B.C. Agricultural Drainage Manual

Chapter 8

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The primary purpose of the B.C. Drainage Manual is to provide farmers as well as water management professionals and consultants with technical information on the design, installation and maintenance of agricultural drainage systems.

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Drainage Planning Requirements 8

8.0 Drainage Planning Requirements

The design and installation of a good drainage system requires information on soils, crops, climate and topographical field data. The drainage plan should provide step by step information on how to construct and install a complete drainage system. The plan should include information on:

- Lot number and location of field,
- Soils types and distribution,
- Outlet location and depth,
- Location, size, depth, spacing and slope of all open ditches and subsurface drains,
- Location of all pertinent obstructions to installations such as buildings, trees, fences, gas, oil, water, telephone and other utility lines, and
- Upland and surface runoff conditions.

A drainage plan allows the landowner to install the system as time, field conditions, labour or finances permit. Once the system has been installed, the plan needs to be updated to show the system "as built". The revised plan provides a record for future reference and should be passed on to future landowners.

8.1 Hydrologic Analysis

8.1.1 B.C. Climate

The need for drainage in B.C. is generally related to climatic factors. Some areas in B.C. require drainage to provide adequate leaching of irrigated soils, reduce occasional high water tables beside lakes or streams, or reduce flooding. However, most of B.C.'s drainage requirements are the result of excessive precipitation. Precipitation quantity and distribution varies greatly between seasons and regions for B.C. Figure 8.1 shows the seasonal and regional distribution of rainfall for B.C. The drainage system designer must decide which season yields the peak design criteria.

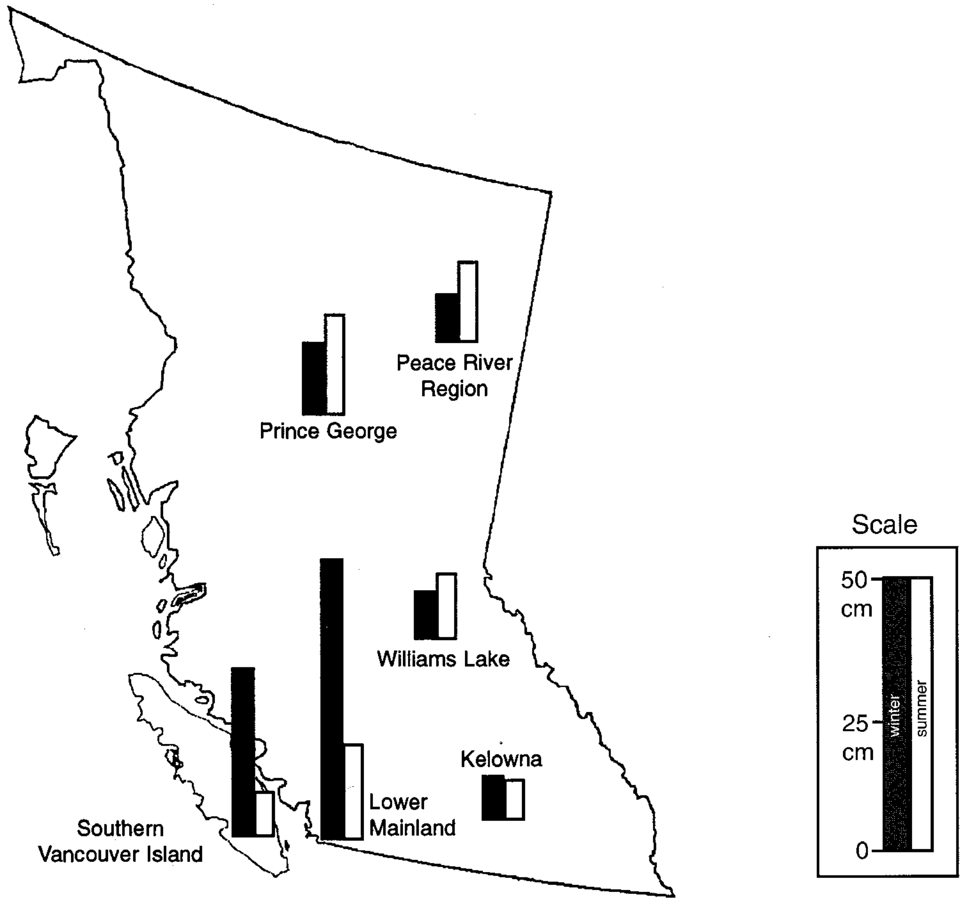


Figure 8.1 B.C. map with summer and winter isohyet showing precipitation depth

8.1.2 Frequency Analysis

Rainfall has different characteristics such as: duration, intensity and frequency. Duration is usually given in hours, intensity in mm per hour and frequency in return period (probabilities). The duration multiplied by the intensity will yield the total quantity of water that fell to the ground during a rainfall event. Intense rainstorms of variable duration occur everywhere in B.C. but the probability of these storms changes from one area to another. Often it is not economical to design water management structures to accommodate the largest rainfall that ever occurred in a particular location. An exception is where human life may be in danger. In such cases, the design capacities should exceed the largest recorded data. For these purposes, graphs or tables providing return periods of different storms of certain intensity and duration are required to design many agricultural water management works. Appendix A provides climatic data on rainfall intensities, duration and frequencies for selected locations in B.C.

Large drainage schemes involving substantial capital expenditures will warrant more detailed hydrological investigations to develop more accurate design criteria.

8.1.3 Peak Runoff Estimation

The objective of peak runoff estimation is to provide necessary data for the design of agricultural surface drainage systems, small water management structures and farm ponds. It should focus on the amount of water that can be expected and its frequency.

For small agricultural areas, Table 8.1 may be used to determine peak runoff. This table should be used **only for situations where the entire watershed is agricultural land**. If upland runoff from woodlands, urban or industrial areas enters the agricultural area, this table should not be used; the Rational or Soil Conservation Service (SCS) method should be used. In order to achieve a good outlet for a subsurface drainage system, the ditch size required may be deeper than the depth determined by the peak runoff requirements shown in this table. **A designer must therefore exercise caution when using Table 8.1 for designing ditches on small agricultural areas.**

There are many methods for peak runoff estimation. The two most commonly used empirical methods are the Rational and SCS methods. Both methods are outlined in this chapter. The fundamental basis for either method is the selection of an appropriate runoff coefficient or curve number. This specifies the fraction of runoff resulting from a precipitation event chosen at a specified risk level or frequency.

It should be kept in mind that both of these methods are over simplifications of a very complex process. Caution should be exercised when using these methods for design purposes.

For instance, peak runoff estimation uses peak precipitation frequency data collected from non-freezing periods of the year. In many areas of B.C., the delayed discharge of accumulated frozen precipitation during freeze/thaw periods and minimal spring vegetative cover is the critical hydraulic situation. Clues, such as high water marks from the performance of existing hydraulic structures or landmarks from past extreme runoff events may assist the design process.

The Rational Method is used in Canada and the USA to predict design flows from small urban and rural watersheds. For rural watershed areas, the upper limit for which the Rational Method is valid is 500 hectares. Two significant limitations to the Rational Method are estimating the time of concentration and selecting an appropriate runoff coefficient. The following considerations should be taken into account when using the Rational Method:

- The rainfall intensity used should be uniform over the entire watershed.
- The peak runoff rate occurs when the entire watershed is contributing.
- For a given region, estimates of the time of concentration may be improved by comparing calculated times with recorded times at stream gauging stations.
- Evaluation of soil types and land uses and comparing Rational Method results with stream gauge data may provide better estimates of runoff coefficients.

Table 8.1 Peak Runoff for Small Agricultural Areas	
Region	**Peak Runoff** $m^3/s/ha$
Vancouver Island	0.006
Gulf Islands	0.006
Lower Fraser Valley	0.006
North Side of Fraser Valley	0.008
Upper Fraser Valley	0.009
Pemberton	0.012
Kootenays	0.005
Okanagan	0.004
Cariboo	0.006
Peace River	0.007

The Soil Conservation Service (SCS) Method utilizes additional analysis of soil/land characteristics. While this method is more complex, the results achieved may be more realistic.

A suggested approach is to use both methods for calculating peak runoff rates. The results should be compared, the analysis procedure reviewed, and appropriate changes made if necessary. An average value of the two different results can then be used.

8.1.3a Rational Method

This method is used extensively in many parts of the world including USA and Canada. It should be noted that this method is not recommended for use on watershed basins larger than 500 hectares. The method may be expressed as:

$$Q = 0.0028CiA \qquad \textbf{(EQ 8.1)}$$

where
- Q = peak runoff rate, m^3/s
- C = runoff coefficient as given in Table 8.2
- i = rainfall intensity, mm/hr, for the design period and for a duration equal to the time of concentration of the watershed area
- A = watershed area, ha

For watersheds with more than one type of topography or vegetation, the following equation should be used to provide coefficient with weighted averages.

$$C = \frac{\Sigma C_1 A_1 + C_2 A_2 + \ldots}{\Sigma A_1 + A_2 + \ldots} \qquad \textbf{(EQ 8.2)}$$

where $C_1, C_2 \ldots$ = Runoff coefficient for area 1, 2, ...
$A_1, A_2 \ldots$ = Area of type 1, 2, ...

