaction. (See Figure 11.)

f) Other Cultural Practices

Other cultural practices that lead to compaction are soil surface exposure, organic matter depletion and the use of some crop nutrition and protection products. The exposure of soils due to lack of vegetative or trash cover allows raindrop impact to disperse soil particles leading to "puddling" of the soil, and ultimately, compaction. One use of tillage is to incorporate organic matter. However, it is also possible for the simple act of tillage to accelerate the breakdown of some types of organic matter in the soil which are required to bind soil particles together.

In reduced tillage and forage production systems, soil structure is improved by microbial decomposition of organic residues without the benefit of tillage. Because many of the binding agents that maintain a soil's structure are the result of the activity of living organisms, excessive applications of soil amendments and pest control products may be harmful to those organisms. This would lead to a decline in the breakdown of organic matter into products that bind soil aggregates and the end result would be an increased risk of soil compaction.

2.3 Soil Fertility

Factors which contribute to soil fertility are the physical factors discussed in Section 2.2, as well as chemical and biological factors. Plants require various amounts of essential nutrient elements which must come from the soil. These include macronutrients such as: nitrogen, phosphorus, potassium, sulphur, calcium and magnesium and micronutrients such as: iron, manganese, zinc, copper, boron, molybdenum, cobalt and chlorine.

In cultivated soils, most of these nutrients are subject to removal by crops, to leaching or conversion to unavailable forms. Therefore, deficiencies occur sooner or later and nutrients must be added to the soil.

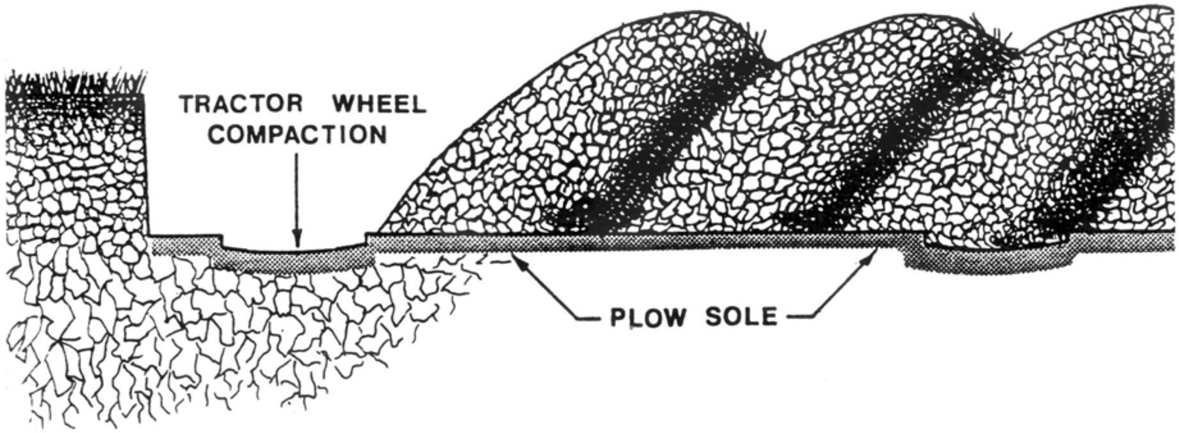


Figure 11

Schematic drawing of the effect of tillage practices on soils

Most Southern Interior soils are deficient in nitrogen and boron. Phosphorus, magnesium, copper, zinc and potassium may be deficient in some soils.

See Section 4.5 for more details of soil amendments that can be used to correct nutrient imbalances or deficiencies.

2.4 Soil Testing

Soil testing is a useful tool for determining fertility requirements of crops. A regular sampling program can also track the trends and efficiency of a fertilizer program. A soil testing program should be coupled with feed or plant tissue testing for a more complete pool of information from which the producer can make crop management decisions.

The value of the soil test is only as good as the method used to take the soil sample. It is important to be accurate in collecting the samples and when recording information about each sample.

Before sampling, you may wish to consult your nearest British Columbia Ministry of Agriculture, Fisheries and Food office or the British Columbia soil testing laboratory of your choice for any specific information regarding sample collecting containers or sampling procedures.

In most areas of the province, including the Okanagan and Similkameen Valleys, the best time to soil sample is either spring or fall. As a general rule, it is best to soil sample several weeks prior to the start of any seedbed preparation. Perennial crops, such as forage and pasture or berries and tree fruits, should have soil sampling done just prior to the beginning of a new flush of growth in the spring.

Fall soil sampling is ideal as it allows the producer to make soil fertility management decisions without having the pressure of an imminent cropping season.

When nutrient symptoms or other growth problems occur during the growing season, two samples should be taken, one each from the poor growth and good growth areas. A matching pair of plant tissue samples may also be useful for diagnosing a problem. These samples should be rushed to the laboratory so recommendations for any corrective action can be made rapidly. The following steps should be taken when collecting soil samples:

- Gather clean sampling equipment including a probe, auger or shovel and at least one plastic bucket for collection and mixing of the cores.
- Obtain the appropriate soil sample bags or boxes from the lab of your choice or use small plastic or paper bags.
- Make a simple map of your farm and identify each field or portion of a field which is to be sampled with a number or letter. Areas in any field that are different due to appearance, fertilization or cropping practice, soil type, slope or drainage should be sampled separately. Care

should be taken to avoid small, low, wet areas, dead furrows and areas close to trees, roads and fence lines unless these areas are of particular importance to the sampling program. Do not sample near manure piles (new or old), fertilizer storage or fertilizer bands or livestock droppings. Samples should be taken from fields or portions of fields that are reasonably uniform and can be managed as one unit.

- Record all pertinent information about the area sampled as soon as the sample is collected. This information should include a cropping history and desired crops to be grown, any recent fertilizer or soil amendment applications and any information relevant to the reason for the collection of the soil sample.
- Wear disposable gloves when taking samples for **micronutrient analysis**, so perspiration from your hands won't contaminate the sample.
- Store samples in a cooler in the field to minimize microbial activity which could give an unrepresentative nitrate result.

Soil samples are usually taken from the top 15 to 20 cm of the soil for most cultivated crops as this is the zone that is normally tilled and contains the major portion of the crop's roots. In perennial row crops such as raspberries, the sample should be taken from within the crop row. Sampling should be done with the tool that is most appropriate for the soil conditions. If the soil is stony or wet, an auger or shovel will work better than a tube type soil probe. Regardless of the implement chosen, the implement and the sampling bucket should be clean.

To begin sampling, remove excess plant residues. When using a shovel, create a V-shaped hole and slice a 2 to 3 cm thick slice down one side to a depth of 15 to 20 cm. Trim this slice on either side to form a 2 to 3 cm wide core and place this in the sample bucket. This core is an individual sample that will be used to create the final composite sample.

When using a probe, push the tube into the soil to the desired sample depth and collect the individual sample.

Take 10 to 20 individual samples from each sampling area. For fields up to 10 hectares in size, a minimum of 20 individual samples is suggested. Once all the individual samples have been collected in the bucket, break up the lumps and remove the stones. Make sure the soil is completely mixed and then remove about 500 grams or 500 millilitres and place this composite soil sample in the soil sample box or bag. The labelling on the sample should be the same as on the rough map of the farm or field.

If, however, the sample is quite moist, it should be air dried before it is sent to the lab unless it is to be hand delivered within a few hours of collection. Moist samples can incubate in warm conditions, such as post offices, bus depots and the inside of warm vehicles, thus changing the chemistry of the soil. **Soil samples should not be treated like dirt !**

Soil sampling is a useful farm management tool, but it is important to keep in mind that the soil test results are only as accurate as the sampling technique and the records kept on each sample. A good soil fertility program requires regular soil sampling, but it may also require feed or plant tissue testing as well. A sampling program that includes the preparation of a farm map each year outlining the location of each sample and the crop management practices that were associated with each field is recommended. Once you have chosen a soil testing lab, it is a good idea to stick with that lab, because each individual lab has its own "soil testing philosophy" for the determination of soil nutrient levels and also for the interpretations and recommendations that come from the test results.

Soil Sampling Methods Specifically For Orchards

Where to Sample for Mature Trees

Take the soil samples under the trees in the area between the tree trunk and the drip line. This is the area where the fertilizers have been applied and is the area where acid conditions usually occur.

Select five to ten trees for sampling in an orchard block where the soils are similar (see Figure 12). For large areas of similar soil, a minimum of 30 trees per hectare should be used. Take one sample beneath each tree at 1 m from the tree trunk and make a composite sample for analysis.

Where to Sample for Young Trees

Select young trees and high density dwarf plantings which are similar in growth characteristics, height and in depth, i.e., less than 0.5 m, 0.5 to 1 m, more than

1 m, etc., in an orchard block where the soils are similar (see Figure 12).

Obtain individual samples from beside four to eight young trees with similar growth and height and make a composite sample for analysis. Obtain a composite sample for analysis from two or more locations with comparable growth and height.

Before Planting

Before land is planted to orchard for the first time or is replanted after removal of an old orchard, soil analyses are strongly recommended. Such analyses can reveal unsuitable soil conditions that may be rectified before planting. Lime, for example, can be incorporated into the soil by cultivation if the pH is found by analysis to be low. Incorporation of any materials by cultivation is difficult once an orchard is established.

Soil samples should be taken from all parts of the acreage in which land contours or soil types obviously vary. When the planting is an old orchard, samples should be taken separately on the sites of removed trees where fertilizer applications have been heavy, and on sites between tree rows that have received little or no fertilizer.

2.5 Plant Tissue Sampling

Plant tissue sampling is another means of assessing fertility, but is only good for some specific crops and growth stages. In general, sample the youngest, mature leaves of representative plants, see Table 9 for an example of tissue sampling strategies. Plants should represent only one area, one variety, one fertilizer treatment and should be of the same vigour. For any crop, particularly blocks of tree fruits, follow a pattern suitable to the field. Use the X-pattern wherever possible. Do not take leaves from the outside trees on the border of a block or from trees within two rows of dusty roads. Figure 13 shows the X-pattern method of sampling. Samples should not be diseased or dead; tissue should not be damaged by

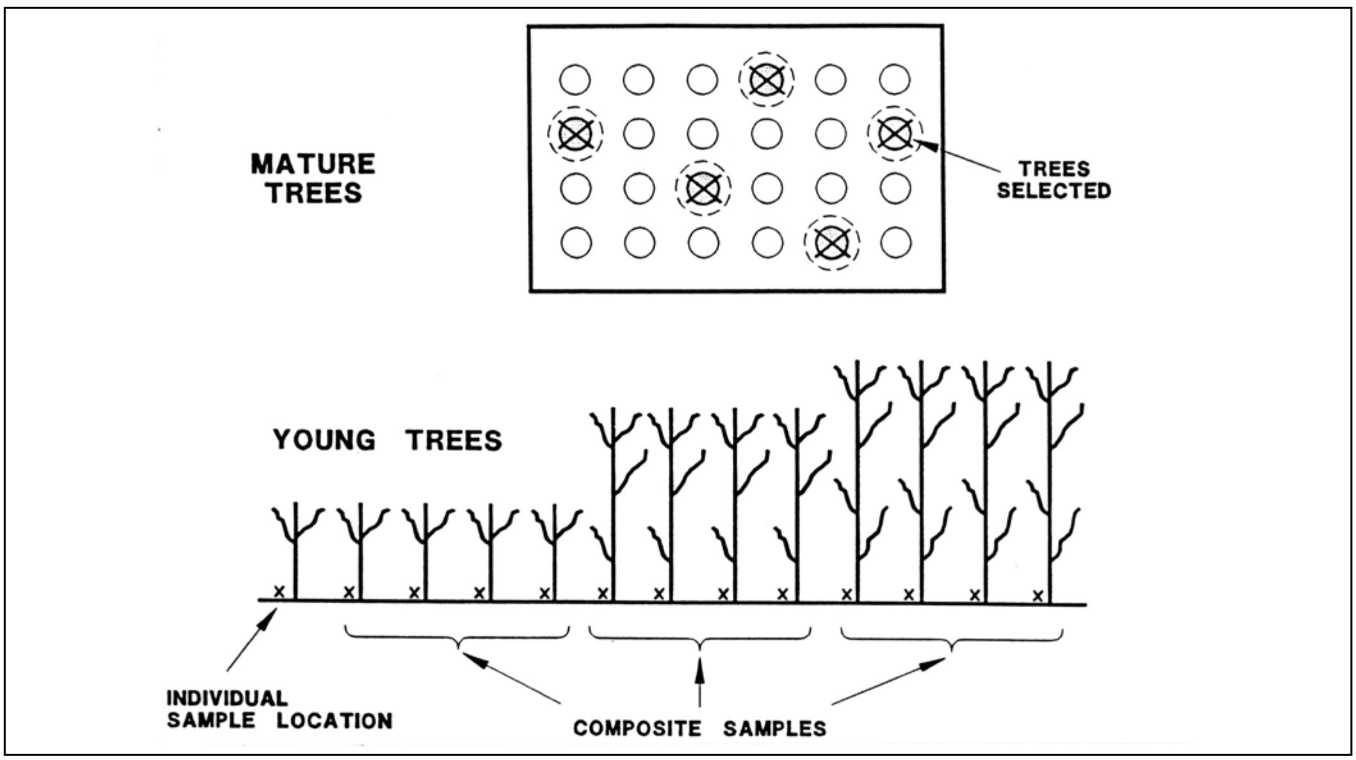


Figure 12

Soil Sampling Methods for Orchards

insects or mechanical equipment. If leaves appear dirty, wash them in a mild detergent solution for one minute, rinse immediately in fresh water for one minute and drain on clean paper towel. Samples should be promptly sent to a laboratory to avoid spoilage, otherwise, they should be spread to air-dry prior to shipment. Contact your nearest British Columbia Ministry of Agriculture, Fisheries and Food office or soil and plant tissue testing laboratory for specific information regarding sampling or refer to the commercial "Production Guides" that are also available.

Table 9

Examples of Tissue Sampling Strategies

Crop	**Stage of Growth**	**Plant Part to Sample**	**# of Plants or Leaves to Sample**
Tree Fruits	Current years growth	Middle $^{1}/_{3}$ terminal growth	50 leaves
Grapes	Bloom to end of bloom	Petioles from leaves adjacent to fruit	100 to 300 petioles
Corn	At tasseling	Entire leaf at ear node	20 to 30 plants
Potatoes	After tuber initiation	4^{th} petiole from growing tip	20 to 30 plants
Alfalfa	$^{1}/_{10}$ bloom	Upper $^{3}/_{4}$ of tops	30 to 50 plants

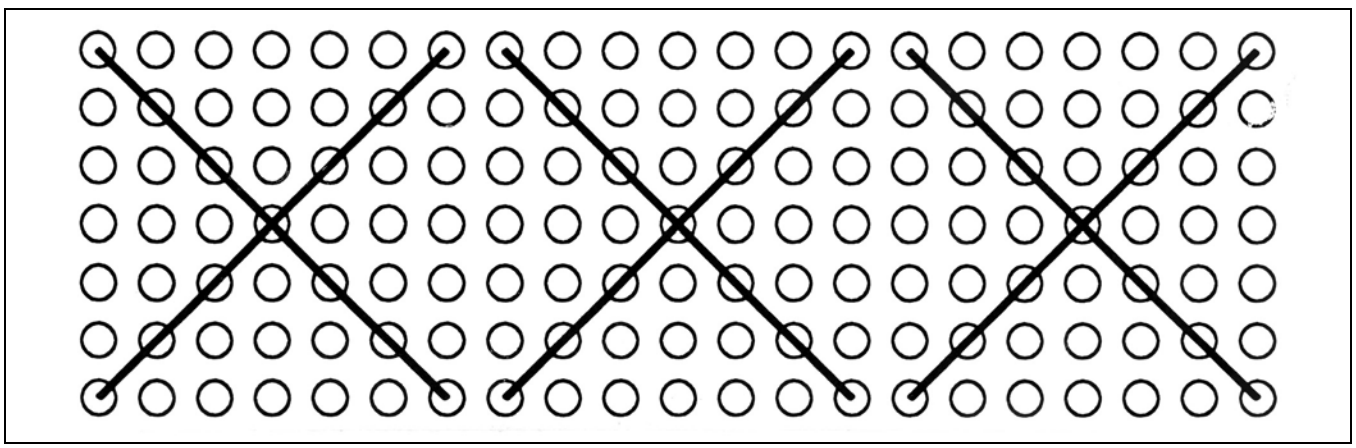


Figure 13

X-Pattern Sampling Method

3. Water Management

High rainfall during the fall and spring periods and during snow melt runoff often causes saturation, flooding and water erosion of most soils, while low rainfall during the summer period often causes a water deficit for most crops. High watertable and water deficit conditions are both detrimental to optimum crop production, but both may be largely overcome with irrigation, appropriate tillage, soil management and drainage.

3.1 Irrigation

Evapotranspiration exceeds precipitation for the period from May through September in the Okanagan and Similkameen Valleys of British Columbia. Climatic moisture deficits (Precipitation minus Potential Evapotranspiration from May to September) range from -498 mm at Oliver to -295 mm at Vernon Coldstream Ranch. Supplemental irrigation is, therefore, required to reduce the climatic moisture deficit and achieve maximum production. Designing an efficient irrigation system requires a good understanding of soil, crop and moisture relationships. The effects of soil type, crop rooting depth and climate are important when considering irrigation system application rates and set times. Four specific criteria must be considered when designing an irrigation system. Those criteria are: 1) Maximum Soil Water Deficit, 2) Maximum Irrigation System Application Rate, 3) Maximum Irrigation Interval and 4) Irrigation System Water Requirement. Some of these criteria will be discussed below, but for a detailed examination of how to design an irrigation system, please refer to the *British Columbia Sprinkler Irrigation Design Manual* and the *British Columbia Trickle Irrigation Design Manual.*

3.1.1 Irrigation System Design Criteria

3.1.1.1 Maximum Soil Water Deficit

The maximum soil water deficit is the maximum amount of water that can be removed from the soil before the crop is affected. It is calculated from the rooting depth and availability coefficient for the crop and the available water storage capacity for the soil that the crop is to be grown in.

3.1.1.2 Effective Rooting Depth

The effective rooting depth of a mature crop is that depth of soil from which a crop removes significant amounts of water. The normal effective rooting depths for crops grown on deep, uniformly porous, friable and fertile soils are given in Table 10. These rooting depths may vary for different species, varieties and planting densities, but the standard depths used for an irrigation system design can be modified for soils which do not permit normal root development. Compaction of the surface or the subsurface soil layers, excessively coarse subsoil, impervious subsoil, poor soil drainage, high watertables, adverse soil chemistry and fertility problems are all factors which could reduce the effective rooting depth for irrigation. Irrigation systems must be designed to meet crop requirements. Shorter duration and more frequent irrigations are required for crops that cannot reach their full rooting depth.

3.1.1.3 Available Water Storage Capacity

The available water storage capacity (AWSC) of the soil is the depth of water that can be retained between field capacity and permanent wilting point. The capacity of a soil to store water depends upon the particle size composition (texture) and particle arrangement (structure) of the soil. To obtain an estimate of the water-holding capacity of a soil, it is necessary to determine the texture of the soil within the effective rooting depth of the crop to be irrigated. Soil textural classes are determined from the percent of sand, silt and clay present within the mineral fraction of the soil. Refer to the textural triangle at the beginning of the soil management section for soil texture classes. Table 11 can be used to calculate the AWSC of the soil once the texture is known. The total AWSC of the effective rooting zone is obtained by adding the AWSC of the various soil textural layers.

Table 10

Effective Rooting Depth of Mature Crops for Irrigation System Design

Shallow 0.45 m	Medium Shallow 0.60 m	Medium Deep 0.90 m	Deep 1.20 m
Cabbage	Bean	Brussel Sprouts	Alfalfa
Cauliflower	Beet	Cereals	Asparagus
Clover (ladino)	Broccoli	Clover (red)	Blackberry
Cucumber	Carrot	Corn (sweet)	Corn (field)
Lettuce	Celery	Eggplant	Grape
Onion	Pea	Pepper	Loganberry
Radish	Potato	Squash	Raspberry
Rangeland species	Spinach	Tree Fruit –Pear	Tree Fruit – Other
Turnip	Strawberry		
Ginseng	Tomato		
	Blueberry		
	Forage grass		

Table 11

Available Water Storage Capacity (AWSC)

Textural Class	AWSC cm of Water/m of Soil
Sand	6.5 – 10.0
Loamy Sand	8.0 – 10.0
Sandy Loam	9.0 – 15.0
Fine Sandy Loam	10.0 – 14.0
Loam	14.0 – 19.0
Silt Loam	19.0 – 23.0
Clay Loam	16.5 – 22.0
Clay	20.0 – 25.0
Organic Soils (Muck)	23.0 – 27.0

3.1.1.4 Availability Coefficient

Different crops have varying capabilities of withdrawing moisture from the soil. Only a portion of the total AWSC is readily available for plant use. The availability coefficient is the maximum fraction of the total AWSC stored in the root zone that can be removed before irrigation is required. Allowing depletion of soil moisture to exceed the levels indicated by the availability coefficient, may result in a reduction of crop yields. Table 12 lists the availability coefficients for various crops.

3.1.1.5 Maximum Irrigation System Application Rate

Water infiltration into the soil surface depends on soil texture, structure and type of ground cover. The irrigation system application rate should be limited to the infiltration capability of the soil. The objective is to eliminate runoff, ponding of water and puddling of the soil under the irrigation system. Exceeding the maximum design application rates shown below, could lead to soil degradation by compaction or erosion over the long term. Soil compaction and erosion can result in lower crop yields if poor irrigation practices are continued from year to year. Proper nozzle selection and maintenance is important to ensure that maximum soil infiltration rates are not exceeded.