Rainfall intensity is obtained using the storm duration and a selected rainfall frequency. The storm duration for this method is equal to the time of concentration (Tc). Time of concentration (Tc) can be estimated from Table 8.3 or from the following equation:

$$Tc = 0.0195\ L^{0.77}\ S^{-0.385} \qquad \textbf{(EQ 8.3)}$$

where L = maximum length of flow (m)
S = grade of drainage area (m/m)
Tc = time of concentration (min)

From the estimated storm duration (Tc) and a selected rainfall frequency, the design rainfall intensity (i) is obtained from the appropriate figure in Appendix A. Agricultural drainage systems are normally designed for a rainfall frequency of 5 to 10 year return period.

A sample calculation for determining peak runoff using the Rational Method is given in Example 8.1.

Table 8.2 Runoff Coefficient (C)			
Topography and Vegetation	**Open Sandy Loam**	**Clay and Silt Loam**	**Tight Clay**
Woodland			
Flat (0-5% slope)	0.10	0.30	0.40
Rolling (5-10% slope)	0.25	0.35	0.50
Hilly (10-30% slope)	0.30	0.50	0.60
Pasture			
Flat	0.10	0.30	0.40
Rolling	0.16	0.36	0.55
Hilly	0.22	0.42	0.60
Cultivated			
Flat	0.30	0.50	0.60
Rolling	0.40	0.60	0.70
Hilly	0.52	0.72	0.82
Urban Areas	**30% of area impervious**	**50% of area impervious**	**70% of area impervious**
Flat	0.40	0.55	0.65
Rolling	0.50	0.65	0.80

Table 8.3 Time of Concentration for Small Drainage Areas, Tc (Minutes)						
Maximum length of flow (m)	**Gradient of Drainage Area (percent)**					
	0.05	**0.1**	**0.5**	**1.0**	**2.0**	**5.0**
100	13	10	5	4	2	2
200	21	16	9	7	5	4
300	29	23	12	9	7	5
400	37	28	15	12	9	6
500	44	33	18	14	11	7
1000	74	57	31	23	18	13
1500	102	78	42	32	25	17
2000	127	97	52	40	31	22
2500	150	115	62	47	36	26
5000	256	196	106	81	62	44

For watersheds with more than one type of topography or vegetation, the following equation should be used to provide coefficient with weighted averages.

$$C = \frac{\Sigma C_1A_1 + C_2A_2 + ...}{\Sigma A_1 + A_2 + ...} \qquad \textbf{(EQ 8.2)}$$

where $C_1, C_2 ...$ = Runoff coefficient for area 1, 2, ...
$A_1, A_2 ...$ = Area of type 1, 2, ...

Rainfall intensity is obtained using the storm duration and a selected rainfall frequency. The storm duration for this method is equal to the time of concentration (Tc). Time of concentration (Tc) can be estimated from Table 8.3 or from the following equation:

$$Tc = 0.0195 \; L^{0.77} \; S^{-0.385} \qquad \textbf{(EQ 8.3)}$$

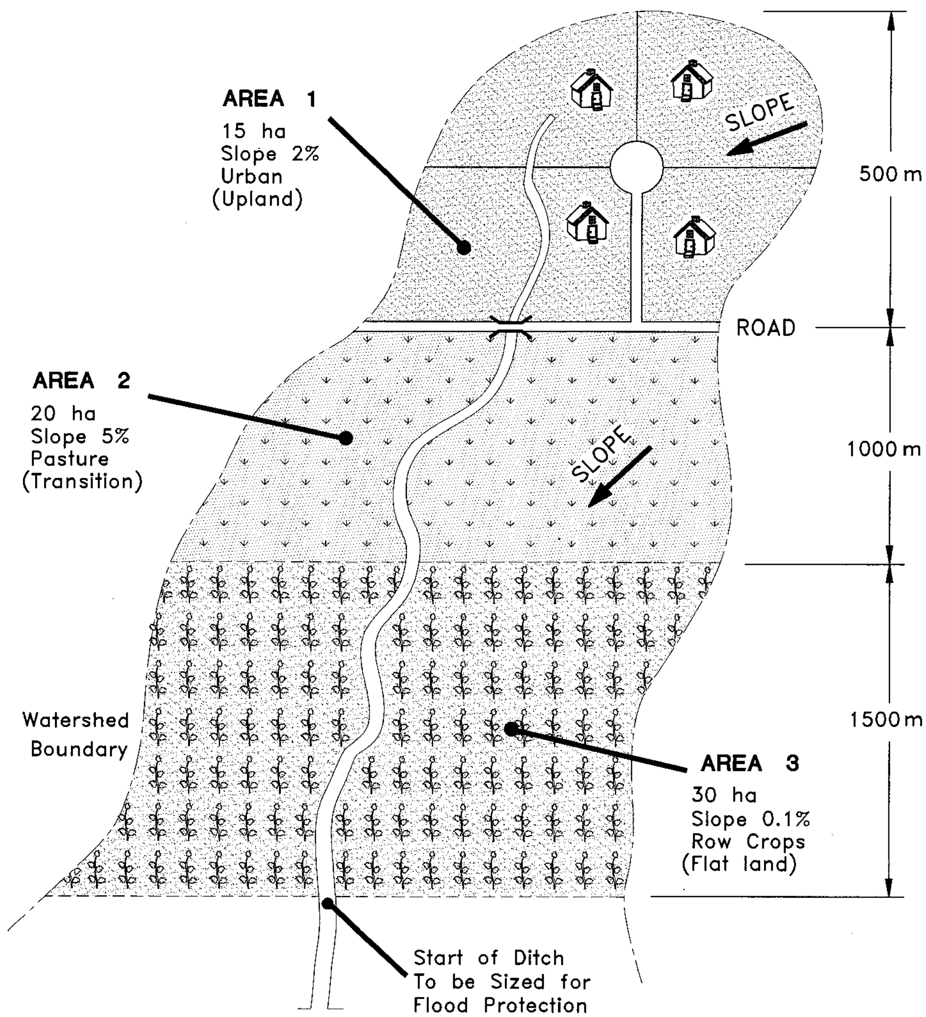
where L = maximum length of flow (m)
S = grade of drainage area (m/m)
Tc = time of concentration (min)

From the estimated storm duration (Tc) and a selected rainfall frequency, the design rainfall intensity (i) is obtained from the appropriate figure in Appendix A. Agricultural drainage systems are normally designed for a rainfall frequency of 5 to 10 year return period.

A sample calculation for determining peak runoff using the Rational Method is given in Example 8.1.

Example 8.1 Rational Method

A Farmer in Surrey wishes to construct an open ditch to carry water from upland runoff. The watershed area is 65 ha of which 50 ha is being farmed. Calculate the peak runoff from the information provided in the following figure:



1. *Runoff coefficient from EQ 8.2:*

A_1 = Area of flat urban development (30% of area impervious)
A_2 = Area of rolling pasture / clay silt loam
A_3 = Area of flat cultivated / clay silt loam
C_1 = 0.40
C_2 = 0.36
C_3 = 0.50

$$C = \frac{C_1A_1 + C_2A_2 + C_3A_3}{A_1 + A_2 + A_3} = \frac{15(0.40) + 20(0.36) + 30(0.50)}{65}$$

C = 0.43

(Continued next page)

Example 8.1 Rational Method *(Continued from previous page)*

2. **Time of Concentration**

For Area 1

Maximum length of flow = L = 500 m

Gradient = S = 2% = $\frac{2\ m}{100\ m}$ = $\frac{0.02\ m}{m}$

$Tc_1 = 0.0195 \times L^{0.77} \times S^{-0.385}$

$Tc_1 = 0.0195 \times (500)^{0.77} \times (0.02)^{-0.385}$

$Tc_1 = 10.53$ min

For Area 2

L = 1000 m

S = 5%

From Table 8.3

$Tc_2 = 13$ min

For Area 3

L = 1500 m

S = 0.1%

From Table 8.3

$Tc_3 = 78$ min

∴ time of concentration of entire watershed = $Tc_1 + Tc_2 + Tc_3$

Tc = 11 + 13 + 78 = 102 min

3. **Rainfall intensity**

Storm duration = Tc = 102 min

Return period = 10 years

For Lower Fraser Valley from Appendix A

Rainfall intensity = 15 mm/hr

4. **Peak Runoff from EQ 8.1**

$Q = 0.0028 \times C \times i \times A$

$Q = 0.0028(0.43)(15)(65)$

$Q = 1.17\ m^3/s$

8.1.3b SCS Method

The US Soil Conservation Service developed a method to estimate the peak runoff rate. It should be noted that this method is not recommended for use on watershed basins larger than 500 hectares. The formula may be expressed as:

$$Q = \frac{0.00208\,Aq}{(0.5D) + (0.6Tc)} \qquad \textbf{(EQ 8.4)}$$

where Q = peak runoff rate, m^3/s
A = watershed area, ha
q = the runoff volume, mm (over watershed)
Tc = the time of concentration, hr
D = the storm duration, hr

The following procedures and information should be used for this method:

1. Determine the drainage basin area, A.

2. From knowledge of the drainage area characteristics, determine the hydrologic soil groups and hydrologic conditions for the different areas of the watershed by using Tables 8.4 and 8.5. Determine with Table 8.6, the runoff curve number for the different areas. A weighted average curve number is then calculated from the different values.

3. This number represents a runoff index for average antecedent moisture conditions and should be modified for wet or dry conditions as described in Table 8.7. If the watershed condition is found to be 1 or 3, the runoff curve number is modified using Figure 8.2.

4. Estimate the time of concentration (Tc) for the watershed from Table 8.3 or Equation 8.3.

5. From knowledge of rainfall characteristics in the region, storm duration (D) is determined. Storm duration may be estimated as 0.7 Tc.

6. From the duration estimated and a selected storm frequency, the design rainfall intensity (i) is obtained from the rainfall intensity curves (Appendix A). Agricultural drainage systems are normally designed for a storm frequency of 5 to 10 year return periods.

7. Estimate the storm rainfall (P) which is the product of the storm duration (D) and the rainfall intensity (i), P = Di.

8. Using the calculated P and the modified runoff curve number, determine the runoff volume (q) from Figure 8.3.

9. Estimate the peak runoff rate (Q) by using Equation 8.4.

Example 8.2 SCS Method

The same example as the rational method will be used. Refer to figure of Example 8.1.

1. **Determine soil groups for the different areas:**
   A_1 = 15 ha → Group D
   A_2 = 20 ha → Group C From Table 8.4
   A_3 = 30 ha → Group C

2. **Determine hydrologic conditions for areas:**
   A_1 = Poor
   A_2 = Fair
   A_3 = Good

3. **Determine runoff curve numbers from Table 8.6:**
   A_1 = 92
   A_2 = 79
   A_3 = 85

4. **Weighted average**

$$\frac{15(92)}{65} + \frac{20(79)}{65} + \frac{30(85)}{65} = 84.76 = 85$$

5. **Using Table 8.7 and Figure 8.2** adjust curve number for antecedant moisture condition. We will assume a watershed Condition 3.
   The curve is adjusted from 82 to 94.

6. **Time of concentration is estimated as in Example 8.1**
   TC = 102 min = 1.7 hrs.

7. **Storm duration**
   D = 0.7 Tc
   D = 1.19 hrs

8. **Rainfall intensity** is determined from Appendix A.
   For 71 minutes and a return period of 10 years
   i = 17 mm/hr

9. **Storm rainfall (P) is calculated**
   P = Di
   P = 1.19 (17) = 20.23 mm

10. **Determine direct runoff volume q from Figure 8.3**
    Direct Runoff = q = 9 mm

11. **Peak runoff rate from EQ 8.4**

$$Q = \frac{0.00208(65)(9)}{0.5(1.19) + 0.6(1.7)} = \frac{1.2168}{1.615} = 0.75 \text{ m}^3/\text{s}$$

Table 8.4 Hydrologic Soil Groups (SCS Method)	
Soil Description	**Group**
Lowest runoff potential, includes deep sands with very little silt and clay, as well as deep rapidly permeable loess.	A
Comprises mostly sandy soils shallower than A, and loess less deep or less aggregated than A. The group as a whole has above-average infiltration after thorough wetting.	B
Comprises shallow soils and soils containing considerable clay and colloid, though less than those of group D. The group has below-average infiltration after pre-saturation.	C
Highest runoff potential, includes mostly clays of high swelling percent, but the group also includes some shallow soils with nearly impermeable subhorizons near the surface.	D

Source: Soil Conservation Service, 1979.

Table 8.5 Hydrologic Conditions (SCS Method)	
Vegetative Condition	**Hydrologic Condition**
Classification of Pasture or Range	
Heavily grazed, no mulch, or has plant cover on less than 50% of the area.	Poor
Moderately grazed, about 50 to 75% of the area has plant cover.	Fair
Lightly grazed, more than about 75% of the area has plant cover.	Good
Classification of Woodlands	
Heavily grazed or regularly burned so that litter, small trees and brush are destroyed.	Poor
Grazed, but not burned. There may be some litter, but these woodlands are not fully protected from grazing.	Fair
Protected from grazing so that litter and shrubs cover the soil	Good
NOTE: Crop rotations range from "poor" to "good" in proportion to the amount of dense vegetation in the rotation. "Poor" rotations (from a hydrologic standpoint) contain row crops and fallow in various combinations. "Good" rotations contain a high proportion of alfalfa or other close-seeded legumes or grasses that will improve tilth and increase infiltration.	

Source: Soil Conservation Service, 1979.

Table 8.6 Runoff Curve Number for Hydrologic Soil-Cover Complexes (SCS Method)

Land Use or Cover	Treatment or Practice	Hydrologic Condition	Hydrologic Soil Group			
			A	B	C	D
Fallow	Straight Row	-	77	86	91	94
Row Crops	Straight Row	Poor	72	81	88	91
		Good	67	78	85	89
	Contoured	Poor	70	79	84	88
		Good	65	75	82	86
	Contoured and Terraced	Poor	66	74	80	82
		Good	62	71	78	81
Small Grain	Straight Row	Poor	65	76	84	88
		Good	63	75	83	87
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	Contoured and Terraced	Poor	61	72	79	82
		Good	59	70	78	81
Close-Seeded Legumes* or Rotation Meadow	Straight Row	Poor	66	77	85	89
		Good	58	72	81	85
	Contoured	Poor	64	75	83	85
		Good	55	69	78	83
	Contoured and Terraced	Poor	63	73	80	83
		Good	51	67	76	80
Pasture or Range		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
	Contoured	Poor	47	67	81	88
		Fair	25	59	75	83
		Good	6	35	70	79
Meadow (permanent)		Good	30	58	71	78
Woods and Forests		Very Poor	56	75	86	91
		Fair	36	60	73	79
		Very Good	15	44	54	61
Farmsteads			59	74	82	86
Roads**(dirt)			72	82	87	89
(hard)			74	84	90	92

*Close-drilled or broadcast **Including right-of-way

Source: Soil Conservation Service, 1979.

Table 8.7 Estimation of Antecedent Moisture Conditions		
5-Day Antecedent Rainfall, mm		Watershed Condition
Growing Season	Dormant Season	
Under 35 mm	Under 10 mm	1
35 to 55 mm	10 to 30 mm	2
Over 55 mm	Over 30 mm	3