Table 12

Availability Coefficients

Crop	Coefficient
Peas	0.35
Potatoes	0.35
Tree Fruits	0.40
Grapes	0.40
Tomatoes	0.40
All other crops until other data available	0.50

Table 13 provides values for the estimated maximum application rates for various soil textures and ground cover under normal irrigation set times. The rates shown are assuming irrigation set times of between 4 to 24 hours. Acceptable maximum application rates for irrigation set times less than this time frame may be different. The values shown below are for level ground. For sloping ground the maximum rate must be reduced. A general rule is to reduce the maximum application rate by 25% for field slopes exceeding 10% and by 50% for fields with slopes exceeding 20%. Field tests under actual sprinkler conditions should be conducted to determine accurate application rates. There is an increased risk of soil erosion, mass wasting or other soil water related problems when application rates exceed those given in Table 13.

3.1.1.6 Maximum Irrigation Interval

The maximum irrigation interval is the maximum number of days between irrigations that a crop can sustain optimum growth and production. It is calculated by dividing the maximum soil water deficit by the peak evapotranspiration rate. The actual irrigation interval may differ from the maximum irrigation interval if the irrigation system does not apply the total amount of water capable of being stored in the soil at the maximum soil water deficit. Irrigation should be applied to most crops when 50% of the water in the soil, which is available to the plants, has been depleted.

3.1.1.7 Evapotranspiration Rates

Evapotranspiration (ET) is a measure of the rate at which water is transpired from plants plus the water evaporated from the soil and crop surface. The peak ET averaged over the irrigation interval decreases as the interval increases. Since the irrigation interval is related to the AWSC of the soil, peak ET decreases with an increase in maximum soil water deficit. Table 14 provides the best estimates of the highest

Table 13

Maximum Design Application Rates (based on a soil infiltration rate when irrigation set is >4 hours)

Textural Class	Grass Sod (cm/hr)	Cultivated (cm/hr)
Sand	1.9	1.0
Loamy Sand	1.7	0.9
Sandy Loam	1.2	0.6
Fine Sandy Loam	1.0	0.6
Loam	0.9	0.5
Silt Loam	0.9	0.5
Clay Loam	0.8	0.4
Clay	0.6	0.3
Organic Soils (Muck)	1.3	1.3

Table 14
Peak Evapotranspiration Rates For the Okanagan and Similkameen Valleys (cm/day)

	Maximum Soil Water Deficits (cm of water)				
Location	**2.5**	**5.0**	**7.5**	**10.0**	**12.5**
Armstrong	.66	.56	.53	.51	.48
Ellison	.69	.61	.58	.53	.53
Joe Rich	.53	.46	.41	.38	.38
Kelowna	.71	.64	.61	.58	.56
Keremeos	.79	.76	.74	.71	.71
Oliver	.74	.66	.61	.58	.58
Osoyoos	.84	.76	.71	.69	.66
Summerland	.76	.71	.66	.61	.61
Vernon	.66	.58	.56	.53	.53

Example Calculation of Maximum Soil Water Deficit and Maximum Irrigation Interval for Apples Grown on a Silt Loam in Summerland

Effective rooting depth of apple crop	1.2 m (Table 10)
Available water storage capacity for a silt loam	21.0 cm/m (Table 11)
Availability coefficient for apples	0.40 (Table 12)

Maximum soil water deficit for apples on a silt loam = 1.2 m x 21.0 cm/m x 0.40
= 10.1 cm

Peak evapotranspiration for maximum soil water deficit of 10.1 cm at Summerland is 0.61 cm/day (Table 14).
Maximum irrigation intervals is 10.1/0.61 = 16.5 days.

Recommended irrigation intervals is 16.5 x 0.5 = 8 days (see Section 3.1.1.6)

average ET during an irrigation interval. The ET values are given in cm per day for maximum soil water deficits of 2.5 to 12.7 cm of water.

3.1.2 Application Systems

There are a number of systems available for applying irrigation water. These include solid set, hand move, wheel move, giant reel or big gun and trickle or drip systems. Each system has advantages for use for specific crops. Sprinkler systems are described in the publication, *B.C. Sprinkler Irrigation Manual.*

Careless application of water can lead to erosion on sloping land. **Excess applications of water on glaciolacustrine cliffs in the Okanagan can cause slumping.** Alkaline (saline) salts are also present in some soils of the Okanagan and Similkameen Valleys and excessive water application may lead to the development of saline seeps. Application rates should be sufficiently low not to exceed the infiltration capacity of the soil. Furthermore, care should be taken not to exceed the water-holding capacity of the soil, since further additions of water will cause saturation and eventually runoff and erosion.

Impact of large drops of water disperses soil particles and leads to compaction. Nozzles should be chosen to discharge water in small droplets. Also, soils that have been wetted by irrigation are more vulnerable to compaction from traffic.

With the increased demand on a limited supply of water in the Okanagan and Similkameen Valleys, trickle or drip irrigation systems have become popular. Trickle systems can deliver water to crops more efficiently than sprinkler systems, although, the level of system design and maintenance is greater. Trickle systems should be designed to match the anticipated peak evapotranspiration rate of the crop. The system should be designed to operate for not more than 20 hrs/day. Trickle irrigation systems are described in the publication, *B.C. Trickle Irrigation Manual.*

Trickle irrigation systems offer additional benefits to sprinkler systems in applying nutrients and systemic pesticides. As water is applied directly to the plant's root zone, nutrients can be efficiently applied. Trickle systems may not be compatible with herbicides or insecticides as the chemical is not applied evenly over the entire ground surface. An exception would be spray emitter systems which could be used for weed control on some crops. At the present time, there are no chemicals registered for this type of use.

Injection systems are required for maintenance of the trickle system. The addition of chlorine and acids to a trickle system may be required in some areas to prevent algae and precipitate buildup in the emitters and lateral lines.

Chemigation

Chemigation is the term used to define the practice of applying chemicals to a crop through an irrigation system. Chemigation, includes fertigation, but also applies to the application of pesticides and growth regulators. The goal of a chemigation system is to apply the proper amount of chemical to the target area in a safe, efficient and uniform manner. The following precautions must be taken to achieve this goal:

- assure personal protection,
- be aware of the danger to the environment,
- calibrate the injection equipment to apply the correct amount of chemical at the right time and in the correct concentration, and
- use a well designed and maintained irrigation system.

Advantages of Chemigation

The application of chemicals through an irrigation system offers many advantages to the producer. Advantages obtained depend on the type of irrigation system used and type of chemical applied.

- Reduces the cost of chemical application by up to 50%.
- Reduces energy consumption by up to 90%.
- Insures timely application of chemicals.
- Reduces chemical use. Studies have shown that less fertilizer or pesticide is required when applied more efficiently.
- Reduces labour costs.
- Reduces machinery equipment needs.
- Improves operator safety. Exposure of the operator to chemicals applied through an irrigation system is greatly reduced.
- Improves crop production by simplifying cultural practices and improving crop production and quality if used correctly.

Disadvantages of Chemigation

Chemigation is not viable for all chemicals. Chemicals may not be soluble or remain in solution or may not act as intended under an irrigation application regime. More than one method of chemical application should be retained.

- Specified use and application according to product label. Pesticide labelling and/or registration restrict application techniques.
- Requires the addition of safety equipment. To prevent the possibility of backpressure or backsiphonage into a potable water source, approved cross connection control equipment must be installed and proper procedures followed.
- Requires an increase in system management. Personnel in charge of the chemical application must fully understand the calibration of injection

equipment and the operation of the injector, irrigation system, check valves and backflow prevention equipment.

- Timing of application may be limited due to wet and/or windy weather.
- Unwanted chemical residue. Sprinkler systems may leave a residue of the chemical on the crop.
- Corrosivity of chemical to irrigation system components. Chemical solutions may be corrosive to irrigation equipment.
- Unnecessary irrigation. Using an irrigation system to apply chemicals may apply moisture to the crop at a time when it is not required or when the soil is already too wet.
- Increasing soil acidity. The injection of some fertilizers into an irrigation system may increase the acidity of the soil.

Fertigation

Fertigation is the application of fertilizers through an irrigation system. It is particularly well suited to perennial row crops such as berry, grape and tree fruit production and annual vegetable crops, it can, however, be used on other crops. Equipment specific to fertigation includes a backflow prevention device and equipment for injecting fertilizer into the system. Various irrigation systems are used such as drippers, microjets, sprinklers, etc.

Fertigation is the only method of ensuring that fertilizers are incorporated into the soil when trickle systems are used to irrigate crops in arid regions such as the interior of British Columbia. Since trickle irrigation systems apply water directly to the plant's root system, better uniformity of fertilizer application to the crop can be obtained. Nutrients can be applied throughout the growing season with precalculated amounts and frequencies to meet crop demand at various growing stages.

With fertigation, there are several advantages as well as disadvantages.

Advantages of Fertigation

- Fertigation carries the fertilizer directly to the root zone; amounts and timing of fertilizer application can be more precise.
- When using a trickle type system, there is no problem with inadequate amounts of rainfall to move the fertilizer to the root zone.
- Studies have shown that less fertilizer is required when the fertilizer is applied directly into the root zone, therefore, there is less chance of fertilizer being leached to ground water which could result in pollution.
- There are also savings of labour when a fertigation system is in place.

Disadvantages of Fertigation

- Overall capital costs is higher.
- If the system is designed poorly, there may be poor distribution of the fertilizer.
- The fertilizer cannot be altered to suit individual plant requirements.
- Not all fertilizer types can be used.
- There is potential for salt and pH problems in the soil.
- The irrigation system may become corroded over time.

Detailed information on fertigation of specific crops (i.e., tree fruits and grapes) can be found in the BCMAFF, commercial "Production Guides"or *Fertigation Guidelines in High Density Apples and Apple Nurseries in the Okanagan-Similkameen*. Fertigation system design information is available from the *Chemigation Guidelines for British Columbia*.

NOTE: Prior to commencing a fertigation program, an Acidification Resistance Index (ARI) test should be completed to determine if the site is sensitive to acidification (see Section 4.5.2.3).

3.2 Water Conservation

The Okanagan and Similkameen Valleys are considered arid to semi-arid, so water for all uses should be considered as a valuable resource. Water supply, in any given year, depends on snow packs and rainfall. Water conservation is essential if all users are to be assured of a reasonable level of supply. Water conservation measures will vary from user to user. However, there are some basic water conservation techniques which can be practiced by agricultural water users.

The single most important soil factor that is beneficial in conserving water is the addition or use of organic matter as a soil amendment or mulch. Organic matter improves soil structure and holds moisture. Mulches allow rain or irrigation water to penetrate, but prevents evaporation.

Water conservation techniques for agricultural water users are as follows:

- Maintain irrigation systems to prevent leaks, replace sprinklers or nozzles to reduce risk of loss or over application.
- Use correct sprinklers, nozzles and pressure for the designed system spacing.
- Keep filtration system clean.
- Irrigate only when required, based on soil moisture conditions or crop needs rather than on a schedule.
- Stop irrigation if rainfall exceeds 6 mm. Rule of thumb is to stop for 1 day for every 6 mm over the initial 6 mm, i.e., a 12 mm rainfall equals a 1 day stop.
- Ensure the system is designed for the soil and crop requirements.
- Use trickle or drip irrigation systems as they reduce water use by as much as 30% over a sprinkler system.
- Use annual or permanent cover crops in perennial crops.
- In the case of perennial crops, keep them pruned to avoid excessive, non-productive shoot growth.
- Use mulches that allow water to enter the soil, but reduce evaporation.
- Recycle or reuse water used for washing produce.
- Improve soil structure.
- Conserve crop residues at or near the soil surface.
- Prevent excess growth of cover crops or weeds.
- Use windbreaks or shelterbelts to reduce wind velocity and evaporation.

3.3 Soil Management for Erosion Control

Soil erosion by water occurs whenever water fails to percolate into the soil and begins to move across the land as runoff. Erosion is greatest under high or intense rainfall conditions or rapid snow melt on frozen ground.
Erosion increases 1.5 times for every doubling of the slope length, and increases 2.5 times for every doubling of the slope percentage. Bare cultivated soil is the most susceptible to erosion. Erosion decreases as the density of the crop increases. Fields in permanent grass or grass-legume mixtures are the most resistant to erosion, and have the least soil loss. Water erosion can also result from improper sprinkler irrigation practices.

The general principles of soil management for water erosion control are:

- Maintain a vegetative cover to protect the soil from the impact of falling rain, to allow better infiltration of water, and to reduce the velocity of runoff water. Use cover crops and crop rotations which include close-growing crops. Crop residues should be left on fields over the rainy months or periods of snow melt rather than working the land.
- Maintain soil structure with large pores and good internal drainage to permit more infiltration of water. Avoid excessive tillage and compaction.
- Carry out tillage and seeding across the slope of the land, preferably on the true contour, rather than up-and-down the hill.
- Runoff water must be controlled rather than allowing it to erode the soil. This may require properly designed and located ditches, interceptor drains or permanently grassed waterways.

The following guidelines for soil conservation methods apply to upland soils with different degrees of erosion hazard due to the steepness of slopes.

1. Low to Moderate Erosion Hazard (2 to 5% Slopes)

Soils with slopes from 2 to 5% have low to moderate erosion hazard, but soil loss may be excessive, particularly if the slopes are long and approaching 5%. Surface runoff from adjacent land, should be intercepted with a drainage structure. Either an open ditch or a tile line backfilled with a porous medium can be used. Areas on hillsides with shallow soils overlying compact subsoils, or areas subject to saturation, should be drained with tile lines placed across the slope and backfilled with a porous medium. The surfaces of these drains should be maintained in a porous, open condition by establishing permanent vegetation on the drain line or by always growing a winter cover crop.

Tillage and planting should be done preferably on the contour, or perpendicular to the average slope of the land. Avoid excessive tillage which pulverizes and compacts the soil.

Soils should not be left bare or cultivated over the winter. Crop residues should be left on the surface, or a winter cover crop grown. A 2 to 4 cm layer of mulch, straw, litter or sawdust is effective in reducing soil loss.

2. Moderate to High Erosion Hazard (5 to 9% Slopes)

Upland soils with over 5% slopes are highly susceptible to erosion and soil conservation practices outlined above are considered essential. In addition, other measures may be necessary to overcome the greater erosion hazard found on steeper slopes.

- If slopes are over 50 m long, a 2 m buffer strip of permanent grass cover should be placed along the contour or perpendicular to the slope to intercept sediment laden runoff water.
- Natural waterways should be left uncultivated and maintained under permanent grass cover.
- Outlets for drains, ditches and natural waterways may require permanent drop structures to allow water to flow gently without causing erosion.
- Where it is feasible, recontour the land to reduce the steepness of slopes and remove abrupt knolls and undulations.

3. High to Severe Erosion Hazard (10 to 15% Slopes)

Regular production of annual crops on slopes between 10 to 15% is not recommended. Production of annual crops on this slope range is possible from a "mechanization" prospective, however, erosion control practices must be used. Crop rotation into perennial forage and/or cover cropping is recommended. If these soils are used for berry production, with the exception of strawberries, the conservation practices recommended above for 5% to 9% slopes should be used. Slopes in this range are extremely susceptible to severe erosion from over application of irrigation water, irrigation system failure and heavy rainfall resulting from "summer" storms.

Additional measures may be necessary to overcome the high erosion hazard.

- If soils are deep and fairly well-drained, terraces may be constructed to reduce the length of slopes. Terraces are not effective in shallow soils overlying compact subsoils.
- Interceptor drains with porous backfill and permanent grass cover should be closely spaced at about 15 m.
- Permanent grass buffer strips or interceptor drains, or both, should be placed on the contour so that no slope exceeds a 15 m length.

4. Extreme Erosion Hazard (Over 15% Slope)

Soils with slopes over 15% cannot be managed successfully for annual crops, or left in a cultivated condition over the winter without severe erosion. It is recommended that these soils remain under permanent vegetation, such as perennial forage crops, grapes or tree fruits, or cane fruits where the surrounding soil is maintained under permanent grass cover.

3.4 Drainage

Generally, poorly drained soils are those with a high watertable present for most of the year. The high watertable restricts the usefulness of the land by limiting the range of crops that can be grown and limiting the trafficability of soils. Although these conditions exist in the Okanagan and Similkameen Valleys, most incidences of high watertables occur during summer (May to July) as a result of spring runoff. These short term periods of high watertables usually coincide with blossom or peak early growth of crops. The result is that many sites with relatively well drained soils may experience poor growth as a result of the high watertables. Deep-rooted annual crops and perennial crops, such as tree fruits, are the most susceptible to these conditions. In most cases, the watertable can be controlled by means of artificial drainage. Usually, the costs of drainage are offset by the value of the crops which can be grown on drained land. Drainage systems are also necessary for erosion control on many upland soils, and in some cases, to overcome salinity.

3.4.1 Saturation

Soils are considered to be saturated when they have a soil moisture content greater than field capacity or the voids between soil particles are filled with water. Saturation of the soil for extended periods of time is harmful to most soils and generally causes reduction of crop yields. In addition, it causes trafficability problems reducing land access and use. It is for these reasons that saturation of the soil should be avoided by means of appropriate drainage systems.

3.4.2 Surface Ponding

Surface ponding may be due to either a high watertable or impoundment of water in depressions at the surface and in some cases due to both. It is harmful to most soils, for reasons described above, and it worsens the situation by causing layers of fine soil particles to be deposited which have a much lower permeability than the original soil. The following methods can be used to eliminate surface ponding: underdrains, with surface inlet provisions; land levelling, in certain situations; cover cropping; and reduced traffic and tillage.

3.4.3 Surface Drainage

The removal of water from the surface by means of shallow open ditches, swales or grassed waterways may be appropriate in some areas. This type of drainage does not lower the watertable and is, therefore, not a substitute for underdrains. Moreover, surface ditches, without permanent vegetative covers, are prone to erosion and restrict traffic on the land. It is for these reasons that surface drainage is a method of water removal which should be used only as a last resort where underdrainage is not possible or as an interim measure.

Surface drainage may be more appropriate for handling extremes of runoff which are the result of storm events. Even where the soil is dense, a subsurface drainage system with surface interception capability is to be preferred. Surface interception is achieved by placing drain rock over the drain to the surface or by means of a standpipe in the lowest area of a field. The drain rock system does not pose a restriction in the field and extends over a much larger area than a single standpipe. Porous interceptor drains have proven to be virtually 100% effective in intercepting surface water on sloping land. Care must be used not to cover such drains with soil during cultivation or allow vegetation to clog the surface of the interceptor.

3.4.4 Soil Management

Drainage and soil management go hand in hand. Cultivation of the soil tends to reduce soil tilth and the capacity of the soil to receive and transmit water. Every effort must be made to enhance tilth if drainage is to be successful. Following are examples of tilth enhancement measures: rotation of row crops with non-row crops such as grasses, and cereals; organic matter addition through application of manure, compost and use of green manure crops; cultivation methods which do not pulverize the soil such as avoiding use of high speed rototillers; avoidance of traffic during wet periods when the soil is most vulnerable to compaction. Surface soil management is the key to good drainage and water infiltration.

3.4.5 Organic Soils

Organic soils decompose and settle when water is removed and air is able to move into the soil. Over time, all the organic matter will disappear and the soil surface will be lowered. In most cases, this process is undesirable because of the high production value of the organic soil in contrast to the lower production capability of the subsoil. In order to halt or reduce the rate of decomposition and settling, drainage must be controlled so that the water level can be held high whenever this does not interfere with cultural practices. This practice is recommended in deep organic soils. Shallow organic soils benefit substantially less from water control measures and will in fact sustain damage to the structure of the subsoil. When organic matter depth is less than 40 cm, water control measures are no longer effective and are not recommended.

3.5 Drainage in Lowland Soils

Most lowland soils are poorly to very poorly drained and have a watertable near the surface for most of the year. Without artificial drainage, these soils have a short period of trafficability and are useful only for a few crops. The benefits of drainage are:

- Increased soil bearing strength, which improves trafficability and extends the opportunity days (when the watertable is 50 cm or more below the soil surface between 8 a.m. and 4 p.m., this gives an indication of the trafficability of the soil as well as the dryness of the potential rooting zone of the crop), by as much as 6 weeks earlier in spring and an extended harvest period. See Table 15, for an example of a fully drained versus undrained site.
- Enhanced timeliness of field operations, permitting more efficient distribution of labour and machine use.
- Rooting depth is increased, providing roots with a greater volume of soil from which to draw nutrients and water.
- Increased aeration, providing more oxygen for plant roots.
- Increased soil temperatures, permitting earlier germination and growth.

Underdrainage is the most effective means of controlling the watertable in most cases. In modern systems, lightweight, continuous flexible, perforated plastic drain tubing is installed using highspeed drain trenchers or drain plows. Drains will work effectively in many soils without additional measures, but some special conditions require additional precautions. Porous envelopes are recommended in tight, slowly pervious soils, and sandy soils require drain filters to prevent sand from entering drain tubes and clogging them.

Organic soils settle and decompose rapidly after they are drained, and the watertable should be more carefully controlled to minimize subsidence. Refer to Section 4.4, Management of Peat and Muck Soils. Drainage systems should be designed according to sound design principles and a topographic survey.

Table 15
Example Opportunity Days*Summary

Year	Fully Drained	Undrained
1982	84	34
1983	83	19
1984	90	4
1985	89	29
1986	90	3
1987	89	33
1988	84	17
1989	79	34
1990	76	13
1991	82	13
1992	88	24
1993	81	0
Mean	**85**	**19**
Range	**76-90**	**0-34**

* Results from: Boundary Bay Water Control Project, 8 am - 4pm watertable depth > = 50 cm midway between drains March 1 – May 31, 92 days

Detailed information is provided in the publication, *B.C. Agricultural Drainage Manual*.

3.6 Drainage in Upland Soils

Most upland soils are moderately well or well drained. However, soils that occur in depressional areas, or have compact slowly permeable layers close to the surface, are poorly to very poorly drained. Springs may also be present in upland sites, therefore, they should/could be intercepted with underdrains to remove wet spots. If the land is sloping, saturated soils will not hold additional water and surface runoff and soil erosion will occur. Uncontrolled soil erosion can bring about substantial, permanent damage to many upland soils, so that soil productivity and manageability are greatly reduced and the livelihood of the land user is threatened. Refer to Section 3.3, Soil Management for Erosion Control, for more information on erosion control in upland areas. Generally, perforated plastic drain tiles should be placed across the field contour between a 0.2/100 and 0.4/100 grade. The laterals should feed into non-perforated mainlines running down slope. A mainline grade should not exceed 5%. The mainlines should discharge into concrete or plastic junction boxes (sumps) before the water is discharged from the field. To discharge water from the junction boxes off the field, a flexible polyethylene pipe can be used. This pipe should be anchored or buried and discharge into rip rap in a stream or ditch bottom. Refer to the *B. C. Agricultural Drainage Manual* for more information.