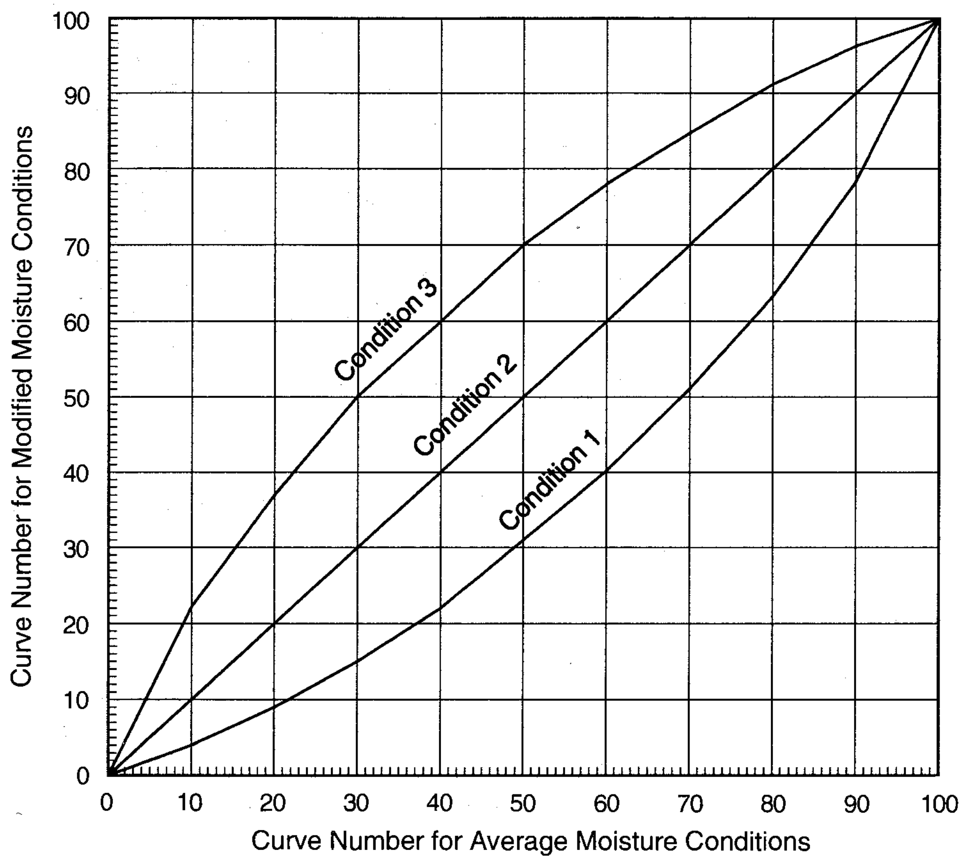


Figure 8.2 Estimation of Antecedent Moisture Condition

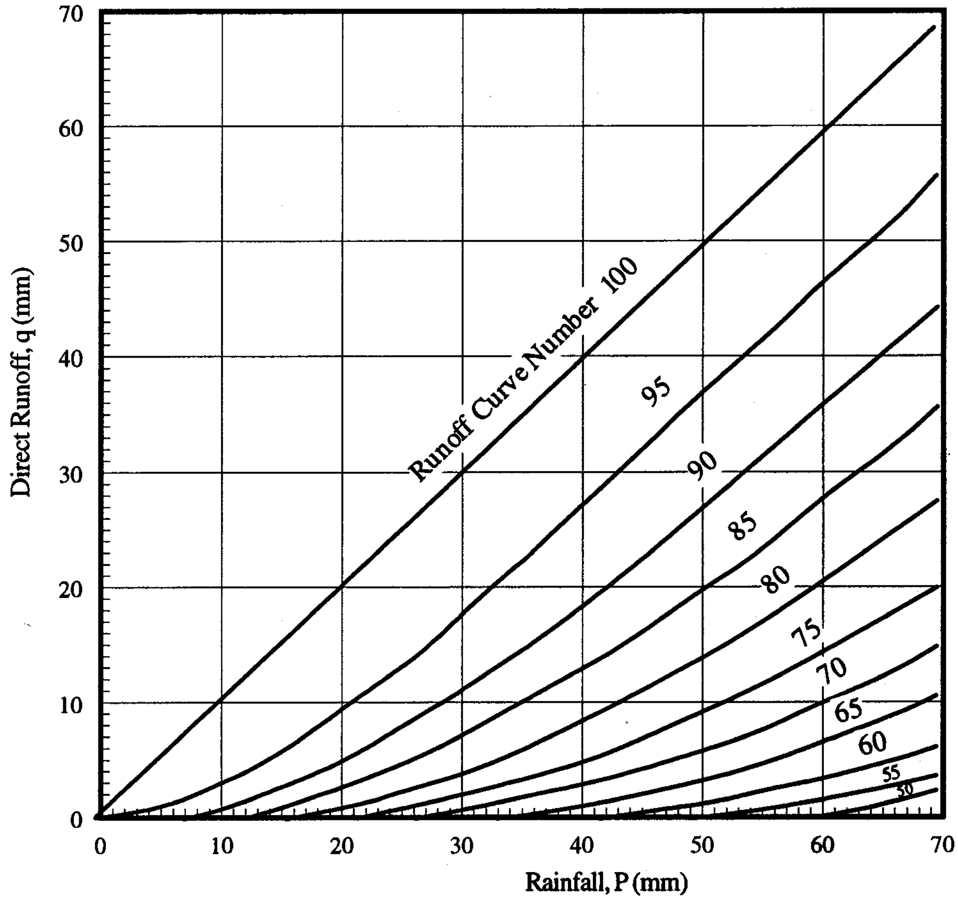


Figure 8.3 SCS Method, Direct Runoff, q (mm)

Review of Examples 8.1 and 8.2

The calculation of peak runoff uses several subjective decisions. It is recommended that both the Rational and SCS methods be used to calculate peak runoff. If the two methods don't provide close result, the various parameters should be reviewed and the peak flow recalculated. In this case, the values calculated were:

Rational method	1.17 m^3/s
SCS method	0.75 m^3/s

The difference in peak runoff rate estimated from both methods is significant. This highlights the different assumptions implied in both methods.

Experience and knowledge of local areas should be used to select an appropriate runoff rate based on these results. In this case, the size of the ditch could be based on the highest value of the two if it is not economically prohibitive to do so.

8.2 Soil Investigation

8.2.1 Preliminary Survey

A preliminary survey should be carried out whenever a drainage problem is evident. Visual observations of field conditions, location of poorly drained areas, topographic and soil features, land use, etc. should be noted. A local soil survey report should be consulted to estimate the soil characteristics. From these observations, the need for saturated hydraulic conductivity measurements and other data is determined and a preliminary evaluation of the anticipated cost and benefits can be made.

8.2.2 Soil Survey

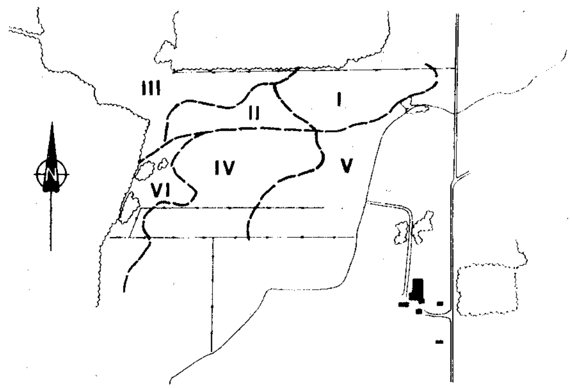
To determine soil characteristics that affect drainage, profile pits should be excavated in a number of locations. These pits are about 0.5 m wide and 1 m deep. An open type Dutch auger can also be used to investigate soil properties and obtain samples to a depth of about 2 m. In well defined uniform deposits of parent materials such as glacial tills where hand augering is difficult to perform, deep boring is not required. The purpose of the pits is to determine the hydrologic properties of the soil from the nature of the exposed soil profile.

The location of profile pits should be carefully chosen so that all features of an area which may have a significant bearing on the layout or construction of a drainage system are known. Some pits will therefore be chosen at the bottom of a depression or at the top of a ridge. The number of profile pits required depends entirely on the variability of the soil, the availability of data and the experience of the investigator. The number of pits should be sufficient to enable the investigator to make a reliable assessment of all pertinent drainage features. Each profile is carefully examined for texture (using the common "hand-feel" method), structure, stones, gravel, hardpan, buried logs or stumps, water table depth, colour (particularly with regard to iron ochre), and any other feature having bearing on the design or construction of the drainage system. The observed features should be noted and recorded on the soil base map using abbreviations or symbols. A soil base map should show land boundaries, roads, creeks and other landscape features. Soil boundaries and profile pits should also be shown. A brief description of the profile pit data and soil survey reports should be included with the soil survey report (see Figure 8.4).

8.2.3 Hydraulic Conductivity

The auger-hole method is a rapid, simple and reliable method for measuring hydraulic conductivity of soil below a water table. A detailed description of its theory and procedures can be found in Van Beers (1958) as well as in Smedema and Rycroft (1983). The general principle is very simple: a hole is bored into the soil to a certain depth below the water table. The water level in the hole is then allowed to rise until equilibrium is reached with the surrounding groundwater. This could take as little as 10 minutes in highly permeable soils or up to a few days in poorly permeable soils. Once equilibrium is reached a portion of the water in the hole is removed.

SOIL MAP



SCALE 1:8,900
LEGEND: SOIL BOUNDARY; FENCE; ROAD; DITCH; UNCLEARED LAND; BUILDING

DESCRIPTION

Soil Type	Depth cm	Description
I	0 - 70	Humified organic material interstratified with thin lenses of mineral sediment (silt loam - clay loam).
	70 - 230+	Mesic to fibric organic material becoming mesic with depth, scattered wood debris.
II	0 - 10	Humified organic material.
	10 - 37	Sandy clay, reddish brown, abundant concretions, in places weak or quasi-cemented.
	37 - 70	Fine sandy clay, abundant concretions distinct mottling and gleying.
	70 - 105+	Stoney, gravelly, sandy clay very firm, strongly gleyed.
III		Not surveyed. Mostly well drained sands and gravelly materials.
IV	0 - 20	Loam - sandy loam, scattered gravels, concretionary, moderately firm.
	20 - 50	Concretionary stoney sandy clay, very firm compact.
V	0 - 30	Loam to fine sandy loam, granular.
	30 - 50	Silt loam to silty clay loam, firm and compact, occasionally weakly cemented.
	50 - 150+	Clay, firm to very firm, strongly mottled, moderately gleyed. Occasional scattered stones.
VI		Similar to type IV soil except for higher degree of poor drainage.

RECOMMENDATIONS

Soil Type	Drain Spacing m.	Drain Depth m.	Remarks
I	10	1.0	Provide controls to prevent excessive decomposition.
II	15	0.80	
III	No drains required		
IV	No drains required	See note.	
V	15	0.80	See note.
VI	-	-	Intercept runoff along N. Boundary (see note).

NOTE:
Water accumulation in the soil occurs mainly due to a combination of poor outlet conditions and dense, impermeable subsoil at shallow depth.
Improvement of the creek level and construction of the drains in adjacent low areas will provide basic discharge and conveyance facilities. However, much of the problem is related to poor structural conditions of the soil itself. Without improvement to the soil, through subsoiling and other cultural practices, the effectiveness of a drainage system is limited. Recognition of the limitations of drainage and the need for special Soil Management Inputs is essential.
Water problems of Soil VI and II are primarily related to seepage from the north and should be alleviated with an appropriated interceptor along the north boundary. However, here also some of the problems are related to adverse soil conditions which depend on soil management for improvement.