3.6.1 Generalized Soil Drainage Guide

This guide presents guidelines for drainage and is a supplement to the *B.C. Agricultural Drainage Manual* which deals with detailed design procedures. It was developed based upon many years of practical experience in the Fraser Valley. The aim is to help in the identification of drainage requirements without the need of having to go through the detailed investigations described in the Drainage Manual.

The basis of this guide is a set of generalized soil profiles or soil categories which are distinctly different in regard to drainage and soil management requirements, see Table 16 (pages 60 to 61). Drainage requirements were formulated for each soil category, see Table 17 (page 62).

Since the recommendations of this guide are based on average conditions and generalized soil profiles, it is possible that, on occasion, site specific conditions are at variance with those for which the guidelines were formulated. It is for this reason, that caution must be used in applying the recommendations. Only through on-site investigation, can the necessary information for completely accurate drainage recommendations be provided.

3.7 Salt Affected Soils

Soils containing sufficient soluble salts to impair their productivity are considered to be either saline or sodic. The major salt constituents of saline or sodic soils are sodium, calcium, magnesium, potassium, carbonates, sulphates and chlorides. In semi-arid and arid regions, like the Okanagan, deep percolation of rain water does not occur frequently enough to leach salts. Any leaching that does occur is usually only local and a result of irrigation, so salt removal is held to a minimum. Salt movement may result in a concentration of salts in "seeps" or salt affected areas within a field particularly where shallow till or glacial lacustrine soils overlie calcareous bedrock.

Salinity is usually caused by natural processes. Salts in the groundwater may become concentrated in the plow layer when water evaporates from the surface, leaving the salts behind.

Salinity may also develop from the application of salty irrigation water applied to poorly drained or undrained land. Repeated applications of excessively high fertilizer rates, without crop use or leaching, can also lead to salinity. Salt affected soil are classified into three groups:

	E.C	E.S.P	pH
1. Saline	>4	<15	<8.5
3. Saline-Alkali	>4	>15	>8.5
2. Non-Saline-Alkali or sodic	<4	>15	>8.5

E.C. = Electrical Conductivity, dS/m
E.S.P. = Exchangeable Sodium Percent

Depending on the classification of the soil, the remedial measures required to manage the salts are different for each group. The following gives a brief outline of the management tools for salt affected soils.

Saline

- Drainage to remove excess groundwater or assist in removal of leached salts.
- Application of non-saline irrigation water.
- Growth of salt tolerant crops.
- Incorporation of organic matter preferably not manure or compost as they often contain high levels of soluble salts.

Saline-Alkali

- Drainage to remove excess groundwater or assist in removal of leached salts.
- Addition of gypsum, calcium chloride, sulphur or sulphuric acid to drive carbonates and sodium out of the soil. The best choice is gypsum as it is soluble and easy to handle.
- Application of non-saline irrigation water.
- Growth of salt tolerant crops.
- Incorporation of organic matter preferably not manure or compost as they often contain high levels of soluble salts.

Non-Saline-Alkali

- Drainage to remove excess groundwater or assist in removal of leached salts.
- Addition of gypsum, calcium chloride, sulphur or sulphuric acid to drive carbonates and sodium out of the soil. The best choice is gypsum as it is soluble and easy to handle.
- Incorporation of organic matter preferably not manure or compost as they often contain high levels of soluble salts.
- Application of non-saline irrigation water.

Crops vary in their range of tolerance to salts. Grapes, asparagus and squash have a moderate to high tolerance to salts where as apples, beans and clover are much less tolerant.

Table 16

Generalized Soil Profile Descriptions and Comments

Soil Category	
1	**0 to 150 cm medium-coarse-texture**. Water infiltration and movement through the soil is good. This allows for easy watertable control. There is little likelihood of surface ponding to occur. Drainage is most effective by means of underdrainage. There is no need for special surface drainage provisions, but land leveling should not be ruled out to eliminate problems in low areas. The water-holding capacity is low making provisions for irrigation desirable. Drains should be fitted with a filter. Iron ochre hazard is high.
2	**0 to 150 cm medium-texture (well structured).** Water infiltration and transmission through the soil is moderately high, but surface ponding can be a problem. Watertable control is effective with underdrains. Surface drainage provisions are not normally required, but land leveling is recommended. The soil holds water quite well and irrigation needs are not high.
3	**0 to 150 cm fine-texture (well structured).** Water infiltration and transmission through the soil is low with a fairly high surface ponding hazard. Watertable control is difficult. Underdrains are suitable, but a close spacing is necessary. Blind surface inlets should be considered in troublesome depressions particularly under sloping conditions. Soils in this category respond well to subsoiling and careful soil management is a prerequisite for effective water control. Land leveling is strongly recommended.
4	**0 to 100 cm coarse-texture (well structured)//100 to 150 cm fine-texture, moderately compact.** Water infiltration and transmission through the soil is high. Ponding hazard is low. Underdrains are the most effective way of controlling the watertable and there is no need for special surface drainage provisions. Irrigation requirements are high. Filters are not needed if the drains can be placed sufficiently deep into the subsoil. Iron ochre hazard is high.
5	**0 to 100 cm medium-texture (well structured)//100 to 150 cm fine-texture, moderately compact.** The capacity of the soil to accept and transmit water is moderate to low requiring a relatively close drain spacing for good watertable control. Where the dense subsoil is less than 100 cm deep, porous soil material or gravel should be used to bind the drains. Underdrains are most appropriate for drainage and land leveling is a good measure to eliminate depressions and the likelihood of surface ponding. Under sloping conditions, there is a moderate to moderately high suitability for subirrigation.
6	**0 to 100 cm fine-texture (well structured)//100 to 150 cm fine-texture, moderately compact.** Control of excess water in this soil is difficult. A close drain spacing must be used for adequate control and considerable emphasis must be placed on proper soil management to achieve satisfactory results. Land leveling and judicious use of blind surface inlets in depressions is recommended. Irrigation requirements are not high due to the high water-holding capacity. This soil responds well to subsoiling. When the land slopes, there is a high risk of water erosion.
7	**0 to 50 cm coarse-texture//50 to 150 cm fine-texture, moderately compact.** This soil accepts water readily, but transmission of water is hampered by the dense subsoil. Drains are well suited to control the watertable and filters are not necessary provided drains are placed at the recommended depth. There is little danger of surface ponding, and except for land leveling, there is no need for surface drainage provisions. Irrigation need is relatively high. Improving the soil depth through subsoiling is recommended. The possibility of encountering ochre is quite high.
8	**0 to 50 cm medium-texture//50 to 150 cm fine-texture, moderately compact.** Excess water management poses difficulties because of the shallow surface soil. Drains must be place close together and at a shallower depth than normal. Blinding with porous soil or gravel is recommended. This soil requires emphasis on drainage measures related to the surface. Land levelling and the use of blind surface inlets in depressions, and in other strategic locations, is needed for optimum water control. With slope, surface interceptors are necessary to stop erosion. Subsoiling will deepen the effective soil depth and aid in water movement, and should be done prior to drain installation. Ochre hazard is low.

9 **0 to 50 cm fine-texture//50 to 150 cm fine-texture, moderately compact.** Water management requirements of this soil are high. A great deal of effort and care is needed to get rid of excess water. Closely spaced drains, with provisions for direct surface drainage with gravel filled trenches, are necessary. Where such surface provisions are not possible, the use of surface ditches may be unavoidable. The soil must be broken with a subsoiler and well supplied with organic matter. Permanent cover crops will work best, but if that is not possible, a careful crop rotation must be selected to prevent the soil from being structurally damaged. Ochre hazard is low. Under sloping conditions, erosion potential is high and surface interceptor drains are required.

10 **0 to 50 cm medium-texture//50 to 150 cm coarse-texture.** Watertable control of this soil is difficult. Underdrains are very effective, but filters are required. Efforts must be directed towards keeping the surface soil in an open, well structured condition, with organic matter applications and sensitive management practices. A fairly high ochre hazard is present.

11 **0 to 100 cm medium-fine-texture//100 to 150 cm coarse-texture.** Although watertable control of this soil is moderately good, surface conditions are poor. Land levelling and surface drainage oriented provisions are desirable as are subsoiling, organic matter applications and sensitive management practices. Filters are generally required and the ochre hazard is moderately low.

12 **0 to 40 cm organic material moderately well to well decomposed//40 to 150 cm fine-texture, medium high density.** Water movement into and through the soil is restricted requiring fairly intensive drainage for satisfactory control. Control of water for inhibiting decomposition is of relatively little effect and should not be used in this soil because of the adverse effect of such measures on the subsoil structure. Subsoiling will be of help in enhancing subsoil porosity and water movement.

13 **0 to 40 cm organic material, moderately well to well decomposed//40 to 150 cm medium to medium-coarse-texture.** Water control prospects are high in this soil which is well suited to the use of underdrains. Filters are recommended where sand is present at drain depth. Accelerated decomposition of the organic material is a consequence of improved drainage. It should be reduced by keeping the watertable level high whenever possible through water control facilities. The effectiveness of these measures, however, diminishes as the depth of the organic material is reduced.

14 **0 to 150 cm organic material.** Movement of water through this soil material is variable, but generally in a medium range. Underdrains control excess water well, but accelerated decomposition is a consequence. Drains must be placed at a maximum depth and provided with a water control system to raise water levels when possible. Drought hazard is low due to a high water-holding capability.

15 **0 to 100 cm organic material, well to moderately well decomposed//100 to 150 cm medium-texture.** Movement of water through this soil material is variable, but generally in a medium range. Underdrains control excess water well, but accelerated decomposition is a consequence. Drains must be placed at a maximum depth and provided with a water control system to raise water levels when possible. Drought hazard is low due to a high water-holding capability.

Table 17

Drain Recommendations Based on Generalized Soil Profiles

Soil Category	Depth (cm)	Texture	Drain Spacing (m)	Depth (m)	Special Requirements
1	0-150	Coarse	20	1.2	Filter
2	0-150	Medium	16	1.2	
3	0-150	Fine	14	1.2	
4	0-100 100-150	Coarse Fine-Dense	18	1.2	Filter
5	0-100 100-150	Medium Fine-Dense	14	1.2	
6	0-100 100-150	Fine Fine-Dense	12	1.0	Subsoiling
7	0-50 50-150	Coarse Fine-Dense	16	0.8	Subsoiling
8	0-50 50-150	Medium Fine-Dense	12	0.8	Subsoiling
9	0-50 50-150	Fine Fine-Dense	10	0.8	Subsoiling
10	0-50 50-150	Medium Coarse	18	1.2	Filter
11	0-100 100-150	Medium-Fine Coarse	16	1.2	Filter Subsoiling
12	0-40 40-150	Organic Fine-Dense	12	1.0	Subsoiling
13	0-40 40-150	Organic Medium-Coarse	16	1.2	Filter
14	0-150	Organic	14	1.3	
15	0-100 100-150	Organic Medium	14	1.2	

4. Practical Aspects Of Soil Management

Good soil management begins with an evaluation of specific soil conditions and an understanding of potential problems before attempts are made to grow a crop. Land under natural vegetation, or cleared land under pasture may prove to be difficult to manage after it is cleared or cultivated. It may be inadequately drained, have shallow topsoil, impermeable subsoil, or it may be too steeply sloping to permit cultivation without excessive erosion.

Many potential problems can be identified with information in soil survey reports and maps. Farmers and other land owners are encouraged to obtain more detailed soil management information by contacting soil management specialists who are members of the B.C. Institute of Agrologists. Specific problems and recommendations for management can only be made on the basis of an examination of actual soil conditions. Therefore, recommendations made in this Handbook should be considered as general guidelines only.

4.1 Land Clearing, Levelling and Recontouring and Terracing

Improper soil management practices during and following land clearing, levelling and recontouring operations, can result in severe soil degradation either due to excessive compaction and/or erosion of the topsoil.

4.1.1 Land Clearing

Land clearing is any operation which includes the removal of excess undesirable vegetation or debris from a site, such as trees, shrubs, stumps, logs or rocks.

The practice of land clearing must be thought of in several phases in the Southern Interior region in order to reduce soil degradation. The site should be mapped to identify intermittent streams, surface water runoff channels and steep slopes such as ravines. Land at the edges of ravines, river banks or other steeply sloping areas subject to erosion, **should not be cleared**. If they are cleared, they should be seeded to a permanent vegetative cover. Intermittent streams or surface water runoff channels should also be left uncleared unless provision is made to keep water from entering them. If these areas are cleared and cultivated without some means of controlling runoff water, they will soon develop into gullies. By identifying water courses and severe slopes, a drainage plan can be prepared and installation take place prior to the fall of the year of clearing. This will reduce the risk of soil saturation and erosion in the first and subsequent winters following clearing.

Every attempt should be made to clear land only during the dry season in order to reduce water runoff and soil erosion. Trees could be removed in the fall and winter, but soil disturbance should be avoided. Once the trees are removed, stumps, rocks and under brush can be removed in the summer and the soil can be prepared with a breaking disc or plow. Discing is recommended for shallow soils, while a mouldboard plow may be more satisfactory in sod, or soils with a deep topsoil. Traffic on and tillage of wet soil should be avoided in order to reduce compaction.

Newly cleared land could be cover cropped with cereals, grasses and/or legumes in order to prevent surface soil degradation from erosion and help rebuild the soil structure.

4.1.2 Land Levelling

Land levelling is any operation which scrapes soil material from high points in the field and places that soil material in low points in order to render the field level (or on a constant grade). Land levelling may take two forms, the first being simply the scraping and dragging of soil around the field until the surface is level with no consideration given to topsoil variability and/or salvage. The second is the deliberate removal of the topsoil, then levelling of the subsoil to a constant grade and the subsequent replacement of the topsoil in a uniform layer over the entire field. This second method may be more appropriate in shallow organic soils with undulating subsoils or in areas where the subsoils are very coarse-textured or high in salts.

Some critical points to remember when preparing to level a field are as follows. Firstly, what are the soil moisture conditions? Soil that is wet or extremely dry is very susceptible to structure degradation. Wet soil smears while dry soil fractures. Very dry soil that is worked excessively becomes powder and structureless.

Secondly, is there adverse chemical or physical constituents in the soil that could be exposed by the levelling operation? Examples of that would be salt layers or compacted or stony subsoils. If this is the case, it may be appropriate to remove the topsoil and level the subsoil.

Thirdly, is there a need to crown the land or put a constant slope on the soil surface to aid in surface drying? Where soil texture, structure or management restrict drainage and underdrains are in place, crowning or shallow sloping of soils may be appropriate to relieve the risk of surface ponding.

4.1.3 Recontouring and Terracing

Recontouring is any operation which reshapes the field surface to eliminate or reduce the effects of micro-topographic undulations while at the same time not producing a constant grade or level field. An example of this would be the development of grassed waterways in upland areas.

When filling in depressions or small gullies, topsoil should be carefully removed from the area to be filled, stockpiled and spread evenly after the land has been filled or levelled with subsoil. Fill material should be somewhat packed with tractor wheels, otherwise loose fill may settle, leaving a depression. Filled gullies may continue to erode if the fill is not packed. Drainage systems may need to be installed to collect or redirect, in a controlled manner, any water which could collect in the gulley.

When spreading topsoil on compact exposed subsoils, it is recommended that the subsoil be loosened with a chisel plow or subsoiler before spreading topsoil. This will help to overcome poor internal drainage caused by a compact layer immediately below the plow layer.

Terracing is any operation which reduces erosion by controlling and managing surface runoff. A terrace is a channel with a supporting downslope ridge constructed across the slope. Terraces break up long slopes into a series of short ones with each one collecting excess water from an area above it. The collected water is then removed from the field safely.

Terraces are the most expensive conservation practice. However, they allow for more intensive row cropping while keeping erosion in check. Studies in the United States show crop yields on terraced land are 10 to 15% higher than those on erodible land that is not terraced. Full recovery of construction costs can occur in as little as three years.

Terraces make more economic sense when combined with other conservation practices such as contouring, strip cropping or conservation tillage.

4.2 Tillage and Tillage Implements

Tillage is done for a number of reasons: to prepare a suitable seedbed; to bury or incorporate crop residues, fertilizers, lime or other soil amendments; to kill weeds; to form raised beds or irrigation furrows. Tillage implements exert mechanical forces on the soil which alter soil structure and bring about changes in soil tilth. As a rule, for most soils, there is a limited range of soil moisture conditions when tillage methods are effective. That is, if soils are too wet or too dry, tillage may leave the soil in poor tilth.

In cultivated soils, the structure in the plow layer is weakened or destroyed by two main agents: the weather and machinery traffic. Bare soil left exposed to the weather, to rain and alternate wetting and drying, will naturally become less porous and more compacted as structural aggregates break down and become more closely packed.

Machinery traffic breaks down and packs soil aggregates directly, and if the soil is wet, the resulting compaction can be very great. Excessive tillage, that is, more tillage than the minimum necessary for the purpose, can also contribute to poor structure in the plow layer.

The effects of tillage implements on the soil are quite variable, depending upon soil texture and structure, the moisture content, and the organic matter content.

Medium and fine-textured soils with a high clay content are most difficult to manage because they can be successfully tilled only when the moisture content is ideal. It is common to find such soils too wet one afternoon, workable the next morning, and too dry the next afternoon. In such soils, it is generally found that high levels of organic matter promote workability and tilth.

Many coarse and medium-textured soils are easy to till over a fairly wide range of moisture conditions, and maintaining suitable tilth is not difficult. Some sandy soils, with very low clay and organic matter content, will not form aggregates at all.

4.2.1 Tillage Implements

There are two main types of tillage implements: plows and discs, which lift and invert the soil; and cultivators and harrows, which lift and stir the soil without inverting it. Some of the more common implements and tillage practices, and their effects on the soil, are explained in the following sections. For more details on tillage implement operation and/or use, a suggested reference is *Fundamentals of Machine Operation - Tillage, by John Deere.*

4.2.2 Rotary Cultivators (Rototiller, Rotovator)

The action of rotary cultivators results in a complete mixing and pulverizing of the plow layer. See Figure 14.

Because of this, the rotovator is popular as a means of breaking up and completely incorporating sod, crop residues, and soil amendments, while preparing a fine seedbed at the same time. However, the implement has some serious disadvantages. First, the plow layer tends to be too pulverized and repeated use over time is detrimental to stable soil structure. Second, the rotovator compacts the subsoil at the depth of penetration. Avoid slow tractor speeds which result in excessive pulverizing of the soil. Rotovating appears to achieve good practical results, but when used without deeper tillage to break up the tillage pan, the rototiller can do more harm than good.

Rotovators are most useful for breaking up old sod prior to plowing, or as a final tillage operation prior to seeding on sandy or organic soils. Deep rotovating is not recommended on medium and fine-textured soils because of the damaging effect the implement has on the structure of these soils. Following rototilling, soils must be rolled to make a firm seedbed as poor seed germination fields are the result of planting into fluffy, rototilled seedbeds. Rotary cultivators do not work very well in stony soils.

4.2.3 Spading or Digging Machines

Used as a primary tillage implement, the spading machine operates on the same principle as a human powered shovel. In most cases, the implements are built with multiple bottoms or spades which are attached to a PTO driven cam shaft. An example of this type of implement is the "Tortella" which has 6 spades on a cam shaft that is driven by a PTO through a variable speed gear box. The spade is driven

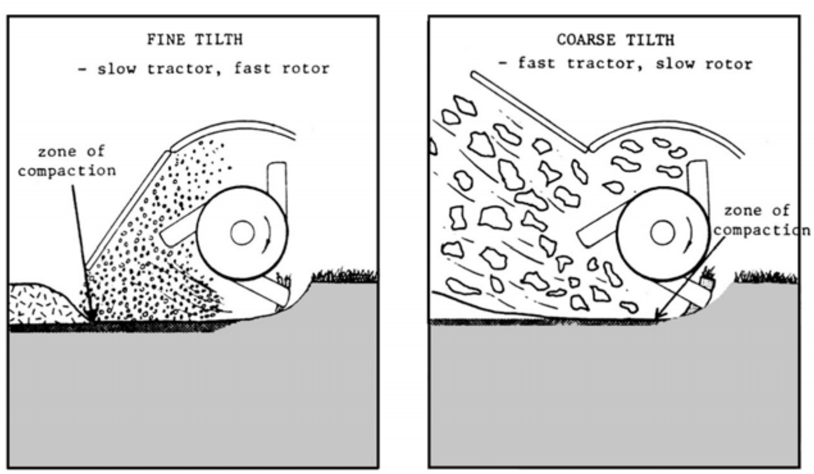


Figure 14

Schematic drawing of the action of rotary cultivation vertically into the soil and as it reaches its lowest vertical position, the cam then kicks the spade back. This action slices and breaks the soil as the implement moves forward. See Figure 15. This digging action reduces the downward compaction forces that are often associated with tillage equipment such as plows. By varying the speed of rotation of the camshaft and speed of travel, the soil can be broken into a wide range of aggregate sizes. Rotary spades, as compared to other tillage implements, work reasonably well in stony soils.

4.2.4 Power Harrow or Rotary Cultivation

Developed as a replacement for conventional rotovators, the power harrow works with a stirring action rather than a pulverizing action. The tines of this PTO powered implement are usually an inverted U-shape. See Figure 16. The advantage of the power harrow is that it exerts very little downward force on the soil. This reduces the risk of developing a tillage hardpan. The power harrow will provide complete mixing of the plow layer and can be used to break sod or prepare seedbeds.

4.2.5 Cultivators

The action of most cultivators is to lift the soil upward and forward, loosening it and allowing it to fall back into place. See Figure 17.