DRAINAGE SURVEY REPORT	SURVEY: M. Oriehuyzen & O. Pedersen REPORT	NAME & ADDRESS EXAMPLE DRAINAGE PLAN NO. 100.448
PROVINCE OF BRITISH COLUMBIA SOILS BRANCH MINISTRY OF AGRICULTURE AND FOOD	PHOTO NO 7761:258 REPORT NO 82-08-13	

Figure 8.4 Sample Drainage Soil Survey Report

Water then seeps into the hole from the surrounding groundwater to recreate equilibrium. The rate at which the water rises in the hole is measured and then used in a suitable formula to approximate the hydraulic conductivity of the soil. This method is only suitable to measure the hydraulic conductivity below the water table hence, **the measurements must be done for soils that are in a saturated condition.**

For analysis purposes, hydraulic conductivity tests must be grouped with a homogeneous soil group. For a soil group to be considered homogeneous, the measured hydraulic conductivities must meet the following criteria:

- $\sigma Kj < 0.5\overline{K}$
- $0.2\,\overline{K} < Kj < 5\,\overline{K}$

Where:

Kj is the hydraulic conductivity of each test hole
σKj is the standard deviation of K values
$\overline{K}$ is the average of K values

When the soil profile is homogeneous over the first meter of depth, 40% of the test must be performed in the first meter and the remaining 60% in the layers below drain depth. The minimum number of tests required for a preliminary survey are shown in Table 8.8. Select a suitable site for the hole, avoiding high or low spots, and areas close to a ditch or a roadway.

The measuring equipment consists of the following:

- A tube, about 60 cm long, the bottom end of which is fitted with a clack valve so that it can be used as a bailer. Provisions should be made for extension pieces that can be screwed to the top end of the tube for deeper holes.
- Light-weight steel measuring tape with a float fastened to the end of it.
- A standard which is used to get water level readings at a fixed height above the soil surface. The standard should be pressed into the soil up to a certain mark, and the tape fastened to it for readings (see Figure 8.5).
- Open type Dutch soil auger (See Figure 8.10).

Table 8.8 Number of Hydraulic Conductivity Tests Required

Area (ha)	Number of Tests
0 < Area ≤ 20	3 for the first 5 ha and 1 for each additional 5 ha
20 < Area ≤ 100	6 for the first 20 ha and 1 for each additional 6 ha
over 100	15 for the first 100 ha and 1 for each additional 15 ha

Procedure

- Using an **open blade soil auger** dig the hole. The auger should always be perpendicular to the soil surface. Empty the auger when it is filled, observe the soil texture, structure, colour and other properties, and record it along with the depth. If a relatively homogeneous soil profile consists of two layers of different hydraulic conductivity, K_1 in the upper layer and K_2 in the lower layer, the values for the separate layers can be determined if the water table is well within the upper layer. Two successive measurements must be made in one hole, the second measurement being taken after the original hole has been deepened. A hole is bored to at least 40 cm below water table, but should not extend further than 20 cm above the lower layer. The deepened bore hole for determining K_2 must reach at least 50 cm into the lower layer. The measurement in the shallow hole gives K_1, the hydraulic conductivity of the upper layer, in the same way as for the one layer (homogeneous) soil. For non homogeneous layered soil, dig two auger holes of different depth to obtain an estimate of the conductivity of each layer.

- Allow the water level in the hole to reach an equilibrium with the surrounding water table to the soil.

- Install a standard near the hole. All measurements are made from the standard, as shown in Figures 8.5 or 8.6.

- Record the depth of the water table (W') and the depth of the hole (D') (see Figure 8.7). The water table must be at least 20 cm from the soil surface. A minimum of 40 cm of water in the hole is also required.

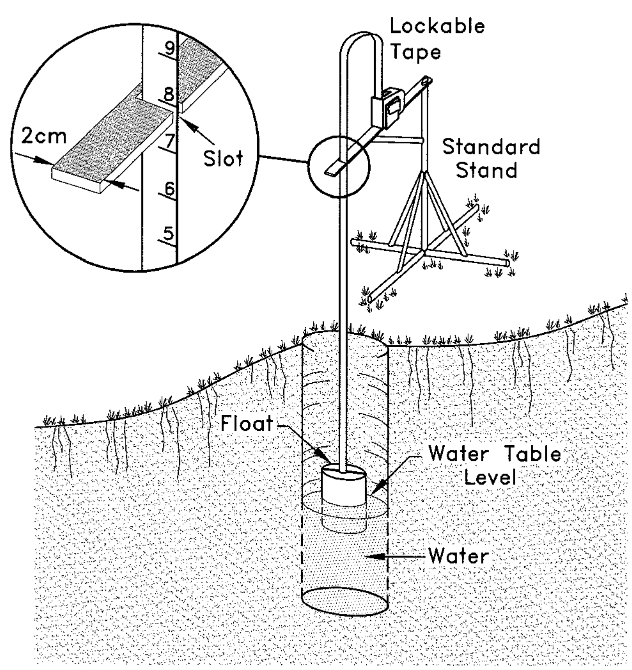


Figure 8.5 Auger-Hole Method for Measuring Hydraulic Conductivity

- Remove the water from the hole as quickly as possible after equilibrium is reached using a bailer. In highly permeable soils the water level in the hole should be lowered by 40 cm. In soils, of low conductivity, 80 cm of water should be removed. In sandy soils where caving in is often a problem, the use of a filter casing is required.

- Using the measuring unit (standard, float, and lockable measuring tape), record the rise of the water in the hole at constant intervals by taking the reading off the measuring tape at the bar level on the standard (see Figure 8.6). Take at least 5 readings to obtain a good average. The intervals can be between 5 seconds and 1 minute depending on the conductivity. **To avoid significant errors due to the water table forming a cone depression around the hole, measurements should be completed before 25% of the water initially removed has been replaced** ($\Delta h \leq 0.25\ h_{(T)}$). Consequently, the time interval readings will be 1/5 of the time it takes 25% of original water to be replaced.

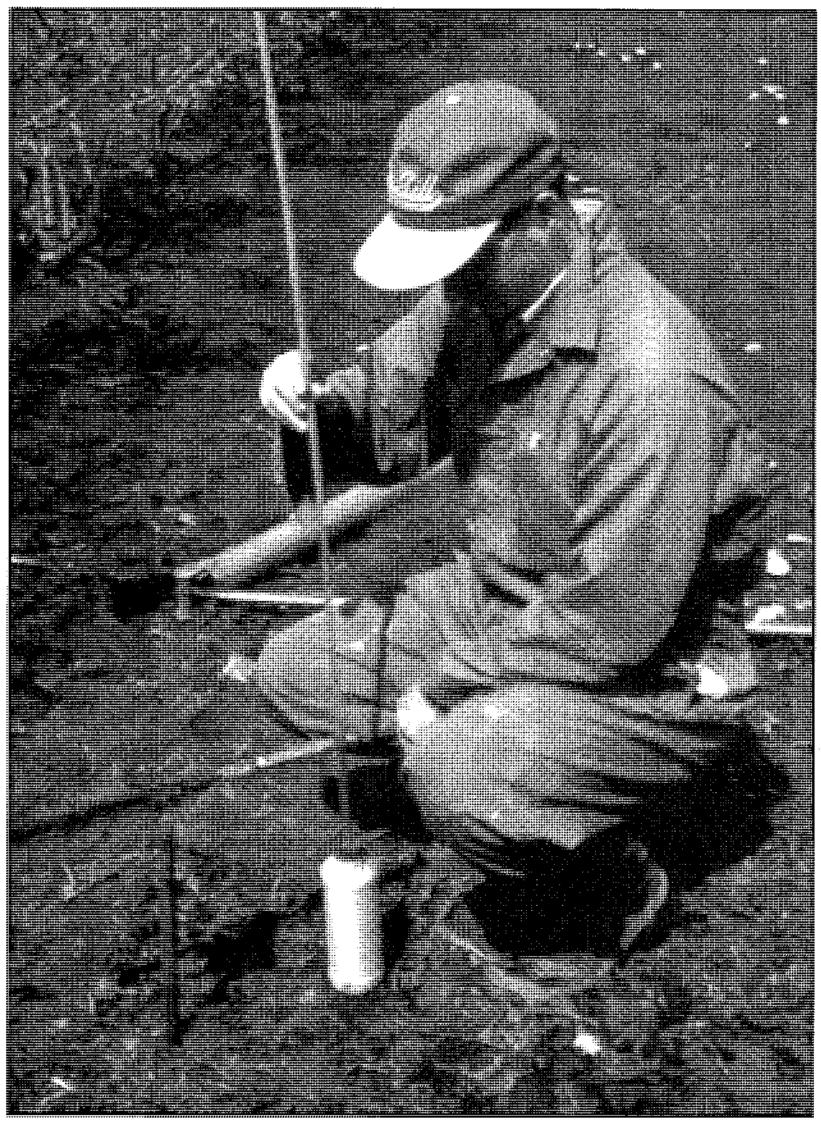


Figure 8.6 Measuring Hydraulic Conductivity

- Using the measured readings calculate hydraulic conductivity from the following equation:

$$K = C \frac{\Delta h}{\Delta t} \qquad \textbf{(EQ. 8.5)}$$

where K = hydraulic conductivity, m/day
C = geometry factor = f(h, H, r, s)
(See Figures 8.8 and Figure 8.9)
$\frac{\Delta h}{\Delta t}$ = rate of rise of water level in the auger hole, cm/s