Cultivators may be used for deep tillage or for shallow surface tillage to prepare a seedbed and to aerate the soil surface, to kill weeds or to incorporate soil amendments. The effects of the cultivator on soil structure are much less severe than the effects of plows and discs. However, too many cultivations with sweep shovels will pulverize the soil, and if repeated cultivations are done to the same depth, compaction and a tillage pan can develop. Chisel points do not bring about compaction. The use of a chisel plow is recommended for relief of shallow traffic of tillage compaction. Working depth should be just below the compacted layer.

4.2.6 Disc

Like the plow, the action of disc implements is one of lifting the soil mass and throwing it sideways, but without a complete inversion of the soil. See Figure 18.

Discing is useful in smoothing a cloddy surface for preparation of a seedbed, or simply as a surface tillage operation to kill weeds or to incorporate soil amendments, fertilizers, lime and pesticides. Repeated shallow discing, to the same depth, may lead to a compaction zone or tillage pan at the depth of the cut, as well as pulverizing the surface.

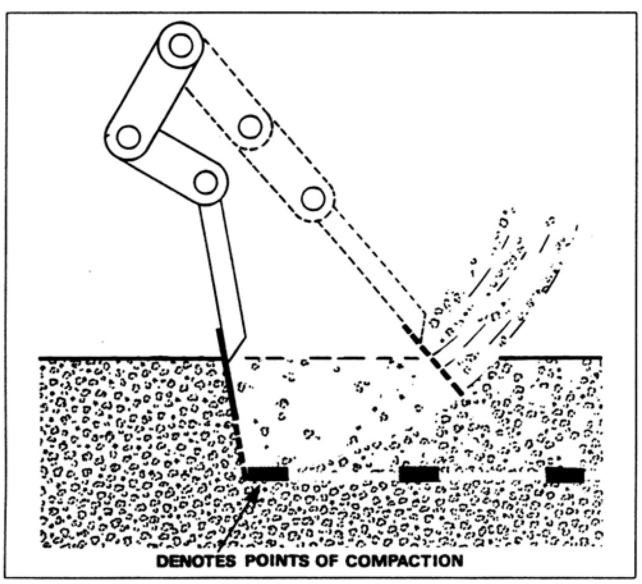


Figure 15

Rotary Spade

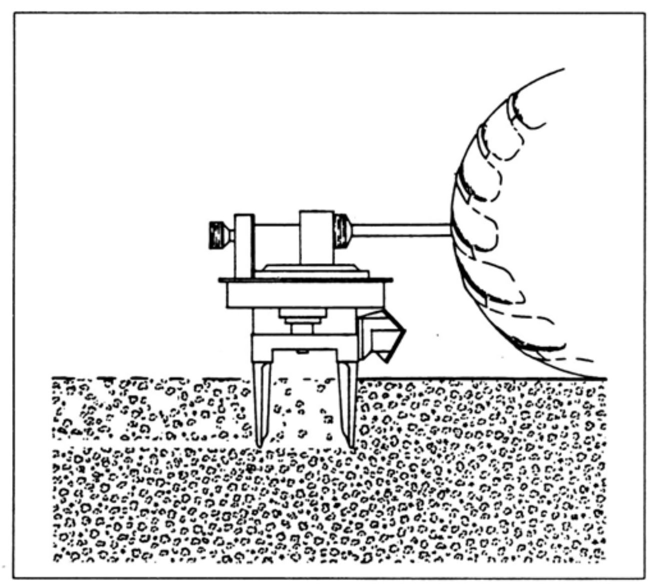


Figure 16

Power Harrow

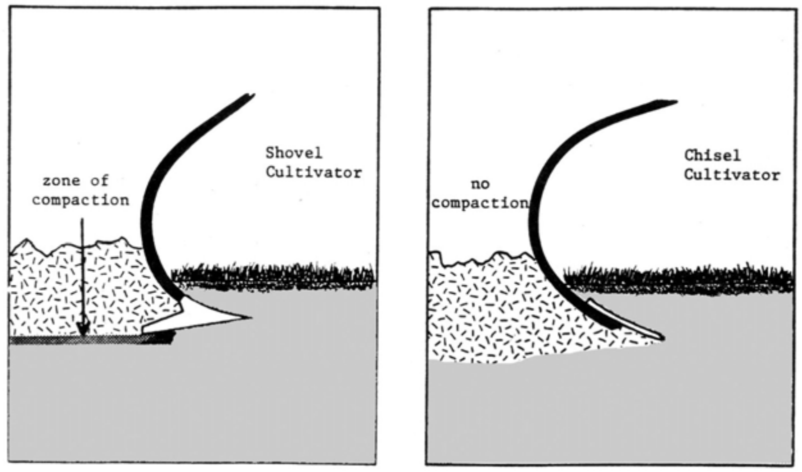


Figure 17

Schematic drawing comparing the effect of shovel and chisel cultivation on soils

It is important to adjust the angle at which the disc moves against the soil; too small an angle will tend to pack rather than loosen the soil.

4.2.7 Plows

The mouldboard plow is designed to lift the soil mass and throw it sideways so that most of the original surface soil is inverted and buried under soil from the bottom of the plow layer. See Figure 19.

Plowing is an effective method of restoring good tilth to a soil in which the surface structure has broken down, while the soil below the surface has developed a granular structure through the action of plant roots. The plow is quite useful for burying sod or a heavy growth of weeds or crop residues.

Plowing when soils are at the right moisture content is most important. If soils are too wet, the plow will turn over a solid mass of soil which has been compressed and compacted by shearing forces of the plow itself. In addition to this, the bottom of the furrow will also be compressed and the pores sealed off by the smearing action of the tractor wheel and the plow

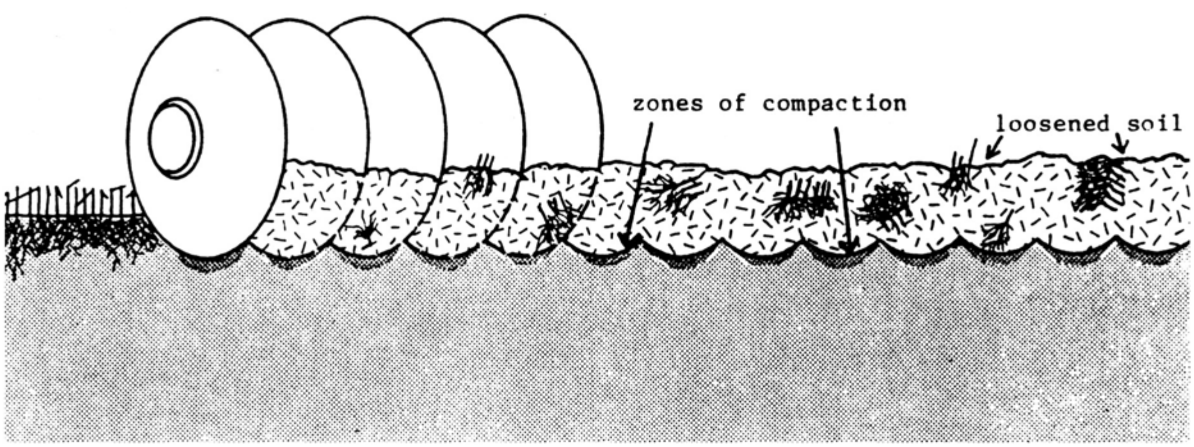


Figure 18

Schematic drawing of the action of disc implements

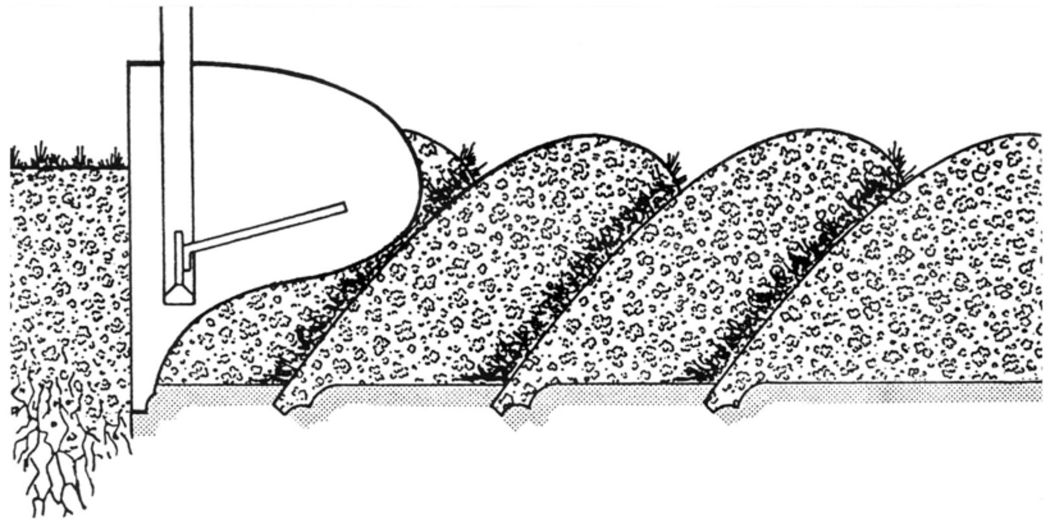


Figure 19

Schematic drawing of the effect of plowing on soils

bottom. It is possible to hitch the plow so that the tractor wheel remains on the unplowed land instead of in the furrow. If soils are too dry, plowing may result in the formation of larger clods which will take longer to break down.

Repeated plowing to the same depth may form a compacted layer (a plow-sole or plow-pan) which can become a severe impediment to air and water movement and root penetration. To minimize the formation of a plow-pan, it is recommended that plowing depth be varied. An existing plow-pan may be broken up by deep tillage with a chisel plow or a subsoiler.

4.2.8 Harrows

Harrows are either rigid or flexible tines which are simply dragged across the soil surface, stirring it and breaking down larger clods. Harrowing may be useful in preparing a seedbed, or to incorporate certain pesticides to a shallow depth, to break up straw and spread it more evenly over the field, or to scarify pastures and break up and spread manure on pastures. Repeated harrowing has the effect of pulverizing the surface and compacting the plow layer.

4.2.9 Aerator

Aerators have been commonly used in the turf industry for many years, however, more recently they have been used in the production of crops such as forage grass. Aerators are designed to break through surface crusts or layers of organic residue and provide a channel to allow air exchange within the surface soil layers. These aeration channels also provide inlets for rainfall and nutrients. Aerators relieve surface compaction and will improve the health of a forage stand.

Turf type aerators come in many forms, the most common being the hollow tine. Aerators with angled rolling tines, such as the "Aer-way" may be most appropriate for use in forage grass production. The tines are ground driven and can be angled to provide variable levels of surface disturbance. This type of aerator can also be used on cultivated land to roughen the surface and lightly incorporate crop residue or manure.

4.2.10 Packers

On some soils, a fine seedbed cannot be achieved conveniently with tillage implements, and it may be useful to pack the soil after seeding. Packers are useful for this purpose mainly on loose, sandy soils, but may be useful on some medium-textured soils. The "Cultipacker", and other dual-purpose implements, combines some form of cultivator with packing wheels. These are well-suited to some soils and are useful as the final tillage operation prior to seeding.

4.3 Soil Loosening/Subsoiling

Many factors influence soil structure, and soil loosening is only one of many practices used to improve soil structure. Soil loosening is no replacement for good management practices, including crop rotation and avoiding tillage when the soil is wet and easily compacted. Practices such as subsurface drainage and cover cropping, which adds organic matter and improves the soil structure, will tend to increase the effectiveness of subsoiling by stabilizing the aggregates formed.

4.3.1 Critical Working Depth

Whenever subsoiling is to be used, the critical working depth of the soil and implement should be determined. Critical working depth is a function of soil texture, soil moisture content and the tractor/implement configuration. Many researchers have reported that subsoiling operations should be designed to work at a depth just below the compacted layer or near the desired rooting depth of the crop. However, the actual working depth should be less than the critical depth of the soil implement combination. The critical depth generally occurs at a depth corresponding to an aspect ratio (tine depth/tine thickness) in the order of 5 to 7, although, it becomes shallower as the soils become more plastic (i.e., wetter) or the surface confining layers become harder and drier. Tine spacing is usually equal to the working depth which gives a considerable overlap of soil disturbance in the upper soil layer and adequate disturbance in the lower layer. For subsoiling to be effective, the critical working depth should always be less than the critical depth. The critical depth is defined as the depth at which maximum soil disturbance occurs. If the working depth exceeds the critical depth, draught will increase, compaction on the bottom of the furrow will occur and the volume of disturbed soil will not be maximized. Also, flow fracture, rather than brittle fracture will occur. Figure 20 demonstrates soil disturbance and critical working depth.

4.3.2 The Six Cases for Subsoiling

Soil loosening has been found to be economically viable in most situations where it would increase yield. The key is to determine under what conditions soil loosening will increase yield. Before a decision can be made to undertake a soil loosening procedure, information on several soil properties is needed. Many soils can be grouped into the following 6 cases. Recommendations for soil loosening are made for each case.

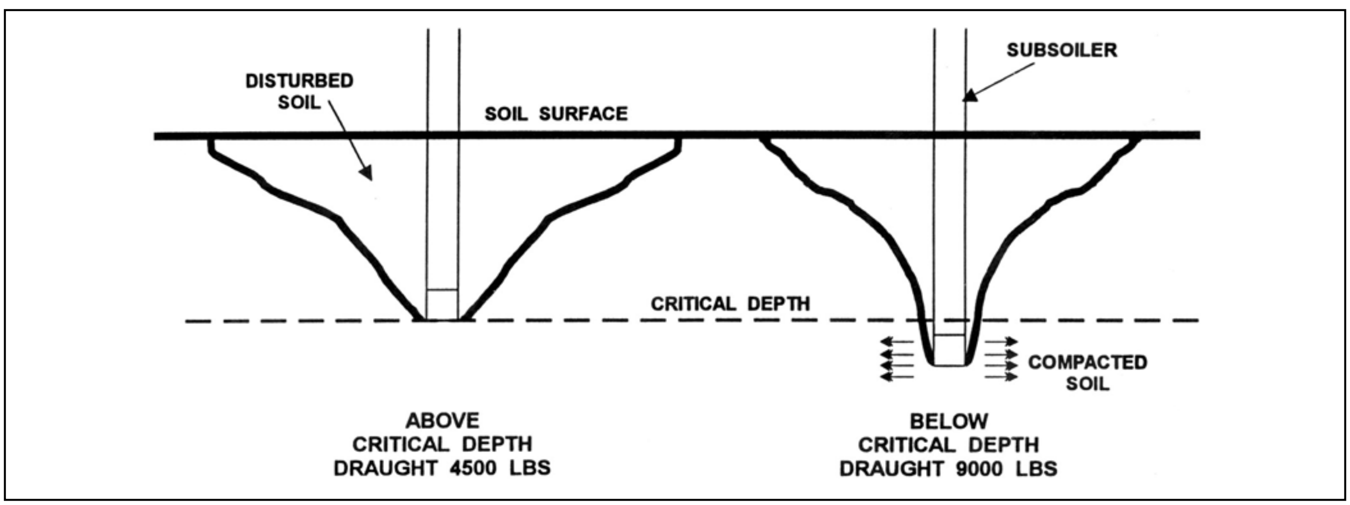


Figure 20

Cross-section showing soil disturbance caused by subsoilers working just above and just below the critical depth

Case 1: Well Structured Soils

If the rooting pattern is well formed (i.e., the rooting is dense and reflects the preferred growing habit of the crop), the field does not require soil loosening. In this situation, the cost of subsoiling will not be warranted. The added traffic and mixing of soil, caused by soil loosening methods, will likely damage the soil structure and reduce yields. If the rooting pattern is restricted, additional observations will be needed to determine the cause.

Case 2: Saline or Sodic Soils

Saline Soils

Excess salts greatly affect yield, soil properties and the response to soil loosening. Salinity may be the result of natural processes, such as residual salts from a marine soil origin or by salts added from groundwater. Cultivation practices, such as irrigating with saline water, over irrigation that causes subsoil leaching or applying excess fertilizer may also cause salinity problems. Often the presence of saline soils is demonstrated by good hydraulic conductivity in the surface soil, good tilth and the soil surface may appear white from salt crystals. Whatever the case, electrical conductivity (E.C.) tests should be run on soil samples taken from at least three soil layers, the root zone (0 to 20 cm), the middle tier (20 to 50 cm) and the subsoil (50 to 100 cm). An E.C. can be performed inexpensively by any soils laboratory. If any soil layer is over 2 decisiemens per metre (dS/m), the soil is somewhat saline. In this case, soil loosening should be avoided and desalinization, using drainage, leaching and altered cropping strategies, should be utilized.

A Sodium Adsorption Ratio (SAR) may also be useful to determine if the soil has the potential to form a hardpan during leaching. SAR's greater than 15 indicate a potential for hardpan formation.

Subsoiling, used by itself, may increase the salinity problem by bringing salts to the surface which will lower infiltration and make the soil harder to desalinize. The normal desalinization practice on these soils is to add soluble calcium to replace the sodium on the soil exchange sites, to improve the soil drainage and to irrigate with low-salt water to leach salts from the root zone. After drainage has been established, subsoiling may be required to help breakup a salt enriched (Bt) horizon. During the period of desalinization, lower yields may occur on the subsoiled areas.

Sodic Soils

Sodic soils are also referred to as alkali or solonetzic soils. They are often characterized by the presence of a sodium and clay enriched layer in the lower root zone. The surface topsoil layers may produce a reasonable crop yield in moist years or under irrigation, however, the hardpan and electrical conductivity (E.C.) of the subsoil restrict root development and air/water movement.

Subsoiling, to physically break this hardpan, has been very successful under dryland conditions. In some cases where the topsoil pH was low or the topsoil layer was shallow, lime or gypsum have been added to the surface prior to subsoiling. This either alters the pH, using lime or adds calcium to the soil to displace the sodium salts from the subsoil, but is an expensive process. pH adjustment should only be used for fine-textured lacustrine type soils. If very shallow topsoil layers exist or there is a hardpan layer, subsoiling should be avoided. Drainage may be required if sodic salts are a result of salty subsoil or salty ground water conditions.

Case 3: Poorly Drained Soils

If salinity was not effecting the rooting pattern, the next possibility is poor drainage. Soil drainage is defined in terms of: 1) soil moisture in excess of field capacity, and 2) duration of the period during which excess water is present in the root zone. Poorly drained soils are defined as having soil moisture in excess of field capacity remaining in all horizons for a large part of the year. Poor drainage conditions are typified by gleying which gives the soil a steel gray appearance. A practical way to assess drainage is to dig a small pit or well about 30 cm in diameter to a depth of 1 m. If the watertable observed in the well is within the normal root zone of the crop for over a week at a time during the growing season, the soil would probably benefit from improved drainage.

It is recommended that drainage be improved by lowering the ditch levels and by the installation of subsurface drains before soil loosening is undertaken. Subsoiling will improve the drainage only if the soil water removal system is adequate to handle the greater volume of drainage water. If a restricting layer persists after the drainage is established, subsoiling above and perpendicular to the drainline will improve the effectiveness of the drainage system, especially on coarser-textured soils which resist compaction.

In some areas, improved drainage will lower yield as the excess water removed may increase the available water during a period of drought. In such situations, both supplemental irrigation and drainage will normally improve yields over either practice by itself.

Case 4: Plow Pans

If a layer of dense soil, just below the plow depth, restricts or stops root penetration, a pan or plow-pan exists. Normally, the pan will be 1 to 20 cm in thickness and will break into large, hard to crumble, clods. Below the pan, the soil will be more friable and will break into smaller crumb-like aggregates. Generally, larger pores will be visible throughout the soil profile, but not visible in the pan.

In the case of the plow pan, deep subsoiling, while possibly beneficial in the short term, is not the best approach. The pan is generally the result of improper conventional tillage. Under conventional tillage, plow pans disrupted by subsoiling will likely reform rapidly. The first and best approach to handling plow pans is to avoid the cause of the problem by adjusting tillage practices and field traffic and equipment ground pressure.

Adoption of conservation or minimum tillage practices may be appropriate for some crops and soils. In this case, the plow pan should be broken up by a subsoiler with closely spaced tines which penetrate just deep enough into the soil to break through the bottom of the pan. Shallow or thin pans can be broken by using a chisel plow or chisel cultivator.

The basic principle of conservation and minimum tillage is to reduce the amount of soil disturbance from tillage and encourage the development of soil structure through increases in soil organic matter and biological activity. These tillage systems also reduce soil erosion and compaction. Conservation tillage systems, such as mulching cultivators, can be complimented by the use of subsoilers such as the "TYE Para-till". The Para-till implement uses a "dog-legged" shank which acts in such a way as to minimize surface soil disturbance while at the same time breaking the subsoil. The Para-till implement is appropriate for non-saline soils.

Another option to break up the plow pan after conventional tillage, is either by attaching tines to the plow or by using a shallow subsoiler. The shallow subsoil should have closely spaced (75 cm) tines that extend into the soil just enough to break up the pan. Conservation or minimum tillage are preferred to simply breaking up the pan, as they avoid further degradation of soil structure rather than simply attempting to ameliorate the plow pan.

Case 5: Soils With Compact Fine-Textured Subsoils

The glaciolacustrine and glaciofluvial soils covered by this Handbook may have compact subsoils or hardpans and could benefit from subsoiling. The following is a discussion of subsoiling in these and other similar soils.

In cases where the root restricting layer comprises all or a large portion of the soil profile, subsoiling may have a distinct beneficial effect. The soil texture of the restrictive layer plays an important role in determining the success of soil loosening.

Fine-textured soils present a problem to soil loosening. When a subsoiling tine (or any implement) is pulled through the soil, two types of fractures may occur. The desired type of fracture is brittle fracture. In brittle fracture, the soil ruptures along planes of weakness, the aggregate size is decreased and large pores are created along the fractures. After the passing of the implement, the soil resettles, but some of the large pores remain. The undesirable type of fracture is flow fracture. Flow fracture is analogous to a knife moving through butter. A large tubular void is created behind the tine and the soil around the void is compressed. The compressed soil has a larger, rather than smaller, aggregate size than the original soil. In the compressed area, the volume percentage of large pores is reduced rather than increased. In practice, both flow and brittle fracture may occur along the path of cultivation.

Flow fracture is increased by three major factors: the water content of the soil, the fineness of the soil texture and the overburden pressure. High water content lubricates soils, therefore, subsoiling should be done in early fall when soils are at their driest. Fine-textured soils are much more prone to flow fracture than coarse-textured soils. Since brittle fracture requires the soil to expand upward, more than flow fracture, the weight of the overlying soil increases the amount of flow fracture. Critical depth is a term used to specify the depth at which flow fracture will start to dominate. Critical depth is greatly dependent on soil texture and water content and the water content will often increase with depth.

Only shallow subsoiling is recommended for the fine-textured soils. The depth of subsoiling should be only 15 cm into the restrictive layer. Fine-textured soils are also more prone to recompaction, than coarse-textured soils. Subsoiling may be required every few years. As the soil structure and drainage improves after repeated treatments, the depth of subsoiling can be increased.

Case 6: Soils With Compact Coarse-Textured Subsoils

Coarse-textured soils are not as prone to flow fracture and recompaction as fine-textured soils. The result of these factors is that it is often possible, and profitable, to deeply subsoil coarse-textured soils. Soils that are loam in texture or coarser, can normally be successfully subsoiled 75 to 90 cm, as long as the implement and its speed also influence fracture. The only dependable method to determine if the critical depth is being exceeded is to dig a trench across the path of the subsoiler and see if the soil is fractured to the depth of the tine. Subsoiling below the critical depth damages the soil structure and will normally have a negative economic effect. It is recommended that the subsoiler tines be 75 cm apart and angled up, so that all of the soil between the tines is fractured. Ideally, the soil surface between the tines should be raised up uniformly. Some re-compaction will take place, so subsoiling may be beneficial every five years or so. In the dry Interior, calcium cemented layers may be present in coarse-textured soils. Subsoiling may be beneficial in fracturing these cemented layers.

4.3.3 Implementation of Soil Loosening

The success of soil loosening depends on many factors, some of which are hard to quantify in advance. It is recommended that test plots be established before a soil loosening operation is carried out on a whole farm. One way of accomplishing this is to put subsoiling, where appropriate, into a normal crop rotation pattern. In this way, only a portion of the farm would be subsoiled each year. Problems, such as movement of salt into the root zone, would be detected and practices could be changed before the entire area is affected. Rotating subsoiling throughout a farm also aids in scheduling operations when the soil is as dry as possible.

4.4 Management of Peat and Muck Soils

Peat and muck soils decompose and subside when they are drained and cultivated. This process is a result of physical settling and biological oxidation of soil organic matter upon exposure to air. Cultivation also breaks the soil particles into smaller pieces which will pack together more closely. Newly drained organic soils may subside as much as one third of their depth in the first ten years. Subsidence has been reported to continue at a rate of about 2.5 cm per year.

In deep organic soils, decomposition and subsidence can be minimized by allowing the soil to be saturated or flooded over the winter. However, flooding has adverse effects on the structure of the soil, particularly at the surface where soil particles may become dispersed and then settle out in a compact, puddled layer. This will further reduce the infiltration and movement of air and water at the soil surface. In addition, flooding may cause surface runoff and soil erosion which can be sufficiently serious by itself to nullify any positive benefits. A controlled watertable, held within 15 cm of the soil surface during the winter period, is a practical and effective way of inhibiting decomposition.

Where the underlying mineral soil is exposed, mixed into the plow layer or within the drain depth, water management becomes critical to prevent surface structure degradation and to maintain the porosity of the soil profile. This is particularly true for the Nisconlith (peaty phase) and Gardom soil series which are underlain by mineral soil which has a high clay content. Drainage installation, deep tillage and surface cultivation operations should be done when the soil is unsaturated.

Tillage contributes to decomposition of peat and muck by increasing its exposure to air. Furthermore, additions of lime and fertilizer, coupled with excessive or improper tillage and heavy traffic, increases soil compaction which leads to reduced water and air movement and eventually to restricted workability of the soil. Ponding on a drained field after irrigation is an indicator of poor structure affecting drainage.

Reduced tillage, using appropriate implements, crop rotation, cover cropping and minimal traffic are recommended to maintain good soil tilth. Good watertable control is essential to reduce subsidence, but it is also essential for reducing surface structure degradation.

4.5 Soil Amendments

Soil amendments are substances added to the soil to improve fertility or structure. The use of several common amendments is discussed below.

4.5.1 Organic Matter

The value of organic matter added to the soil cannot be overstated. Organic material serves as a food supply for soil organisms which decompose it, releasing plant nutrients and promoting better soil structure. Most soils will benefit from the addition of organic matter; but loose, sandy soils will benefit more from the effects of organic matter on improving water-holding capacity and fertility, while fine-textured soils benefit from improved granular structure. Advantages of adding organic matter to peat and muck soils are not as easily recognized when compared to additions to mineral soils.

Among the many organic materials that may be used to some advantage are farm products such as crop residue, straw, manure and litter, compost and cover crops; industrial products such as vegetable processing wastes, peat, sawdust; and municipal wastes such as paper and domestic sewage sludge (biosolids). The main benefits of these are from the addition of organic matter itself, and secondarily, from addition of nutrient elements contained in the organic matter.

4.5.1.1 Straw

Straw can be a beneficial source of organic matter for soil. It is generally available in large particles which aid in aeration and porosity within the soil. However, when large quantities of straw are added directly to the soil, most available nitrogen in the soil may be used by soil bacteria in the decomposition of the material. This "tie up" of nitrogen can lead to nitrogen shortage in the crop and it is recommended that livestock manure or a soluble nitrogen fertilizer, such as Urea (46-0-0) or an Ammonium Salt (34-0-0, 16-20-0 or 21-0-0) be added at the same time at a rate of 20 to 40 kg/ha actual nitrogen equivalent to approximately 1% N by weight of straw. Beneficial uses of straw include mulching for moisture retention and erosion control or to increase soil tilth. Straw may also be a source of weed seeds.

4.5.1.2 Woodwaste

"Woodwaste (as defined by the *Code of Agricultural Practice for Waste Management*) includes hog fuel, mill ends, wood chips, bark and sawdust, but does not include demolition waste, construction waste, tree stumps, branches, logs or log ends". Woodwaste, like straw, can be a beneficial source of organic matter and aid in the improvement of soil tilth. Woodwaste can also be the source of very toxic leachate. Generally, woodwaste leachate will not be generated in the arid conditions of the Okanagan and Similkameen Valleys. However, if woodwaste is used in such a manner that it is subjected to leaching from rainfall or irrigation, a woodwaste leachate will be generated. The use of woodwaste is recommended for a plant mulch, soil conditioner, ground cover or livestock bedding.

Applications of woodwaste should not be greater than 30 cm in total. However, in many cases, no more than 5 to 10 cm is required. Woodwaste should not be placed within 30 m of a domestic well and must not be used as landfill. It is recommended that a "Woodwaste Discharge Information Sheet" be filled out and sent to the B.C. Ministry of Environment, Lands and Parks for each site which has >50 m^3 of woodwaste in place. Applications of woodwaste are generally recommended only if they fall within the "Code of Agricultural Practice for Waste Management". Compliance with the "Code" does not imply compliance with the Federal Department of Fisheries and Oceans/Department of Environment or the B.C. Ministry of Environment, Lands and Parks.

When fresh woodwastes are added to the soil, the woody material requires large amounts of nitrogen to fully decompose. Sawdust, shavings and coarser woodwastes added to the soil will effectively "tie up" soil nitrogen. There will be nitrogen deficiencies for cultivated crops, gardens or lawns for two or more years following application of heavy rates of woodwastes. Woodwaste used for mulch will also "tie up" some soil nitrogen, although to a lesser degree.

To overcome nitrogen deficiencies in soils amended with woodwastes, a sufficient quantity of nitrogen, to allow for decomposition, should be added to the woodwaste before or during the application. Note that still more nitrogen may be required for cultivated crops. The rates suggested below are nitrogen requirements for the woodwaste only and are calculated to reduce the C:N ratio of the woodwaste to 100:1 or less. An example of the amount of nitrogen required to achieve a C:N of 100:1 or less is as follows: for 10 cm (4 in) of sawdust, an equivalent of 1000 m^3/ha (536 yds^3/acre), use 785 kg of N per hectare (700 lbs of N per acre). This example is based on Douglas fir sawdust at 270 kg/m^3 (16.9 lbs/ft^3) wet or 155 kg/m^3 (9.7 lbs/ft^3) dry. Typical C:N's of Douglas fir is 471:1 for bark and 1268:1 for wood.

4.5.1.3 Peat Moss

Peat moss or other types of organic soil material provide a small quantity of plant nutrients, but their greatest benefit comes from improving the water-holding capacity of sandy soils and improving the tilth of fine-textured soils. Abundant, economical sources of peat moss for soil amendments are not readily available for field scale agriculture. However, in intensive horticulture markets, nursery and greenhouse, supplies are available. In place of using peat moss in field scale agriculture, products such as composted animal manures may be more readily available and also have the benefit of supplying some plant nutrients.

4.5.1.4 Compost

Compost is made from organic materials such as crop residues, clippings, leaves, small animal morts, animal manures or woodwastes. Soil organisms almost completely decompose the organic matter and the end product is a humus-like substance which is a valuable soil amendment. Composting organic waste is a method of converting raw organic materials into a more decomposed stable product from which plant nutrients are more readily available.

The main benefit of composting is that it allows the use of low nitrogen organic materials, such as straw or woodwaste, without reducing available soil nitrogen, which would occur if these materials were added directly to the soil. If adequate time is allowed for decomposition of crop residues or manures on the field prior to crop seeding, composting will not likely provide benefits in addition to those derived from direct incorporation of underdecomposed organic materials. Significant amounts of compost can improve soil structure, water-holding capacity and supply of plant nutrients.

Compost quality, for non-agricultural compost, is discussed under the "Production and Use of Compost Regulation". Not all composts or composting operations are covered by this Regulation, however, it does provide guidance for siting, operation and quality.

Compost made with digested sewage sludge (biosolids) or large quantities of woodwaste should be used with caution, since some of these materials may have high concentrations of toxic metals or harmful organic compounds. The use of composted biosolids is controlled by the "Guidelines for Disposal of Domestic Sludge" and the Waste Management Act for B.C. Woodwaste should be used with caution as leachate generated from woodwaste is toxic and can cause pollution. These may be harmful to some plants.

For more information on composting, there is a series of Composting Factsheets available at the Resource Management Branch, BCMAFF, Abbotsford.

4.5.1.5 Seaweed

Aquatic weeds are useful soil amendments which provide organic matter and a wide range of plant nutrients. Seaweed is the most concentrated organic source of potassium and contains about the same amount of nitrogen as cow manure. The phosphorus content of seaweed is quite low.

Seeding of some crops immediately after a heavy seaweed application may result in reduced emergence and growth due to high salt concentrations. Seaweed is inherently saline, so caution should be taken if it is repeatedly used as a soil amendment. Rinsing with fresh water will remove residual salt water.

Eurasian Milfoil (freshwater aquatic weed) is sometimes available in the Okanagan. The organic matter from this weed does not contain salts like seaweed, however, the nutrient content is unknown.

4.5.1.6 Industrial Wastes

Municipal Solid Waste (MSW) and Domestic Sewage Sludge (biosolids), in various forms, may be beneficial when added to soils. They can provide plant nutrients, organic matter and physical amendments. However, many industrial wastes can contain diseases or organisms and high concentrations of heavy metals or other contaminants. It is recommended that safe application rates be determined through consultation with the B.C. Ministry of Agriculture, Fisheries and Food, the B.C. Ministry of Environment, Lands and Parks or other government ministries before using composted MSW or biosolids on agricultural lands. Some industrial wastes that could be used as soil amendments are not necessarily classed as organic materials, but rather as inorganic, i.e., gyproc. The use of these industrial wastes is regulated by the Waste Management Act.

Many by-products of the food industry, including vegetable pulp and other organic refuse such as whey, blood meal and bone meal, are considered suitable and beneficial as soil amendments. These by-products are not considered to be agricultural wastes as defined under the Code of Agricultural Practice, therefore, they are subject to the permit regulations of the Waste Management Act.

Biosolids, MSW and all other non-agricultural wastes, fall under the jurisdiction of the B.C. Ministry of Environment, Lands and Parks, Waste Management Act. "Production and Use of Compost Regulation" and the "Guidelines for the Disposal of Domestic Sludge", under the Waste Management Act, deal specifically with the use and/or disposal of MSW and biosolids.

4.5.2 Inorganic Matter

4.5.2.1 Chemical Fertilizers

Chemical fertilizers are commonly used to effectively overcome nutrient deficiencies in the soil.

Although fertilizers are valuable, and often essential crop production inputs, they are not a substitute for good soil management. Supplementary practices including crop rotation and additions of organic matter, are strongly recommended to ensure that good soil structure and organic matter levels are maintained.

Fertilizers may be applied directly to the soil or in irrigation water (see Section 3.1, Irrigation). Some fertilizers applied to the soil surface (i.e., phosphorus fertilizers) and not incorporated, have much less effect on plant growth.

Many fertilizer materials will lower soil pH over time and excessive application rates can result in temporary salt injury or nutrient imbalances which interfere with normal crop growth. Use of chemical fertilizers, as with the additions of any nutrient source, should be in accordance to a soil and/or plant tissue testing program to ensure crop and soil health and to avoid adverse effects on the environment.

4.5.2.2 Lime and Liming

The addition of liming materials is effective in raising soil pH. Many orchard soils in the Okanagan and Similkameen Valleys are somewhat acidic due to the effects of nitrogen fertilizer applications and irrigation on soils with a low cation exchange capacity. These soils require periodic liming to maintain soil pH at levels high enough for good plant growth. In addition, lime provides calcium, which is an essential plant nutrient and which promotes granular structure in soils. Generally, soils with high clay/organic levels have a higher buffering capacity and require higher lime application rates to initially change the pH.

Common liming materials include ground limestone (calcium carbonate), ground dolomite (a type of limestone which contains both calcium and magnesium), hydrated lime (calcium hydroxide) and packinghouse or CA lime (calcium hydroxide, which has been exposed to carbon dioxide and has a chemistry equivalent to wet calcium carbonate). CA lime is often lumpy and should be pulverized prior to application. Hydrated lime is quite caustic and it raises soil pH quickly. Excessive applications of hydrated lime can adversely effect soil organic matter and plant growth by raising the pH very rapidly.

All soils which have not received lime, but have low pH's, may require a high rate of lime to initiate pH change. The degree of fineness and calcium carbonate equivalency will affect the effectiveness of the liming material (for more information on liming, refer to the following Factsheets: Soil Acidity and Liming Facts, Liming Acid Soils in Central B.C. and Soil Liming Recommendations available at the Resource Management Branch, BCMAFF, Abbotsford).

For best results, lime should be applied in the fall or a few weeks prior to seeding, and thoroughly incorporated into the plow layer on tilled fields. For grape and tree fruits, lime can be applied at any time, except within one month of fertilizer application. Where possible, lime should be evenly broadcast and incorporated with care between rows. Liming programs should be considered carefully during the establishment of perennial crops. Lime has a low level of solubility, so lime applied and left on the soil surface will only be slightly effective in raising soil pH in the rooting zone.

Soil pH is a poor indicator of lime requirement. Factors, such as organic matter levels, clay content and age of soils, markedly affect the amount of lime needed to adjust the pH level one unit. A lime requirement test, performed by a reputable soil testing laboratory, is recommended to ensure the correct rate of lime application.

Surface application of lime on low pH areas under trickle or drip irrigation may not alter the soil pH below the soil surface. The use of lime in these situations may have some affect on the soil nutrient solution and reduce the negative impact of iron, aluminum and manganese toxicity.

4.5.2.3 Acidification Resistance Index (ARI)

ARI is a soil test which measures the amount of acid required to lower a soil to pH 5.0 from its present level. From the ARI, recommendations on fertilizer and lime use can be made to aid in controlling the pH level of a soil. ARI takes into account both the buffering capacity and pH of the soil.

Acidification often occurs in poorly buffered soils due to irrigation and use of acidifying fertilizers such as ammonium sulfate (21-0-0). Any producer considering fertigation of orchards should have an ARI test completed. The table below gives general recommendations for 3 ARI ranges.

ARI Ranges

0 to 5	Very sensitive to acidification, lime to pH 7 prior to planting tree fruits, use calcium nitriate
6 to 25	Moderately sensitive to acidification, lime to pH 7 prior to planting, use calcium nitrate in combination with other sources of nitrogen.
>26	Not sensitive, do not lime, use any nitrogen fertilizer source.

4.5.2.4 Sulphur and Acidification

Sulphur

Sulphur may be required as an essential plant nutrient, however, this section will refer to the use of sulphur as a soil acidifier.

In some areas of the Okanagan and Similkameen Valleys, soil pH is above 8.0. It may be desirable to lower the pH to increase the availability of some plant nutrients. Lowering soil pH involves the same cultural practices and considerations as raising the pH with liming, except that different products are required. Adjusting a soil pH downward is more difficult and often more costly than moving a soil pH up. Care must be taken to ensure that the high pH >8.0 is not the result of an alkali (sodium) or saline condition which may require other soil management such as gypsum addition or drainage.

Acidification

The principal agents used to lower soil pH are elemental sulphur, sulphuric acid, aluminum sulphate and iron sulphate (ferrous sulphate). Ammonium sulphate, ammonium phosphate and other ammonium containing fertilizers are also quite effective in reducing soil pH, though they are primarily sources of plant nutrients.

For large areas, elemental sulphur (or a mixture of it and bentonite to improve its stability and safety when handled in confined spaces) is probably the most economic product. However, elemental sulphur has to be oxidized by soil microorganisms. Sulphuric acid can of course also be used, but it is unpleasant to handle as well as very corrosive. Generally, elemental sulphur, when fully converted to sulphuric acid, will react with three-fold its applied weight of residual carbonate. As with limestone applications, limiting the maximum rate of applied sulphur at any one time (about 2 tonnes per hectare) will lower the pH gradually while preventing or minimizing the chance of salt buildup. The soil test laboratory will determine the total soil acid and sulphur requirement to attain a desired soil pH upon request. For more information, refer to the Soils Factsheet: "Acidifying Soils" available at the Resource Management Branch, BCMAFF, Abbotsford.

4.6 Pesticide Use

Pesticide use is controlled by the Pest Control Products Act administered by Agriculture Canada and the Pesticide Control Act administered by the B.C. Ministry of Environment, Lands and Parks.

Concerns about pesticide use are related to potential contamination of air, soil and surface and groundwater. Pesticides may pollute air and water by means of:

- vapour drift;
- runoff carrying pesticides;
- leaching of pesticides through the soil into groundwater aquifers; and
- pesticide spills.

Those factors which affect pesticide movement in the environment also determine the risk of contamination by pesticide use. Movement of pesticides is dependent on:

- pesticide characteristics;
- site characteristics; and
- pest management practices.

Pesticides differ in their chemical structure. The characteristics of the active ingredients in pesticides have implications for the risk of environmental contamination.

When you have a choice among pesticides, those with low solubility, high capacity to bind in the soil, low volatility and short breakdown period are better environmental choices.

The environmental impact of pesticides that leach into groundwater, or enter waterways via runoff can be severe. A number of factors influence the probability of pesticides entering aquatic systems, including the climatic conditions and physical characteristics of pesticides being used on the farm.

Soil factors influencing the probability of pesticide contamination include:

- Soil physical properties, including the relative percentages of sand, silt, clay and organic matter, influence water movement and the mobility of pesticides. Water moves easily through coarse-textured soils (higher % of sand), and pesticides may be transported to groundwater with little retention. Fine-textured soils, such as clays, not only impede the movement of water, but have a higher ability to bind chemicals and thus take them out of the solution. The higher the organic component in a soil, the greater its ability to hold water and chemicals and thus reduce the likelihood of migration.
- Permeability of the soil, or hydraulic conductivity is a measure of the soils ability to move water through the soil matrix. The more permeable the soil, the greater the possibility of pesticides moving into the watertable. Hydraulic conductivity is affected by soil texture (sand, silt and clay) and by soil structure, especially as the structure controls the size of large water conducting pores.
- The processes that influence the fate of pesticides in soils are adsorption, runoff, leaching, absorption and breakdown (microbial, chemical and photodegradation).

Adsorption is the binding of pesticides to soil particles. This may affect both the application rate and breakdown rate of the pesticide.

Runoff is the movement of pesticides in water over a sloping surface. The pesticides are either mixed in the water or bound to eroding soil. The amount of pesticide runoff depends on slope, soil texture, soil moisture content, irrigation or rainfall and type of pesticide used.

Runoff from areas treated with pesticides can pollute streams, ponds, lakes and wells. Pesticide residues in surface water can harm plants and animals and contaminate groundwater. Water contamination can affect livestock and crops downstream.

Pesticide runoff can be reduced by using minimum tillage techniques, reducing steepness of slopes, dyking to contain runoff and developing a vegetative buffer.

Leaching is the movement of pesticides in water through the soil. Leaching occurs downward, upward and sideways. Leaching is increased when the pesticide is water soluble, the soil is sandy, irrigation or rain occurs shortly after application and the pesticide is not strongly adsorbed to the soil. Groundwater may be contaminated if pesticides leach from treated fields, mixing sites, washing sites or waste disposal areas.

Absorption is the movement of pesticides into plants and microorganisms. Breakdown of plant or microbial tissue may release pesticides back to the soil.

Breakdown of pesticides occurs by either microbes, chemical reactions or light. When pesticides are broken down, they are no longer toxic. This is good for eliminating pesticide residues from soil or crops. However, when pesticides break down too rapidly, they may not control a pest or may provide only short-term control.

<u>Microbial breakdown</u> is the use of pesticides as food by microorganisms such as fungi and bacteria. Microbial breakdown tends to increase when the temperatures are warm, the soil pH is favourable, the soil moisture and oxygen are adequate and the soil fertility is good.

Microbial breakdown is one of the ways pesticides are more readily destroyed in soils. Sometimes you need to use the higher application rate on a pesticide label to make up for rapid microbial breakdown. In a few cases, certain pesticides are no longer useful because the microbes break them down so fast they do not have time to work.