The hydraulic conductivity for the lower layer in a two layered soil can be computed from the following equation:

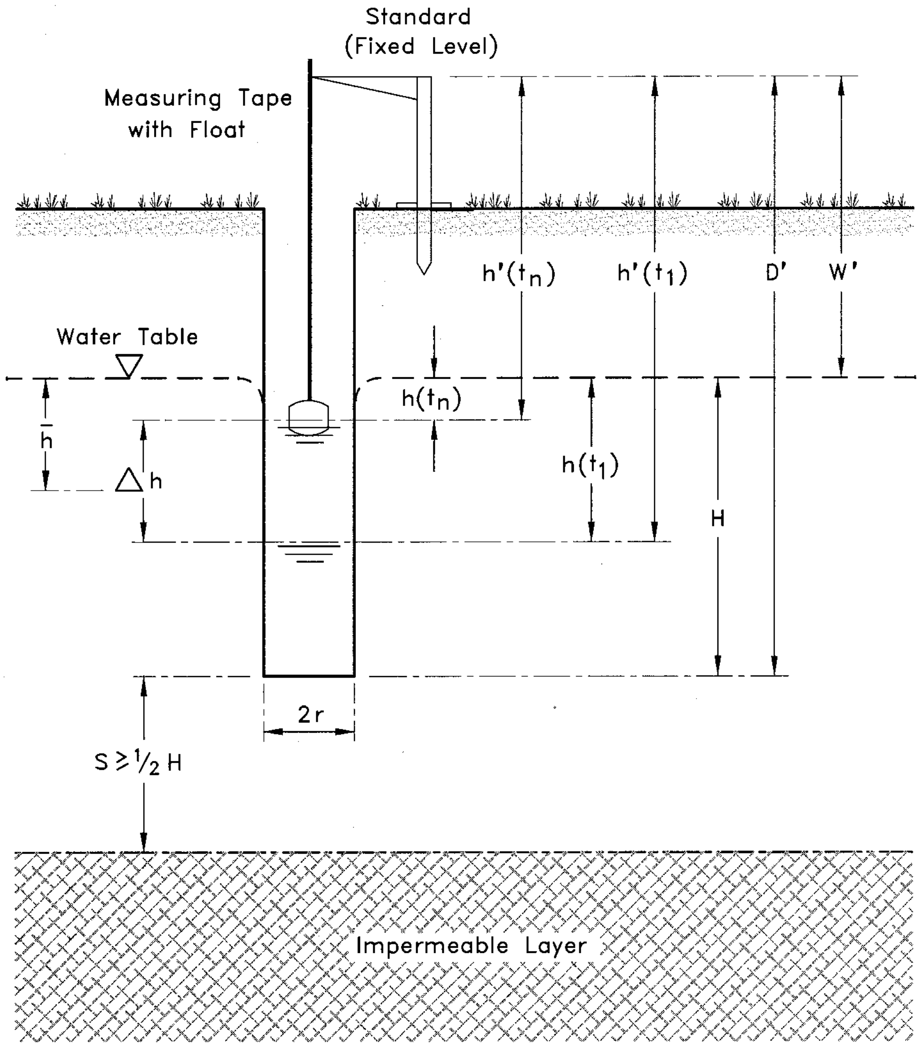
$$K_2 = \frac{C_0\left(\frac{\Delta h}{\Delta t}\right)_2 - K_1}{\frac{C_0}{C_2} - 1} \qquad \textbf{(EQ 8.6)}$$

where K_1 = is hydraulic conductivity of first layer, m/day
K_2 = is hydraulic conductivity of second layer, m/day

$\left(\frac{\Delta h}{\Delta t}\right)_2$ = rate of rise of water level in the deepened hole, cm/s

C_o = $f(h_2, H_o, r, S_1 = O)$
(See Figure 8.8)
C_2 = $f(h_2, H_2, r, S_2 > 1/2\ H_2)$
(See Figure 8.9)

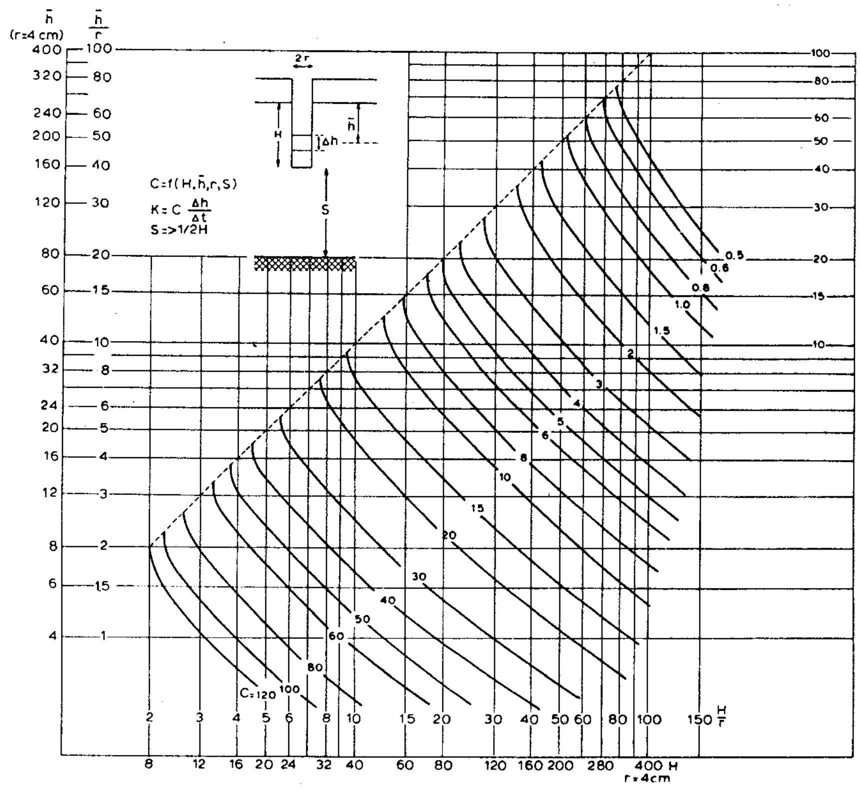
Sample calculations are shown for one layer and two layered soils in Examples 8.3 and 8.4.



where

D'	=	depth of the auger hole below level of the standard, cm
W'	=	depth of the water table below level of the standard, cm
H	=	$D'-W'$ = depth of the auger hole below water table, cm
$h'(T_1)$ $h'(T_n)$	=	depth of the water table in the hole below standard level at the time of the first reading (T_1) and after some readings (T_n) Usually about 5 readings are taken, cm
Δh	=	$h'(T_1)-h'(T_n) = h(T_1)-h(T_n) =$ the rise of water level in the hole during the time of measurements, cm
$\bar{h}$	=	$h(T_1)-\frac{1}{2}\Delta h$ = average head during the time of measurements, cm
s	=	depth of impervious layer below the bottom of the hole, cm
r	=	radius of the hole, cm

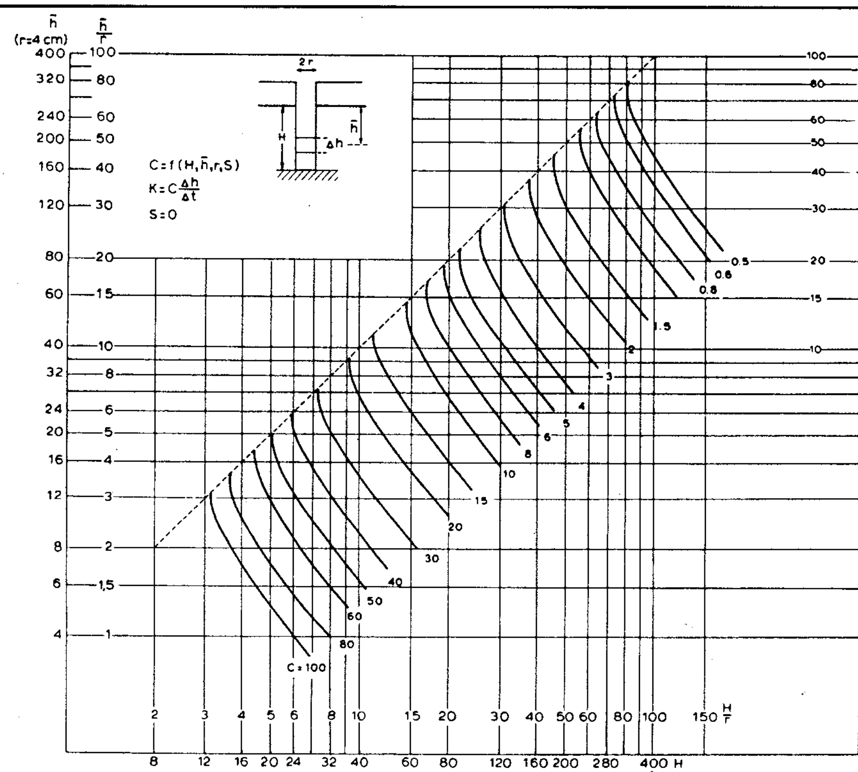
Figure 8.7 Auger Hole Method Variables



"C" is given as a function of $\frac{\bar{h}}{r}$ and $\frac{H}{r}$ when $S > ½ H$

(From ILRI, Pub. 16 VOL III)

Figure 8.8 Nomograph for Determination of C in Auger Hole Method



"C" is given as a function of $\frac{\bar{h}}{r}$ and $\frac{H}{r}$ when $S = 0$

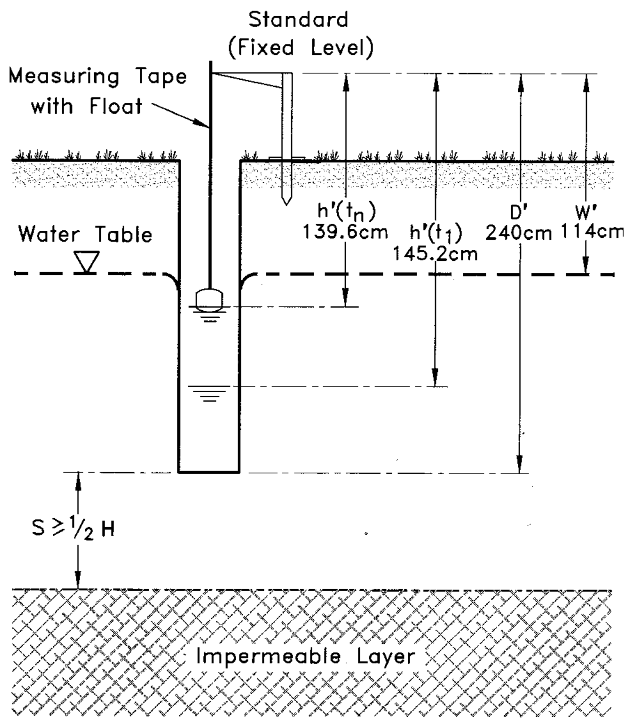
(From ILRI, Pub. 16 VOL III)

Figure 8.9 Nomograph for Determination of C in Auger Hole Method

Example 8.3 Hydraulic Conductivity – 1 Layer Soil

Calculate hydraulic conductivity using data collected in the following figure:

1. **A hole is augered out** and left until the water level in the hole is level with the water table. A standard is installed near the hole.



2. **W′, D′, r are measured**

   $D' = 240$ cm
   $W' = 114$ cm
   $r = 4$ cm
   $S \geq \frac{1}{2} H$

3. **Calculate H**

   $H = D' - W' = 126$ cm

4. **Water is removed from the hole** using a bailer, a float is inserted and the following measurements are taken every 10 sec:

i	T_i	$h'(T_n)$	Δh
observation	second	cm	cm
1	0	145.2	-
2	10	144.0	1.2
3	20	142.8	1.2
4	30	141.7	1.1
5	40	140.6	1.1
6	50	139.6	1.0

$\Delta T = 50$ sec $\quad \Delta h = 5.6$ cm

(Continued next page)

Example 8.3 Hydraulic Conductivity 1 Layer Soil *(Continued from previous page)*

$h(T_1) = h'(T_1) - w' = 145.2 - 114 = 31.2$ cm

measurements should be compiled before 25% of the water initially removed has been replaced.

check $\Delta h < \frac{1}{4} h (Tn)$

$5.6 < 25\%$ of 31.2 ✔

5. **Find C from Figure 8.8 or 8.9. Only measurements before $\Delta h = 7.8$ cm should be considered.**