<u>Chemical breakdown</u> is the breakdown of pesticides by chemical reactions in the soil. The rate and type of chemical reactions that occur are influenced by the binding of pesticides to the soil, the soil temperatures, the pH levels and moisture. Many pesticides, especially the organophosphate insecticides, break down more rapidly in alkaline soils or in spray tank water with a high pH level.

<u>Photodegradation</u> is the breakdown of pesticides by sunlight. Some pesticides are rapidly broken down by photodegradation. This is why some labels direct you to disc or water a pesticide into the soil.

Site conditions affecting the probability of pesticide contamination include:

- Permeability of various geological deposits between the soil surface and groundwater, affecting the speed and movement of water and pesticides to groundwater. For example, layers of gravel move water fairly quickly in a downward direction.
- Depth to groundwater; the closer the watertable is to the surface, the greater the probability of contamination.
- Slope of the ground surface controls the direction of contaminant movement.
- Proximity of surface water bodies.

Pesticide properties that influence the possibility of water contamination:

- Water solubility is critical, the higher the solubility in water, the greater the likelihood of contamination.
- Soil adsorption which is a factor of both the soil and pesticides.
- Degradation rate in soil is critical, the faster a pesticide degrades in the soil, the less likely it is to be carried to aquatic systems and groundwater in large quantities.

5. Animal Manure Management

The purpose of this section is to describe manure management options that are environmentally sound and which comply with existing environmental laws, i.e., the *Code of Agricultural Practice for Waste Management.* There is a series of environmental guidelines that were written to support the Code, and other legislation, and to provide industry with various options for managing their farms in an environmentally sound manner. A copy of the Code and commodity oriented guidelines are available from the Resource Management Branch, BCMAFF, Abbotsford. Animal manures are a valuable source of plant nutrients and organic matter and contain a vast array of organisms that add to the biological activity of soils. However, if not managed with sufficient care, manures can be major sources of pollution and contribute to contamination of surface and ground waters.

5.1 Managing Manures for Crop Production

Management is the key to using manures to promote crop production and soil improvement while minimizing any hazard to the environment. Management means application of manures at rates and times of year that:

- are compatible with the nutrient requirements and growing characteristics of the crop;
- take into account soil characteristics, drainage and the slope of the land; and
- recognize the presence of surface and ground waters.

Table 18 provides a general indication of the nutrient contents of various manures. Note that the moisture content of manures varies considerably. These values must be adjusted accordingly before they can be used as a guide to adjust fertilization rates.

5.2 Factors Affecting Contamination from Manures

5.2.1 Soil Characteristics

The proportion of sand, silt, clay and organic matter in a soil determine the water and nutrient-holding capacity. In general, soils with a high clay and/or organic matter content have a relatively high capacity to hold water and nutrients in the root zone. Sandy soils, on the other hand, have a low capacity. Therefore, the leaching of nutrients from sandy soils is greater rate than from fine-textured soils or soils with a high level of organic matter.

5.2.2 Drainage

When poorly drained soils become saturated, precipitation can no longer enter the soil and, therefore, water accumulates on the soil surface and eventually runs off into adjacent ditches or other water courses. When this happens, materials, such as manures, that have been applied to the soil surface are removed with the water.

5.2.3 Slope

If water does not infiltrate into soils on sloping land, it must run off. If such lands also become saturated, runoff is even greater.

5.2.4 Nitrates in the Root Zone

The nitrate form of nitrogen is of major concern in the region due to its potential to contaminate drinking water and increase the nutrient content of lakes and streams. Nitrate is also the dominant form of plant available nitrogen found in agricultural soils. When nitrate-nitrogen (NO_3-N) in the root zone is exposed to excessive rainfall or irrigation, it can leach into ground water. Unlike coastal regions of B.C., NO_3-N leaching in the interior is commonly associated with over use of fertilizers, manures in conjunction with irrigation and porous soils. Where soils are over ground waters used for drinking or adjacent to surface waters, the nitrate has a high potential of contributing to water contamination.

Excessive levels of root zone nitrates are found in soils where the spring application rates of manure and fertilizer have been high in relation to the ability of the crop to use the nitrogen, or in soils where there has been a fall application of manure after harvest.

Table 18

N, P and K Content of Various Manures

	% Moisture	Total N	Ammonia N	P_2O_5	K_2O
		Nutrient Content (kg/tonne) (x 2.0 = lb/ton)			
Beef [a] (solid)	67.8	4.2	0.2	4.8	8.2
Dairy [a]					
Solid	76.8	3.9	0.4	3.4	9.0
Liquid	89.9	2.6	0.9	1.7	4.9
Swine [b]					
Covered pit	92.8	6.3	4.5	3.3	3.9
Uncovered pit	98.1	3.5	2.6	1.5	1.7
Horse (shavings)	74.0	2.3	0.7	1.3	3.1
		Nutrient Content (kg/m^3) (x 1.7 = lb/yd^3)			
Poultry [c]					
Broiler	25.0	15.8	2.6	11.4	6.1
Layer	50.0	11.4	2.1	14.6	5.6

Source: [a] North Okanagan Soil Conservation Group, 1994
[b] Hog Producers' Sustainable Farming Group, 1993
[c] Sustainable Poultry Farming Group, 1994

1 tonne of liquid manure = approximately 1000 litres = 220 imperial gallons

Nutrient values for manure, particularly nitrogen, assume proper storage, handling and application to minimize losses.

5.2.5 Lack of Cover Crops

Permanent grassland and, to a lesser extent, fall planted winter hardy cover crops take up soil nitrates (and other nutrients) during the fall and early spring. In addition, cover crops protect the soil surface from erosion. Bare soil, on the other hand, is susceptible to leaching and erosion.

5.3 Factors Contributing to High Fall Nitrate Levels in the Root Zone and Nitrate Leaching

5.3.1 Crop Growth Characteristics

Annual crops begin growth in April, May or June (depending on planting date). Nitrogen, and other nutrient, uptake is minimal in the early growth stages and then proceeds rapidly through July and tapers off in August and September. This growing habit means that very little of the nitrate produced in the soil during September and October is used by crops.

5.3.2 Soil Processes

Nitrate is produced naturally in the soil by the decomposition of organic matter. Additions of manure and fertilizer further raise the level of nitrate in the root zone. Under favourable soil moisture and temperature conditions, nitrates are produced regardless of the presence or absence of an actively growing crop. In the Okanagan and Similkameen, such favourable conditions often exist during much of August, September and October when crop uptake of nitrate is decreasing or has completely stopped due to the harvest of the crop. If fertilizer and manure application rates have been in excess of crop demand or if manure is applied in the fall, then soil nitrate levels will be high to excessive.

5.3.3 Climate

The climate of the Southern Interior of B.C. is characterized by relatively mild winter temperatures where soils are deeply frozen for a limited amount of time. Under these conditions, all mobile soil nutrients, such as nitrate, can be leached. Long term soil test data indicates that any nitrate levels in the root zone in the fall of the year are often higher than those found in the following spring. Although the situation differs markedly from the heavy precipitation and leaching that occurs in South Coastal B.C., nitrate leaching can be an important issue in some of the more humid parts of the region.

5.4 Practical Guidance on Land Application of Manure

5.4.1 January to February

In most cases, manure application cannot be contemplated due to frozen soils and snow cover. If field access is possible, manure application should only be considered if there is a minimal chance of runoff during the spring breakup period.

5.4.2 March to May

On annually cropped land, apply and immediately incorporate sufficient manure to supply up to 75% of the crop requirement for nitrogen. Do not attempt to completely fertilize the crop with manure. Excess manure will result in a high rate of nitrate production in the latter part of the growing season and after harvest when nutrient uptake is minimal. Supplement the manure with fertilizer at planting or sidedress time.

5.4.3 June to August

If manure must be applied, in most cases it can be applied only to grassland due to the presence of actively growing crops on other lands. Manure nitrogen efficiency for grassland can be greatly increased by irrigation immediately following application, by manure injections or by application of very wet slurries (95% or higher). Application of additional fertilizer nitrogen to grassland should be fine-tuned according to the protein content of the forage. Research has shown that grasses with a protein level of 20% or more have a high probability of nitrate accumulation and/or high levels of rumen-degradable nitrogen compounds.

Although manure cannot be applied to annual crops during this period, crops can be supplemented with fertilizer nitrogen. Since limited correlation testing has been completed in the interior, a late spring soil test (also known as Pre-sidedress Nitrogen Test) has been found to be useful in some regions for indicating if additional nitrogen is required. The test is used for forage corn. The critical range is 20 to 30 ppm NO_3-N in the plow layer (0 to 30 cm) measured when the corn is about 30 cm (typically mid-June). Soils below this range are usually deficient in nitrogen and require supplementation before the crops will achieve adequate yields. Soils above this range will generally supply all of the crops' nitrogen requirements. (Refer to *Nitrogen Guidelines for Silage Corn in the North Okanagan*, prepared by the North Okanagan Soil Conservation Group.)

5.4.4 September to October

Because of frozen soils and low winter precipitation, winter losses of nitrate due to leaching are minimal in the Okanagan and Similkameen Valleys. Therefore, a high percentage of any nitrate left in the root zone following harvest will be retained for subsequent crops. A fall or spring soil test will assist producers to take advantage of nitrogen from manure and reduce the need for fertilizer nitrogen. However, in some of the more humid parts of the region, nitrate leaching can be a problem.

If manure must be applied during this period, it should be restricted to grasslands that are well drained and not subject to flooding or runoff. Grasses are still actively growing and their roots will capture much of the nitrate and prevent leaching. Even so, only 40% of the annual allowable application should be spread in the fall and winter periods.

5.4.5 November and December

With the onset of winter, soils cool to the point where there is very little nitrate produced in the root zone. However, many soils are now too wet to allow ready access for spreading without causing severe soil compaction.

In most cases, manure application cannot be contemplated due to frozen soil and snow cover. If field access is possible, manure application should only be considered if there is a minimal chance of runoff during the spring breakup period.

Some areas of the South Okanagan and Similkameen may be suitable for winter spreading because there is a low risk of runoff or flooding during spring thaw.

6. Soil Conservation

6.1 Crop Rotations

Crop rotation means growing a series of different crops over the years on the same field. Continuous cropping to the same crop or related crops often results in a build-up of soil-borne plant diseases or weeds. If this occurs, it will be necessary to grow a different crop in the diseased or weedy field. Continuous cropping to cultivated row crops leads to a breakdown of soil structure, compaction, increased erosion and a loss of organic matter. For these reasons, it is a good practice to grow crops in a rotation so that disease and weeds can be controlled and soil quality can be maintained.

The most beneficial crop rotations are those which include grasses or grass-legume mixtures. If this is not possible, rotations which include fibrous rooted crops should be used. These crops are most effective in building stable soil structure, increasing soil organic matter and improving the porosity and structure of the subsoil (see Figure 4, page 37). A soil which has been seeded to a hay crop for a number of years will have better and longer lasting structure and tilth than the same soil continuously used for annual crops. A rotation of deep-rooted crops with shallow-rooted crops will allow plant nutrients to be extracted from the subsoil. Some of these nutrients are added to the plow layer when residues from deep-rooted crops are incorporated into the plow layer. The best example of crop rotation in the Southern Interior of the Province is corn/grass used by the dairy industry. The most significant improvement that could be made to that rotation would be to include a winter cover crop after corn harvest.

On steeply sloping land, crop rotations, which include close-growing crops or perennial grass-legume hay or silage crops, are recommended for direct protection against soil erosion and for building up and maintaining a stable structure which is more resistant to erosion.

Although crop rotation is not feasible in perennial fruit crop production, growth of cover crops and occasional tillage to relieve traffic compaction is recommended. Tillage will allow for the incorporation of organic matter where traffic compaction is a problem. Reseeding to a diverse cover crop mix will be beneficial to the soil in perennial forage crops. Management of the cover crop may require inputs other than just mowing, such as interseeding, weed control or reseeding.

6.2 Cover Crops

The current level of knowledge about cover crop use in the Southern Interior of B.C. is limited for most crops. However, cover crop use in vineyards is covered quite well in the Vegetation Management Section of the *Management Guide for Grapes 1994-95*. This section of the Handbook will give an indication of the commonly used cover crop species and their seeding rates and dates. Cover crops are also called catch crops, green manures and living mulches.

Catch crops are grown for the purpose of trapping leachable nutrients in the plant. Green manures are crops grown for the purpose of adding organic matter to the soil. Living mulches have many uses and are commonly seen as grass under growth in orchards or vineyards.

Cover crops are useful for many purposes in the region. These purposes include: control of wind and water erosion in annual crops, suppression of weed growth, beneficial insect habitat, nutrient capture, soil structure improvement, increased trafficability, production of livestock or water fowl feed and most importantly, their influence on microclimate under perennial crops. It should be noted that crops such as grapes are poor competitors for water and nutrients. Therefore, care must be taken in choosing a cover crop species.

A cover crop may also be established between the rows of perennial crops, to protect the soil from erosion and to reduce the need for cultivation. The most common use of cover crops has been for over winter soil protection. Because rainfall intensities are lower in the Interior, the risk of severe winter water erosion is not great, therefore, winter cover cropping for soil protection may be less important than it is in the Lower Fraser Valley. However, cover crops grown over the winter are beneficial to soil tilth. In the South Okanagan and Similkameen Valleys, many of the sandy soils are susceptible to wind erosion.

Annual or permanent cover will reduce wind erosion by protecting the surface and increase the soil organic matter content. Perennial grass crops have a significant impact on increasing soil strength and aggregate stability. Throughout the Okanagan and Similkameen Valleys, most soils are susceptible to water erosion. Spring through fall cover cropping will protect the soil from water erosion caused by high intensity "thunder" storms and irrigation runoff.

Table 19 below lists the production crop (or crop group) and the most appropriate cover crop(s) for use with that crop.

If legume crops such as clover, peas or vetch are used, there is a good possibility that the crop will add significant amounts of nitrogen to the soil, provided that the proper strain of nitrogen-fixing bacteria is active in the soil and good growing conditions exist.

Table 19

General Cover Crop Recommendations for Soil Conservation

Crop	Cover Crop	Recommendation
1. Tree Fruits	Perennial grass mixture such as creeping red fescue, perennial ryegrass or wheatgrass	Plant when soil moisture and traffic will allow for good establishment, seed at 20 to 30 kg/ha mixture
2. Raspberries	Spring barley or oats or permanent cover of white clover	Before early September, 80 to 150 kg/ha, seed clover at 5 kg/ha
3. Strawberries	Spring barley or oats	After last cultivation, but before mid-Sept., seed at 80 to 150 kg/ha
4. Other Small Fruits	Annual/perennial grasses such as ryegrass or sheep or hard fescue or cereals such as barley or oats	Plant between rows when soil moisture and traffic will allow for good establishment, seed grasses at about 25kg/ha, seed cereals at 80 to 150 kg/ha in September.
5. Vegetables		
5a. Early harvest	Any cereal or cereal/legume mix, use spring oats or barley with peas or clover. Annual ryegrass	Plant immediately after harvest at a rate of 80 to 150 kg/ha oats or barley and 25 kg/ha for annual ryegrass
5b. Late harvest	Fall rye or winter wheat or a mixture with winter peas or hairy vetch	Prior to mid-Sept. at a rate of 80 to 150 kg/ha, consider broadcasting ahead of harvest with root crops
6. Forage Corn	Spring or winter cereals with or without a legume. Annual ryegrass	80 to 150 kg/ha for cereals and 10 to 30 kg/ha for legumes, plant immediately after harvest or consider intercropping prior to the last sidedress with a small seeded legume, underseed annual ryegrass prior to sidedress at 25 kg/ha
7. Nursery	For non-permanent cover, oats and barley or annual ryegrass. For permanent cover, a mixture of sheep or hard fescue, perennial ryegrass and creeping red fescue	Seed oats and barley at 80 to 150 kg/ha and annual ryegrass at 25 kg/ha, seed mixture at 20 to 30 kg/ha, mow to keep cover from growing into nursery stock
8. Grapes	Perennial grass mixture such as sheep or hard fescue, perennial ryegrass or various wheatgrass species	Plant when soil moisture and traffic will allow for good establishment, seed at 20 to 30 kg/ha of mixture

If cereal or grass crops are grown, there are three groups that should be considered. Firstly, spring cereals, particularly barley and oats, or annual or Italian ryegrass, such as Westerwolds, grow well from spring through the late summer. They will usually winter kill if planted in late September, but can provide rapid fall cover. Secondly, winter cereals, such as winter wheat and fall rye, are better used for late summer and fall growth or where an overwintering cover or early spring forage is desired. Winter cereals grow slowly in the fall, but will continue to grow later than spring cereals. One advantage of cereals is that they are large seeded so they can be seeded by many methods including broadcast-harrow. Thirdly, perennial cover crops, mainly grass species such as fescues, ryegrasses and wheatgrasses, should be utilized for perennial crops such as grapes and tree fruits.

Before making the decision to plant cover crops, some other factors must be considered. The method of managing the cover crop residue prior to planting the following crop is the most important. If the cover crop survives the winter, it must either be controlled by mechanical means (tillage or mowing) or sprayed out with a herbicide. Cover crop species which winter kill may be appropriate if early spring planting is desired. Cover crops can become difficult to manage if they are allowed to set seed, so planting date and control methods are crucial for in-season or overwintering cover crop species. Some cover crop species have been reported to adversely affect following crops either due to the amount of cover crop residue remaining at the soil surface or due to chemicals present in the residue. Other cautions for cover crop use are that they may harbour diseases and insects and may change microclimates in perennial crops. Their management is important. Cover crops used for winter erosion control must be well established by late August to early September. After this date, cool temperatures reduce growth. Surface protection of the soil, to prevent structure degradation and soil loss, will be provided by either a standing or matted down cover, but volume of plant leaves or residue is important.

Although the use of cover crops can pose management challenges, their use for erosion control, nutrient capture and soil structure improvement is very beneficial for this region.
Where permanent cover is established in perennial crops, these covers require some annual maintenance, i.e., mowing over the summer especially near harvest. Use of tillage or herbicide will be required to control vegetation in the row and in the area adjacent to the crop.

6.3 Mulching

A mulch is any material placed on the soil surface for the purpose of reducing soil erosion, insulating the soil surface, reducing evaporation of soil moisture or weed control.

Crop residues left on the surface are a type of weed free mulch. Other materials which may be used include: straw, woodwaste, compost or plastic materials. Use of woodwaste is generally only recommended for blueberry production or in nursery container operations.

When mulches are used over the winter, soils do not warm us as quickly in the spring. This may be a disadvantage for certain crops. Where hot, dry summers lead to high soil temperatures and high rates of evaporation, a mulch is effective in reducing soil temperatures and evaporation. Organic materials used as a mulch will be decomposed by soil organisms and the mulch will eventually become part of the soil humus. When woodwaste or straw are used, their decomposition may result in some soil nitrogen deficiency for the crop, and it is recommended that a nitrogen fertilizer be added to the mulch to overcome this situation. The suggested rate of application is 20 to 40 kg/ha actual nitrogen (equivalent to approximately 1% N by weight of organic matter).

A mulch which becomes compact may reduce aeration in the soil below the mulch. For most situations, a mulch should not be greater than 10 cm thick.

Various plastic or fabric mulches have also been used successfully in field production of vegetables such as peppers, tomatoes, cucumbers and strawberries. Some use of plastic mulches is also recommended for tree fruit production if rodents or weed control are problems.

6.4 Conservation Farming

Conservation farming must address the issue of maintaining environmental quality while maintaining or improving production levels. All factors that affect agricultural production, its impact on the environment and other resource users must be taken into account.

6.4.1 Conservation Tillage

Conservation tillage systems are currently defined as any cultivation and planting system that leaves 30% of the previous crop residue on the soil surface after planting. The various types may include no-till or direct seeding, minimum till or one pass before seeding systems, plow-plant, ridge-till, chisel plow, etc.

Successful conservation tillage systems reduce soil erosion, improve quality of runoff water by soil retention, improve soil structure by retaining crop residue at the soil's surface and decrease the soil structure degradation by reducing field operations. Fuel consumption may decline, but may be replaced with other inputs for weed, disease or insect control. Labour requirements may decline by reducing the number of field operations needed to cultivate and seed crops.

No-till or direct seeding systems have been successful for cereal and oilseed production. Herbicides are used to control weeds, replacing cultivation. Crop disease incidence may be higher, but can be avoided through crop rotation. The increased surface crop residue and soil organic matter are potential disease vectors, but disease has not been a significant factor in dryland, zero-till grain production.

6.4.2 The Role of Soil Structure, Drainage and Acidity

Well drained soils with good structure and organic matter content, or the ability to develop good structure, are likely to succeed under a reduced or no-till system. Poorly drained soils, with massive or cohesive structure, are difficult to manage successfully under no-till. Direct seeding into wet clayey soils can cause poor seed-soil contact due to smearing of the soil by the seed placement tools.

High spring moisture levels and lower temperatures at the soil surface, due to increased surface crop residue levels, may cause reduced yields from zero-till. This is especially true for longer season annual crops such as corn or cereal grain when grown on fine-textured clay soils. The alternative is to use a reduced tillage system (ridge-till) that elevates the seeding zone from the soil surface by shaping the soil ahead of the planting tool. Reducing soil erosion to acceptable levels may be accomplished by using a reduced till system where a no-till system does not seem appropriate.

Equipment induced plow pans may create saturated soils, seriously reducing the oxygen required in the root zone for proper crop growth and nutrient response under no-till systems. Subsoiling with minimum disturbance implements, such as the Para-till, may be appropriate to use within a no-till system.

High soil acidity will also have to be considered as a deterrent to the establishment of a no-till system when lime is incorporated into the soil every few years to re-establish appropriate soil pH levels. Lime amendments may be incorporated prior to establishing a no-till system at rates that will be retained for the sensitive crops in the rotation. Over-liming soils can cause nutrient deficiencies and some precautions should be taken to avoid this from happening.

6.4.3 The Role of Nutrient Management

Fertilizer and livestock nutrient management need to be re-thought when a no-till or reduced-till system is being considered. Appropriate seeding equipment which can place required fertilizer near the seed should be chosen. This is especially important for phosphorus and potassium, as there are no cultivation operations to mix fertilizer into the soil in the no-till cropping systems.

Increased surface crop residues and soil moisture levels under reduced-till conditions may cause an increase of nitrogen loss due to denitrification or volatilization. Subsoil placement of fertilizer nitrogen at the time of seeding can avoid losses to the atmosphere.

Similarly, the subsoil injection of livestock wastes will conserve nutrients and place them in a zone that is available to the crop. The only drawback is that injection of manures may cause significant soil disturbance for a no-till system, increasing the potential for weed seedling germination.

6.4.4 Systems Approach to Conservation Tillage

Conservation tillage is a package of cultural practices that are specifically developed to conserve soil and water resources, sustain high and satisfactory returns and minimize soil and environmental degradation. Conservation tillage systems should be adapted to fit the needs of soil and water conservation in the region. Figure 21 shows the interrelationship between conservation tillage and cultural practices that is required for the successful agricultural management of the soil surface that improves rather than degrades this natural resource.

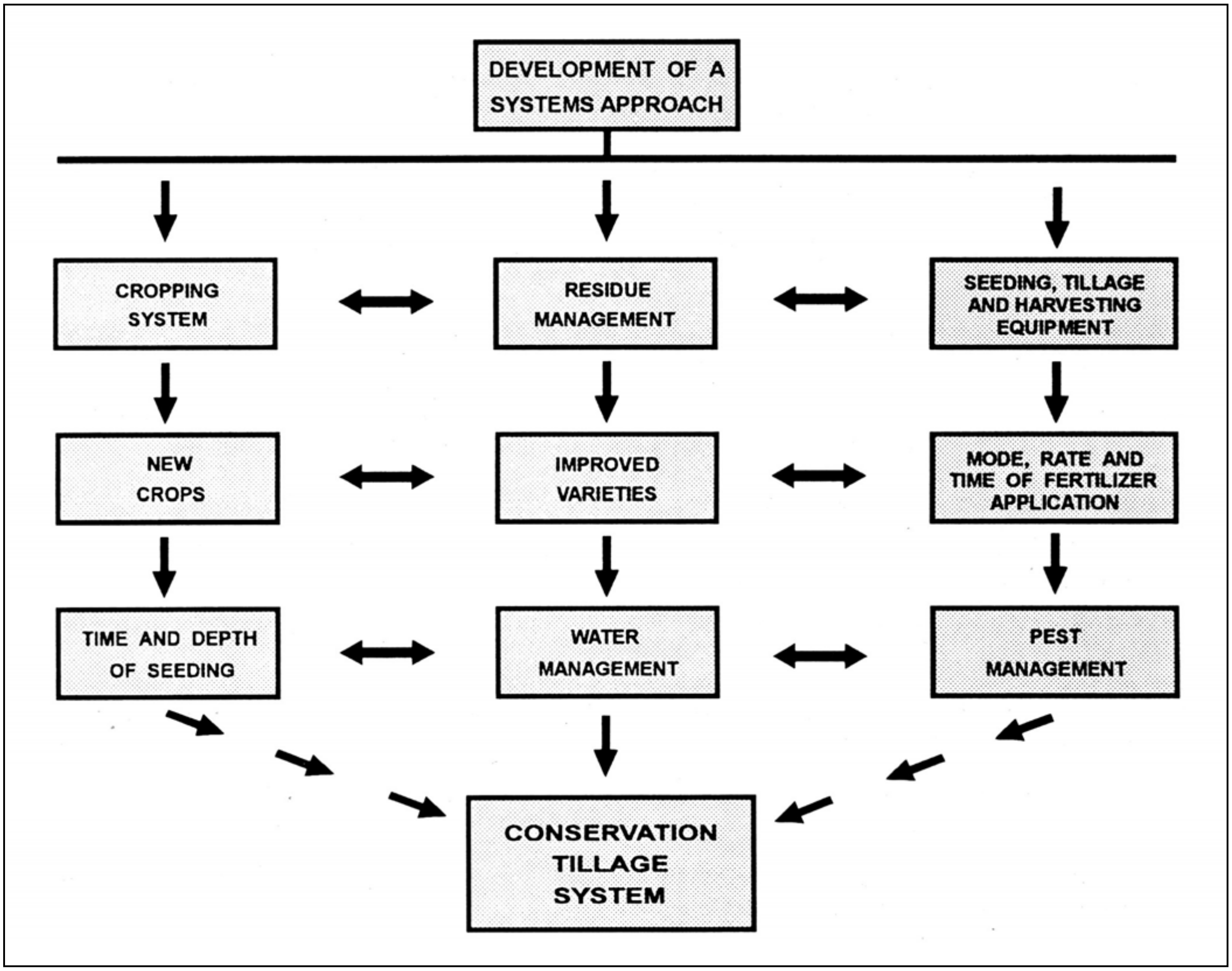


Figure 21

Conservation Tillage – A Systems Approach

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Appendix A:

The Climate of the Okanagan and Similkameen Valleys

The climate in the Okanagan and Similkameen Valleys is governed by the region's location in the lees of the Coast Mountain Range. These mountains, with peaks to over 2,450 metres (8000 ft), are extremely effective at removing moisture from the precipitation bearing westerly winds through orographic lifting of the air mass, resulting in a wet mild climate west of the Coast Range. In the lee of the Coast Mountains, a rain shadow effect is produced and cloud and precipitation amounts are decreased, sunshine is increased, humidities are lowered and the range of seasonal temperature is greater than on the windward side. (See Figures 1 and 2).

Precipitation and Other Moisture Related Parameters

During the winter months, the predominantly westerly upper air flow contains weak weather systems which produce light rain or snow in the interior valleys. Frequently, severe outbreaks of arctic air penetrate into the Okanagan and Similkameen Valleys reducing minimum temperatures below -25°C. In the past 10 years, these outbreaks have brought about a 50% risk of severly reducing some crop production (i.e., grapes and tree fruits) in the Okanagan and Similkameen Valleys. Heavy snowfall often occurs as these cold air masses are replaced by more moist and mild Pacific air masses (see Figure 1). Summer months are dry and warm with precipitation usually in the form of brief showers or thunderstorms. Although climate has a strong influence on crop production, mesoclimate is often the overriding climate consideration for perennial crop suitability. June is the wettest month while July, August and September are usually dominated by a high pressure ridge which produces warm and dry conditions over the interior. The dry, hot summers lead to soil moisture deficits in most areas during the growing season and irrigation is required for the production of most agricultural crops (see Figure 2). However, the northern section of the area will experience a higher rate of annual precipitation overall, i.e., Armstrong at 457 mm as opposed to Keremeos at 242 mm.

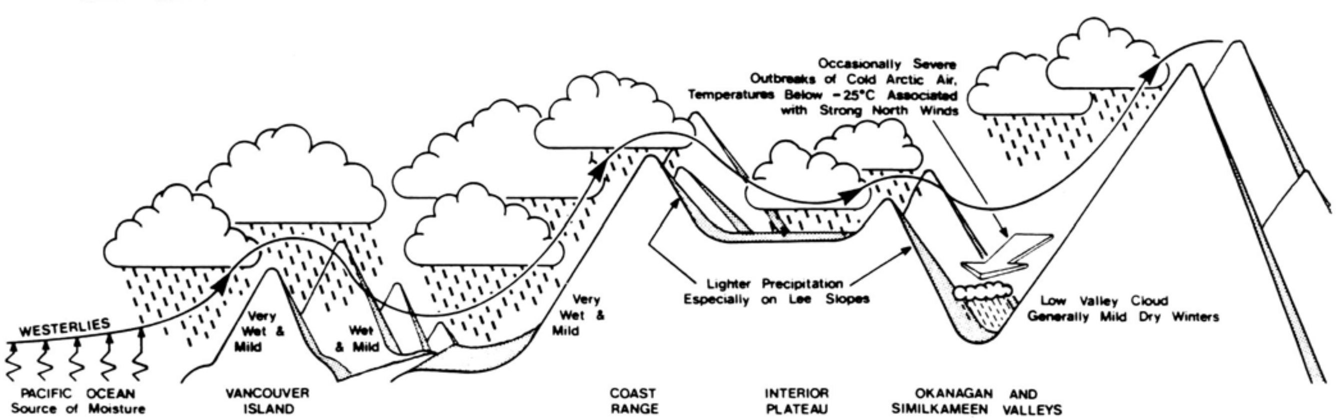


Figure 1

Typical winter weather patterns in Southern British Columbia

Source: Atlas of Suitable Grape Growing Locations in the Okanagan and Similkameen Valleys

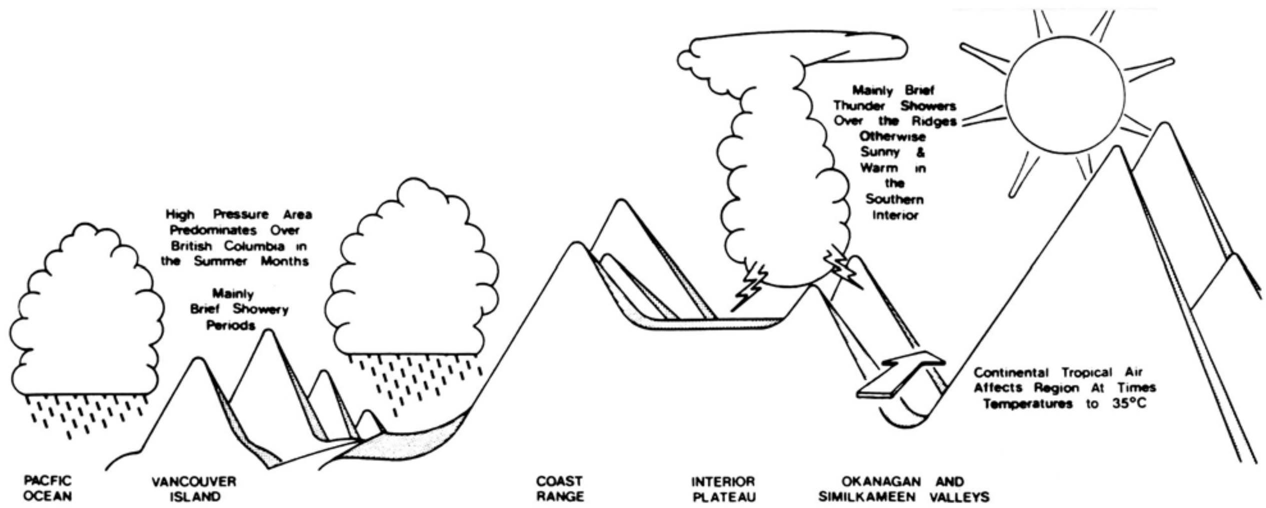


Figure 2
Typical summer weather patterns in Southern British Columbia

Source: Atlas of Suitable Grape Growing Locations in the Okanagan and Similkameen Valleys

Temperature and Other Parameters Derived from Temperature

Brief, very hot periods occur when modified dry continental tropical air invades the area from the desert region of the southwestern United States often raising temperatures to 35°C or more. The highest maximum temperature ever recorded include Keremeos at 41.1°C, while at Winfield, the highest is 37.2°C. The lowest temperature ever recorded in Armstrong is -42.2°C, while at Winfield, the lowest is -25.5°C. Large bodies of water, especially slow moving ones, serve to moderate temperature effects on surrounding areas. Such bodies of water have a large heat storage capability, warming the surrounding areas in the winter. They have a cooling effect in the summer. In addition to this moderating effect, crops located on slopes close to large lakes or rivers benefit from the refection of solar radiation from the water surface increasing the length of the frost free period. Lakes or large rivers also increase the surrounding area humidity and cloud cover. All of these factors reduce the risk of late spring or early fall frosts and extend the growing season.

Irrigation in arid areas can modify the surrounding climate significantly. Overhead irrigation can be used to reduce stress on crop production through atmospheric cooling. Crop quality in cool climate areas, therefore, may benefit more from low level irrigation rather than high, overhead sprinklers.

Mesoclimate

Mesoclimate refers to small areas of the earth's surface that may not be representative of the general climate of an area. It includes the climate created by moisture, solar radiation, small valleys, frost pockets, openings in a forest, hillsides, temperature, shelterbelts and wind the lowest areas of the standard weather stations.

Factors that influence mesoclimate include: solar radiation, soil type and texture, slope and aspect, heat unit accumulation, elevation, wind, water and vegetation.

Solar Radiation

Solar energy is the primary source for all biological processes. Radiation from the sun has an effect on air and soil temperature, transpiration, soil moisture, atmospheric humidity, all plant processes, cell division, topism and factors such as sugar accumulation, bud fertility, wood maturity, etc. Yield and quality are also influenced. The amount of solar radiation received at a site and the duration of sunshine during the growing and harvesting season has a direct influence on all these factors. Shading from the afternoon and evening sun in mountainous areas, caused by topography or nearby trees, may have a negative effect on crop quality. Solar radiation is associated with heat summation at particular sites and factors such as the length of the growing season, although not directly related with heat accumulation, are associated with solar radiation. Long growing seasons with low heat unit accumulations are found in cool growing areas such as coastal climates where solar radiation is limited.

In cool climate areas, such as the Pacific Northwest, the selection of sites for some high value crop production must take into account slopes; aspects; elevation above sea level; protection from winds; proneness to fog in spring or fall; the best sources of solar radiation; and hence, increased heat accumulation and sunlight. The effect of solar radiation is also noticed on soils. Soil texture and soil water content differences can influence the heating and cooling rates in crop production. Dry, sandy soils have the greatest range of daytime to nighttime temperatures. Clay soils at field capacity have the least fluctuation in temperature. These differences are greatest close to the soil where only a few centimeters change in elevation can be responsible for significant differences in temperatures. The table below gives an indication of the effect of surface cover on temperatures within a crop.

The use of soil textures, soil moisture and soil cover for frost protection is an established practice. For example, wetting a dry soil improves the transfer of heat from the atmosphere to the soil and at the same time increases the heat storage capacity in the soil proportional to the volume it contains. Imposing a living vegetation barrier between the soil and the atmosphere reduces the transfer of heat to the soil.

The amount of radiation lost as heat from soil varies with the shape of valleys. Depressions are traditionally frost pockets, however, narrow, steep valleys, such as the Okanagan and Similkameen Valleys, tend to restrict the amount of radiation. Soil heat is transferred to the atmosphere in large amounts due to the relatively large ground surface area. The location of Okanagan Lake and the chain of lakes located in the Okanagan Valley contribute significantly to the collection and release of thermal radiation and cloud formation. Increased cloud cover, particularly in winter months, reduces the outgoing radiation keeping the area warmer than the surrounding plateau.

Effects of Soil Surface Cover on Temperature Within a Crop

Surface Cover	Temperature (°C)
Bare, firm, moist soil	Warmest
Shredded cover crop, moist soil	1/2 degree cooler
Low cover crop, moist soil	1/2 degree cooler
Dry, firm soil	1 degree cooler
Freshly disced soil	1 degree cooler
High cover crop	1 to 2 degrees cooler

Slope and Aspect

The amount of solar radiation accumulated at a site varies depending on the slope of the land and the direction of the slope. In the northern hemisphere, southern slopes are the best choice to gain increased solar radiation. North facing slopes gain the least while west slopes intercept more solar radiation than east slopes. Total accumulated heat units are generally greatest near the midslope, less on the hilltops and lowest near the base of the slope. Exposed hill tops have lower maximum temperatures and slightly cooler minimum temperatures than midslopes. Cold air flows down slopes and collects at the base creating frost pockets and areas with late spring frost and early fall frost. The angle of the slope, in relation to the location of the sun, is very important to maximize the amount of solar collected at a site. Figure 3 illustrates the effect of the slope on the amount of solar radiation collected at Summerland.

South slopes may lose the protective snow cover in winter months, resulting in root damage from penetrating frost on light sandy soils. South slopes may demonstrate advanced bud break and increased water requirements. In warm areas of the Pacific Northwest, south slopes may be too warm for certain crops or varieties. In contrast, the growing season and winter conditions on north facing slopes are all negative except for slopes of less than 10 degrees. Such slopes in warm areas may be useful only for some early maturing crops or varieties.

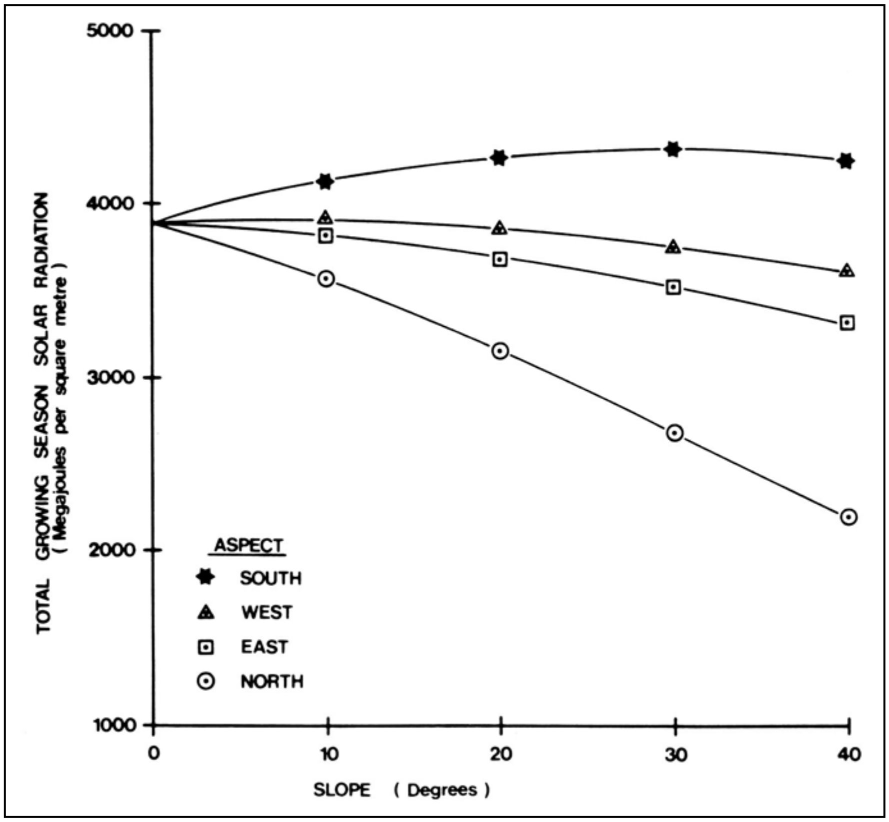


Figure 3

Total growing season solar radiation (MJ/m^2) at Summerland as a function of slope and aspect

Source: Atlas of Suitable Grape Growing Locations in the Okanagan and Similkameen Valleys

Elevation

Crops are grown over a wide range of elevations in the Okanagan. There are limits in elevation above sea level (ASL) where some crops can be grown economically. Increases in elevation of 100 metres may reduce the average annual temperature by as much a 1°C. For example, 660 metres ASL is considered to be the cut off for tree fruits in the Okanagan. Exceptions have been noted on south slopes and in areas where air inversions may form. Fields at higher elevations are, therefore, generally cooler than fields at lower elevations in the same region. Higher elevations are generally wetter due to increased precipitation during the growing season and winter months. Cooler temperatures at higher elevations delay bud break, flowering and ripening dates.

Wind

Many studies illustrate the negative effects of high wind on crop production and quality. Exposure to moderate and high winds has a desiccating effect (due to the high evapotranspiration rates) and causes physical damage. During the winter, wind removes snow cover; increases the risk of soil drying and root desiccating, as well as causing damage to roots of perennial crops as a result of low temperatures. High winds often result in tattered leaves, smaller leaves, broken shoots, extensive lateral growth, reduced insect activity in blossoms and thicker skins on berries. Wind in excess of 12 km/hr cause stomata to close, resulting in reduced photosynthesis. Stomates are reported to recover slowly if the reason for their closure was high winds and more quickly if the wind speeds were moderate.

Windbreaks with 50% reduction of wind may be beneficial for areas of the South Okanagan and Similkameen Valleys in the Oliver/Osoyoos area where strong daily winds are typical weather patterns in spring and summer. Studies have shown that sheltered crops protected by artificial or natural windbreaks have better crop vigor, quality and yield. The benefits of wind shelters will vary, with the frequency and the degree of high winds.

Economic benefits of wind breaks depend on:

- wind behaviour
- crop species or variety
- pruning or trellis system used and crop row layout
- soil moisture and temperature during the windy period
- growth phase of the crop when high winds occur
- design of windbreak
- cost of windbreak
- increase in income as a result of windbreak

Economical production may not be possible in some areas due to high winds. Not all wind is bad though. The turbulent effect of winds may help in sunny continental climates, such as the Okanagan and Similkameen Valleys where background levels of carbon dioxide are relatively low. Assimilation of carbon dioxide may be restricted by low concentrations in the leaf canopy.

Summary

The integrated climate of the Okanagan and Similkameen Valleys creates a pleasant environment to live in. The climate of the area, although not suited to grow all types of crops, are well blended to support a flourishing culture of vegetables, field crops, cereal crops, small and tree fruits, pasture and other minor crops.

Abbreviations Used in Table 1

Lat.	Latitude (degrees-minutes) North
Long.	Longitude (degrees-minutes) West
Elev.	Elevation (m)
GDD	Growing Degree Day above 5°C
LSF	Average date of last spring frost
FFF	Average date of first fall frost
FFP	Freeze free period (days)
P_A	Annual precipitation (mm)
P_S	May-September precipitation (mm)
Snow	Mean snowfall (cm)
GP	Greatest precipitation in 24 hrs (mm) ever recorded
PE_S	Estimated May-September potential evapotranspiration (mm)
Ext. Min.	Lowest minimum temperature ever recorded (°C)
Ext. Max.	Highest maximum temperature ever recorded (°C)
Jan. Min.	Average January minimum temperature (°C)
July Max.	Average July maximum temperature (°C)

Table 1

Summary of Climatological Data for Some Representative Atmospheric Environment Service Stations in the Okanagan and Similkameen Valleys

STATION	Lat.	Long.	Elev.	Yrs. of Record	GDD	LSF	FFF	FFP	P_A	P_S	Snow	GP	PE_S	Ext. Min.	Ext. Max.	Jan. Min.	July Max.
Armstrong	50 26	119 12	375	26	1867	May 18	Sept 20	124	457	174	159	55	565	-42.2	40.6	-9.6	28.0
Kelowna Airport	49 58	119 23	430	12	1801	May 26	Sept 20	116	312	129	104	22	489*1	-36.1	38.6	-9.3	28.0
Keremeos	50 12	119 47	430	29	2424	Apr 18	Oct 17	181	242	103	64	52	534	-30.6	41.1	-6.5	29.0
Lumby	50 15	118 58	509	10	1711	May 25	Sept 11	108	420	193	143	37	---	-33.3	38.3	-10.4	27.4
Okanagan Centre	50 4	119 27	348	29	2040	Apr 26	Oct 17	173	356	148	81	44	495	-30.0	40.0	-5.5	27.3
Oliver	49 10	119 33	315	29	2194	May 11	Sept 28	139	291	118	56	51	620	-30.6	42.8	-6.9	29.2
Osoyoos	49 4	119 31	331	27	2459	Apr 18	Oct 16	180	336	126	69	41	517	-25.6	39.5	-6.1	29.1
Oyama	50 06	119 22	396	5	1909	May 15	Oct 12	149	387	169	91	40	---	-26.5	39.0	-7.0	27.4
Penticton Airport	49 28	119 36	344	30	2136	May 8	Oct 4	148	283	122	76	45	549	-27.2	40.6	-5.3	28.6
Summerland CDA	49 34	119 39	455	30	2196	Apr 22	Oct 10	165	291	127	78	46	513	-30.0	40.0	-6.3	27.8
Vernon	50 14	119 17	555	9	2011	Apr 22	Oct 15	175	348	151	103	30	471*2	-26.7	38.5	-7.4	27.0
Winfield	50 02	119 25	503	10	2043	Apr 19	Oct 3	176	332	141	106	38	---	-25.5	37.2	-6.5	27.1

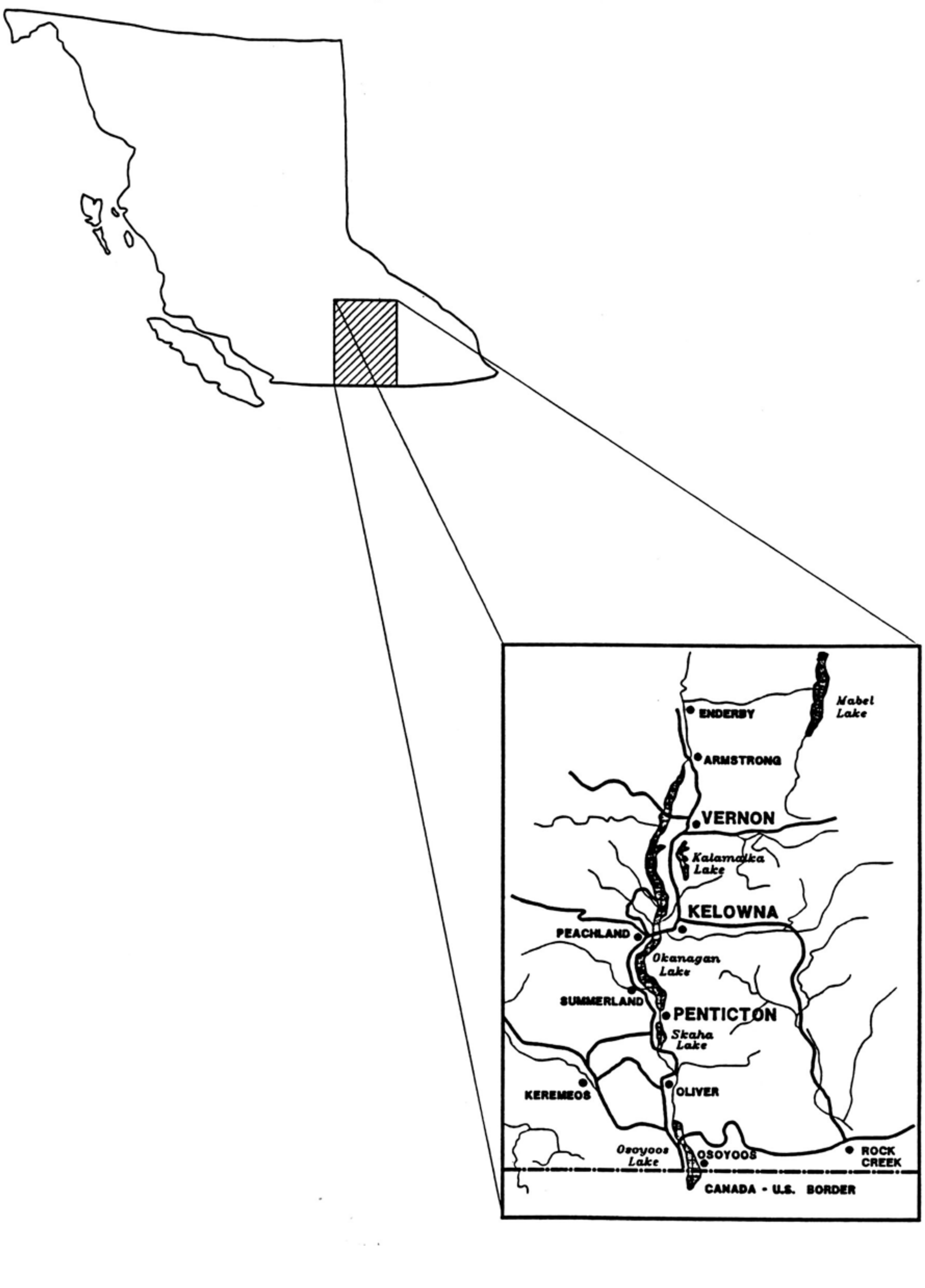
Sources: Environment Canada. Atmospheric Environment Service, 1982. Canadian Climate Normals, Volumes 2, 3, 4 and 6: 1951-1980. Downsview, Ontario

Air Studies Branch. Climatic Capability Classification for Agriculture in British Columbia, RAB Technical Paper 1. Ministry of Environment, Victoria, B.C., 1978.

*1 Kelowna CDA *2 Vernon Coldstream

Appendix B:

Soil Series And Locations



Chopaka Soil Management Group

Bessette (BT) series are a widespread group derived from low lying stream and river alluvium and are classified at elevations that lie between 360 and 660 metres (1,200 and 2,200 feet).

Chopaka (CK) soils occur in the lowest lying portions of the Similkameen River floodplain near Keremeos and Cawston and the Okanagan River floodplain between Osoyoos and Penticton.

Duteau (D) series and complex cover a minor portion of the soil map. There are a few areas in the vicinity of Waby Lake, between Lumby and Mabel Lake.

Gillanders (GS) occurs on the eastern side of the Similkameen River floodplain south of Cawston.

Nisconlith (N) (N:ca)[1] soils are scattered throughout the map area except in the valley bottom north and east of Lumby.

Priest Creek (PT) soils occur near Kelowna in association with Guisachan, Summerland and Pandozy soils.

Strutt (ST) soils occur in scattered, depressional to very gently sloping areas near Summerland, Kaleden and Oliver.

Gammil Soil Management Group

Debeck (DE) soils are scattered throughout the map area, mainly near Oliver, Kaleden, Summerland and East Kelowna.

Ellison (EN) soils occupy a minor area near the south end of Ellison Lake.

Gammil (GM) soils are common in the Okanagan Valley between Vaseaux Lake to Ellison Lake.

Glenemma (G) soils were mapped along Equesis Creek, near the north end of Okanagan Lake. Other areas lie adjacent to BX Creek northeast of Vernon and along the south side of the Coldstream Valley.

Nahun (H) (H:db)[1] soils occupy gravelly terraces in the natural grassland section of the map area. The main areas occur northwest of Armstrong, south of Glenemma and in the vicinity of BX Creek.

Peachland (PA) soils occur near Trepanier, Westbank, East Kelowna and north of Ellison.

Rutland (R) soils occupy areas throughout the Okanagan Valley portion of the map area and also near Keremeos in the Similkameen Valley.

Seaton (SE) soils are scattered throughout the mapped area.

Glenmore Soil Management Group

Boucherie (BE) soils are mapped near Westbank, Okanagan Mission and in the Glenmore Valley.

Broadview (B) soils are located in the valley between Vernon and Enderby.

Glenmore (GL) (GL:dg)[1] soils occur in the Glenmore Valley north of Kelowna, and near Ellison, Westbank and Okanagan Mission.

Plaster (PLA) soils occur north of Armstrong on the valley sides.

Spallumcheen (S) (S:gl) (S:gl,ca)[1] soils occur in the North Okanagan Valley bottom between Kalamalka Lake and Enderby.

Tappen
(T) soils are located from Spallumcheen to Swan Lake north.

Westbank (WK) soils are located east of Westbank, within the Glenmore Valley north of Kelowna and near Ellison.

[1] Legend of Soil Phases and Variants, Page B-8

Greata Soil Management Group

Greata (GT) (GT:bl) [1] soils occupy scattered areas near Peachland, Westbank and Okanagan Mission.

McKinley (MK) soils occur only near McKinley Landing and in the Glenmore Valley.

Valley Creek (VK) soils occupy gentle to extreme slopes along either side of Okanagan and Skaha Lakes.

Guisachan Soil Management Group

Guisachan (GN) soils occupy areas near Kelowna (Scotty and Mission Creeks) and near Keremeos in the Similkameen Valley.

Tanaka (TA) soils occur near Kelowna adjacent to Mission Creek and in isolated pockets west of Ellison Lake, the Richter Pass and near Olalla.

Winslow (WW) soils are scattered throughout the Okanagan Valley portion of the map area.

Kelowna Soil Management Group

Armstrong (A) (A:sw) (A:sw,cb) [1] soils are located mainly east of Rutland near Black Knight Mountain.

Bluespring (BP) soils occur on the upland between Armstrong and Enderby and on the south side of the Coldstream and Bluespring Valleys.

Cherryville (CY) soils developed in the area between Cherryville and Hilton and on the upland west of Enderby in the vicinity of Deep Creek Valley.

Giants Head (GH) soils are common in the southern and central portions of the map area.

Grizzly Hill (GH) soils are on the upland between Glenemma, Enderby and Armstrong and in small, scattered areas that occur south of Lumby.

Harrland (HD) souls are mainly found near Okanagan Falls, West Summerland, Lakeview Heights, Rutland and north of Kelowna.

Hayman (HN) soils occur near Okanagan Falls, Westbank, Lakeview Heights and north of Ellison and Kelowna.

Kelowna (KE) soils occur in small areas near Okanagan Falls, Summerland and Westbank.

McDougall (ML) soils occur near East Kelowna, Lakeview Heights and Westbank.

Reiswig (RS) soils occur on the uplands to the north of Lumby and in the Bluespring Valley.

Keremeos Soil Management Group

Cawston (CA) soils occur on the floodplains of the Similkameen and Okanagan Rivers.

Coulthard (CD) soils occur on the floodplain of the Similkameen River.

Keremeos (K) soils occur mainly near Keremeos, Cawston and Nighthawk.

Nighthawk (NG) soils are common on the floodplain of the Lower Similkameen River and in a small area near Vaseaux Lake.

Snehumpton (SN) soils occur on the floodplains of the Similkameen and Okanagan Rivers.

Munson Soil Management Group

Carlin (CN) soils are located from Spallumcheen to Swan Lake north.

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[1] Legend of Soil Phases and Variants, Page B-8

Chapman (CH) soils occur on strongly to steeply sloping, often eroded areas generally adjacent to Okanagan Lake.

Enderby (EY) soils are mainly found in an east-west valley that lies between Glenemma and Enderby and in the Deep Creek Valley.

Gellatly (GY) soils occur in Westbank and Glenmore Valley.

Higgin (HG) soils occur in small areas near Summerland, Penticton and Westbank on very gentle to moderate slopes.

Hullcar (HR) soils occupy minor areas in the east-west valley between Glenemma and Enderby. A deposit occurs as a strip along the valley side with one face exposed and subject to erosion.

Kalamoir (KR) soils are common in Westbank, Lakeview Heights and East Kelowna.

Knox Mountain (KN) soils occur north-east of Kelowna and near Okanagan Mission.

Lambly (LY) soils occur near Boucherie Mountain.

Mission Creek (MC) soils are found in the vicinity of Mission and Daves Creeks.

Munson (MU) soils are found adjacent to Okanagan and Skaha Lakes.

Naramata (NM) soils occur on the east side of Okanagan Lake between Penticton and Naramata and along Skaha Lake.

Olhause (ØH) soils are found adjacent to Okanagan and Skaha Lakes and in Summerland as well.

Penticton (P) soils are found adjacent to Okanagan and Skaha Lakes.

Osoyoos Soil Management Group

Glenfir (GF) soils are found in the Inkaneep Valley near Oliver and at Okanagan Falls.

Grandview (GR) (GR:dg)[1] series is confined to the natural grasslands in the southern part of the map area. Larger areas occur northwest of Armstrong, on Grandview Flats and on Mission Hill.

Haynes (HA) soils occupy sloping areas near Oliver and Osoyoos.

Kaleden (KA) soils occur near Oliver, Okanagan Falls, Kaleden and Summerland.

Moffat (MT) soils occur scattered areas from the vicinity of Grandview Flats to Glenemma and east to Deep Creek.

O'Keefe (ØK) soils are found in the vicinity of Glenemma, eastward to Enderby and from there southward to Armstrong.

Osoyoos (Ø) soils occur in the south Okanagan from Oliver to the United States border.

Oyama (ØY) soils occur throughout the Okanagan Valley, mainly near Summerland, Rutland, East Kelowna and Ellison.

Parkill (PR) soils occur near Oliver, Okanagan Falls, West Summerland, Westbank and East Kelowna.

Shuswap (SH) soils occur in the most humid parts of the map area, chiefly around Waby Lake and Deep Creek.

Stepney (SY) soils occupy three small areas on the highland southwest of Enderby.

Trepanier (TR) soils occur in small areas near Trepanier Creek and Lakeview Heights.

Trewitt (TW) soils are scattered throughout the mapped area.

[1] Legend of Soil Phases and Variants, Page B-8

Postill Soil Management Group

Eaneas (ES) soils occur throughout the south Okanagan area from Osoyoos to Summerland.

Equesis (ES) soils are scattered on upland ridges north of Okanagan Center to Armstrong.

Faulder (FR) soils are scattered throughout the central part of the Okanagan map area.

Fowler (FR) soils are scattered on upland ridges north of Okanagan Center to Armstrong.

Nkwala (NK) soils occur in association with Faulder and Gammil soils and rock outcrops near Okanagan Falls and Summerland.

Pari (PAR) soils are scattered on upland ridges north of Okanagan Center to Armstrong.

Postill (PL) soils occupy numerous hilly areas in the northern portion of the map area.

Roy Creek Soil Management Group

Cameron Lake (CNA) (CN) soils occur primarily near Kelowna.

Inkaneep (IK) soils occur throughout the Okanagan Valley from Osoyoos Lake to Ellison Lake.

Roy Creek (RY) soils occur throughout the Okanagan Valley portion of the map area.

Rumohr Soil Management Group

Darke Lake (DL) soils occur near Oliver and Summerland.

Gardom (GMA) soils occur in the Waby Lake – upper Deep Creek area and in the vicinity of Lumby.

Kendall (KD) soils occur in scattered areas near Oliver, Summerland and Kelowna.

Nisconlith (N:p)[1] soils are scattered throughout the map area except in the valley bottom north and east of Lumby.

Okanagan (Ø) soils are scattered throughout the map area, most common in the drainage channel that lies between Armstrong and the north arm of Okanagan Lake, and in the Deep Creek – Waby Lake area.

Rumohr (RH) soils occur only near the Kelowna airport and in the Okanagan Mission area.

Waby (WY:m)[1] is a minor soil which occurs in the Waby lake – upper Deep Creek locality, to the north and east of Enderby and to the southeast of Lumby.

Similkameen Soil Management Group

Coldstream (CS) (CS:wd) (CS:wd,ca)[1] series are widely scattered, but most common in the Coldstream Valley, between Lavington and Lumby.

Kalamalka (K) (K:dg) (K:1)[1] soils are located in the Coldsream Valley between Vernon and Lumby. There are also scattered in small areas in the Black soil region between Vernon and Enderby.

Olalla (ØL) soils only occur north of Keremeos.

Shannon (SA) soils occur in a few, small, nearly level to gently sloping areas near Westbank.

Similkameen (SM) soils occupy areas east of Keremeos and Cawston and in small areas near Oliver, Penticton and Naramata.

Skaha Soil Management Group

Acland Creek (AC) soils occupy areas near West Summerland, Okanagan Falls, Rutland and East Kelowna.

[1] Legend of Soil Phases and Variants, Page B-8

Agar Lake (AA) soils occur near Oliver, Penticton and Summerland.

Dartmouth (DH) soils occur throughout the central Okanagan Valley portion of the map area.

Paradise (PE) soils occur mainly near Oliver, Okanagan Falls, West Summerland and East Kelowna.

Skaha (SK) soils are common and occur on nearly level to extreme slopes, usually in association with Debeck, Osoyoos, Haynes and Agar Lake soils.

Trout Creek (TC) soils are scattered throughout the Okanagan map area, but are most common in the West Summerland, Peachland and East Kelowna areas.

Stemwinder Soil Management Group

Burnell Lake (BL) soils are common in the South Okanagan Valley near Oliver, Penticton, Naramata and Summerland.

Canyonview (CY) soils occupy small scattered location near Oliver, Penticton, Summerland and adjacent to the Ashnola River west of Keremeos.

Hupel (HU) soils are located north of Lumby in the White and Trinity Valleys and east of Lumby toward Cherryville in Bluespring Valley.

Lumby (LY) (LY:gl)[1] soils are scattered throughout most of the classified area, but are more common in the vicinity of Lumby.

Manery (MY) soils occur throughout the map area and are usually associated with Canyonview, Roy Creek, Tomlin and Inkaneep soils.

Pandozy (PY) soils only occur on the Mission Creek fan near Kelowna.

Ponderosa (PØ) soils occur only in the vicinity or Oliver.

Ratnip (RN) soils occur near Oliver, Summerland and East Kelowna.

Stemwinder (SW) soils are common in the Similkameen Valley from the International Boundary to the Ashnola River, they also occur in small areas near Oliver, Penticton and Peachland.

Tomlin (TM) soils occur throughout the map area, mostly near Penticton, Okanagan Falls, Summerland, Westbank and Kelowna.

Twin Lakes (TL) soils are limited to the southern part of the map area, mostly near Olalla.

Summerland Soil Management Group

Gartrell (GR) soils occur in a few scattered areas throughout the Okanagan Valley portion of the map area.

Summerland (SR) soils occur mainly near Osoyoos, West Summerland, Westbank and Kelowna.

Swanson (SN) (SN:vp)[1] soils are scattered near the north end of Okanagan Lake, along the shore of Swan Lake and in the area between 345 and 450 metre elevations.

Susap Soil Management Group

Bullock (BK) soils occur on nearly level and very gentle slopes on the floodplain of the Similkameen River.

Kinney (KY) soils occur on the Okanagan River floodplain between Penticton and Osoyoos Lake.

Monashee (MØ) soils occur along Cherry, Creighton, Bluespring and Bessette Creeks.

Susap (SU) soils are common on the floodplain of the Similkameen River.

[1] Legend of Soil Phases and Variants, Page B-8

Miscellaneous Soils

Armstrong (A:er)[1] soils are located mainly east of Rutland near Black Knight Mountain.

Corporation (CP) soils occur in scattered locations mainly in the southern portion of the map area.

Dub Lake (DU) soils are relatively uncommon in the map area and only occur north of Oliver on extreme slopes.

Enderby (E:er) (E:li)[1] soils are mainly found in an east-west valley that lies between Glenemma and Enderby and in the Deep Creek Valley.

Glenemma (G:er) [1] soils were mapped along Equesis Creek, near the north end of Okanagan Lake. Other areas lie adjacent to BX Creek northeast of Vernon and along the south side of the Coldstream Valley.

Iltcoola (IL) soils occur on nearly level and very gently sloping islands, bars and low terraces in and adjacent to the Okanagan and Similkameen River channels.

Kloag Pass (KG) soils occur adjacent to Osoyoos Lake on gentle and moderate slopes.

Maynard (MD) soils occur on gentle to extreme slopes in the Okanagan Valley, mainly adjacent to Osoyoos, Skaha and Okanagan Lakes.

Nahun (H:er) [1] soils occupy gravelly terraces in the natural grassland section of the map area. The main areas occur northwest of Armstrong, south of Glenemma and in the vicinity of BX Creek.

Rutland (R:er) [1] soils occupy areas throughout the Okanagan Valley portion of the map area and also near Keremeos in the Similkameen Valley.

Solly (SØ) soils occur adjacent to Osoyoos, Vaseaux, Skaha and Okanagan lakes.

Miscellaneous Land Types

MLA, MLB, MLC, MLD, MLE, MLF, MLG

Refer to page 30 for location and descriptions.

[1] Legend of Soil Phases and Variants, Page B-8

Legend of Soil Phases and Variants		
bl	black variant	soil classification is Orthic Black
ca	calcareous phase	soils are generally strongly or extremely calcareous to the surface
db	dark brown variant	soil classification is Orthic Dark Brown
dg	dark gray variant	soil classification is Orthic Dark Gray
er	eroded variant	soils occur on steep terrain where most of the topsoil and solum has eroded off
gl	gleyed variant	soil classification is a gleyed mineral soil and is imperfectly drained
gl,ca	gleyed, calcareous variant	
l	loam variant	
li	lithic variant	depth of soil material is between 10 and 100 cm and overlies bedrock
m	mesic variant	organic soils with dominantly mesic material, which is at a stage of decomposition intermediate between fibric and humic materials
p	peaty phase	a mineral soil having a surface horizon of 15 to 60 cm of fibric moss peat or 15 to 40 cm of other kinds of peat
sw	slope wash phase	a fluvial veneer originating from steeper upper slopes

FOR FURTHER INFORMATION CONTACT

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