   $\bar{h} = h(T_1) - \frac{1}{2}\Delta h$

   $h = 31.2 - \frac{1}{2}(5.6) = 28.4$ cm

   $\frac{H}{r} = \frac{126 \text{ cm}}{4 \text{ cm}} = 31.5$

   $\frac{h}{r} = \frac{28.4 \text{ cm}}{4 \text{ cm}} = 7.1$

   From Figure 8.8 since $S \geq \frac{1}{2} H$

   $C = 6.0$

6. **Calculate K using Equation 8.5**

   $K = C\frac{\Delta h}{\Delta T} = 6.0 \frac{(5.6)}{(50)} = 0.67$ m/day

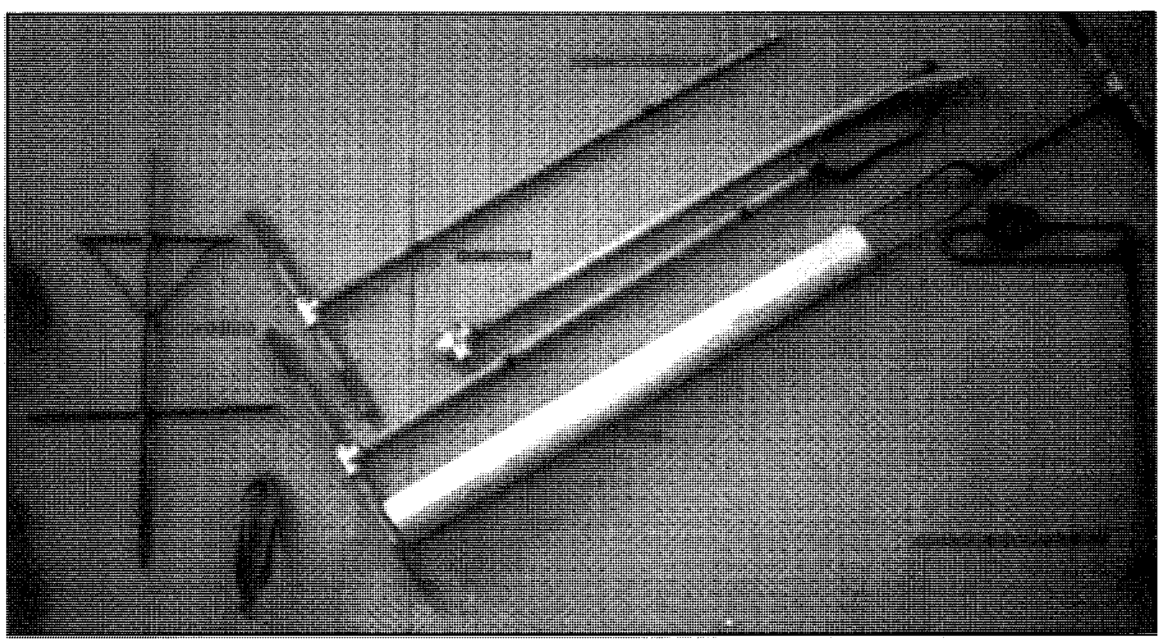


Figure 8.10 Auger Hole Equipment

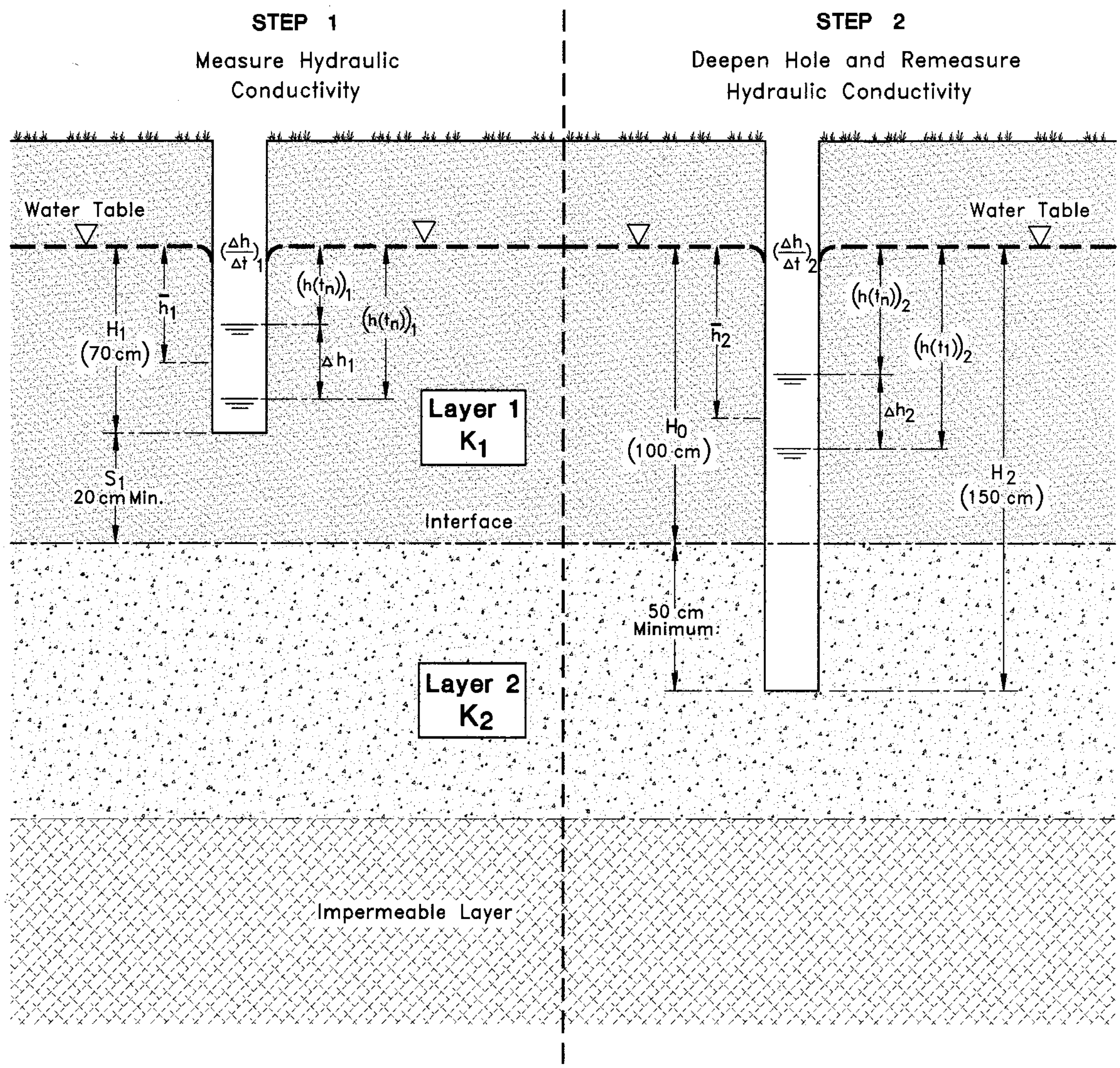
Example 8.4 Hydraulic Conductivity – 2 Layer Soil

Calculate hydraulic conductivity for a two layered soil using data collected in the following figure:

1. **A hole is bored** to at least 40 cm below the water table, but should not extend further than 20 cm above the interface layer.

2. **The hydraulic conductivity is calculated** for the first layer as in example 8.3.

   Assume K_1 is found to be 1.5 m/day.



(Continued next page)

Example 8.4 Hydraulic Conductivity 2 Layer Soil

(Continued from previous page)

3. **Next the hole is deepened** to reach at least 50 cm into the second layer. Make sure to note the depth of the interface layer.

   Measure H_2 $\quad H_2 = D_2' - W_2' = 150$ cm

4. **Water is again removed from hole** using a bailer and measurements are taken as in #4 of Example 8.3.

   Assume this yields $\frac{\Delta h_2}{\Delta T_2} = 0.26$

   $\bar{h}_2 = 40$ cm
   $H_2 = 150$ cm

5. **From Figure 8.8** $\quad$ **(S_2 > 1/2 H)**

   $C_2 = 3.9$

6. **Calculate H_o**

   $H_o = 100$ cm
   $h_2 = 40$ cm
   $S_1 = o$

7. **From Figure 8.9**

   $C_o = 6.3$

8. **Calculate K_2 using Equation 8.6**

$$K_2 = \frac{C_0\left(\frac{\Delta h}{\Delta t}\right)_2 - K_1}{\frac{C_0}{C_2} - 1}$$

$$K_2 = \frac{6.3\ (0.26) - 1.5}{\frac{6.3}{3.9} - 1} = 0.22 \text{ m/day}$$

8.3 Topographic Survey

Topographic surveys are required for the design of both surface and subsurface drainage systems. The purpose of the survey is to develop a topographic map showing important elevations and key physical features of the property. Used in conjunction with the soil survey, it enables the designer to layout the system and provide the necessary construction details. Various types of field survey methods are used depending on the equipment available, the surveyor's preference, and the detail required. Stadia-level or transit surveys are commonly used.

8.3.1 Preliminary Assessment

As a first step, obtain existing maps for the problem area. Air photos are often very useful in preliminary assessments of the problem and to plan a survey strategy. They could also be used for properties involving substantial areas of land development (e.g. land clearing and reclamation) or drainage of irregularly shaped fields, as background for plotting the survey and layout data.

Maps and air photos are readily available for most areas of B.C. Air photo enlargements are also available. Air photos and maps for a particular piece of property can be obtained from:

Ministry of Environment, Lands and Parks
MAPS B.C., Geographic Data B.C.
3rd Floor, 1802 Douglas Street,
Victoria, B.C., V8V 1X4
Phone (250) 387-1441, Fax (250) 387-3022
Internet: http://www.env.gov.bc.ca

Government Agent Offices across the province have microfiches showing flight lines of available aerial photography.

8.3.2 Topographic Survey

Before beginning the survey, the crew should walk the property with the farmer with airphotos or maps in hand. The farmer or landowner will often have had years of experience to relate to the drainage problem. Discuss the normal and high water levels in the adjacent ditches, streams and poorly drained areas. Locate existing and potential outlets, the property boundaries, all problem areas, and any other important topographic features that should be included in the survey.

Suggested topographic survey procedure is as follows:

1. Start the survey from an existing permanent geodetic bench mark, if located within a reasonable distance. This is **NOT** important if the survey will not be related to topograph of other areas not adjacent to the field. The location of these bench marks can usually be found by contacting the local Highways office or from :

Ministry of Environment, Lands and Parks
Resource Mapping Branch
Geodetic Reference System Unit, Data Services
4th Floor, 1802 Douglas Street,
Victoria, B.C., V8V 1X4
Phone (250) 387-3164, Fax (604) 387-7831
Internet: http://www.env.gov.bc.ca

2. Mark a **permanent** bench mark on the most stable, describable item around, usually a concrete footing of an existing building or a nail in a large tree. Make a detailed note and description of the location of this bench mark.

3. Survey the farm on an approximate grid of 30 m x 30 m. On level or uniform topography this grid may be increased. On hilly or irregular fields the grid spacing should be reduced. Spot readings of erratic features must be taken as well. The field data should be sufficient to provide an accurately contoured topographic map. Contours at 0.5 m intervals are common, with 0.25 m intervals used on level sites.

4. During the survey, record the following:

    - Elevations and locations of ditch bottoms and banks at regular intervals. These will be required to design drain outlet plans. Sufficient data should be taken to plot an accurate ditch profile. Ditch water levels should be taken while surveying the ditch bottom. Existing culvert diameters, invert elevations and conditions should be noted.

    - Field and property boundaries (i.e. fences, etc.).

    - Existing buildings, trees, rock out croppings, power poles and other obstacles.

5. Establish temporary bench marks throughout the farm in locations convenient for construction.

6. Close the survey by taking a reading back to the permanent farm bench mark. Although a high level of horizontal accuracy is not usually required, good vertical accuracy is required because of the low grades in agricultural land drainage.

8.3.3 Base Map and Drainage Plan

Complete the survey calculations in the field book, checking each calculation of elevation. Plot the data to suit the topography and the size of the drafting paper. Use a standard scale such as 1:1000, 1:1500, 1:2000 or 1:5000.

Draw the topographic contour lines, ditches and other relevant information. Contours should be drawn lightly so that the drainage design can be super imposed onto the topographic base map.

A drainage plan is essential for the installation of a drainage system and equally important for future maintenance purposes. In producing a drainage plan, the following standards are recommended:

- Use a plan scale of 1:1000 or 1:2000 (i.e. 1 mm on paper equals 2 m in the field) or other suitable scale based on data obtained in the field.
- Show bench marks and give their descriptions and locations.
- Use 0.5 m contour lines or 0.25 m contour lines on very level fields and include numerous spot elevations for the field and ditches.
- Locate ditches, drains, culverts, miscellaneous structures and appropriate landmarks on the drawing.
- Show the invert elevation and size of culverts and other structures which could restrict water movement.
- Indicate the sizes, grades, lengths and control elevations of drains plus the locations of changing grades and sizes of drains.
- Provide various cross sections and complete profiles of new and existing outlet ditches.
- Show the maximum, minimum and normal water levels of the outlets (i.e. ditch water level fluctuations).
- Provide a clear legend of all the symbols used.
- Include a north arrow and suitable geographic landmarks (i.e. major roads, rivers, and all utility lines, special caution may be required for underground services.
- Supply a table of the total length of drains and their sizes.
- Provide special notes and recommendations (if any) for the system designed.
- Provide a map of the soil boundaries with a description and recommendations.
- Indicate pump location and provide information on size, capacity, and power location.

A sample soil map is shown in Figure 8.4. A properly prepared drainage plan is shown in Figure 8.11.

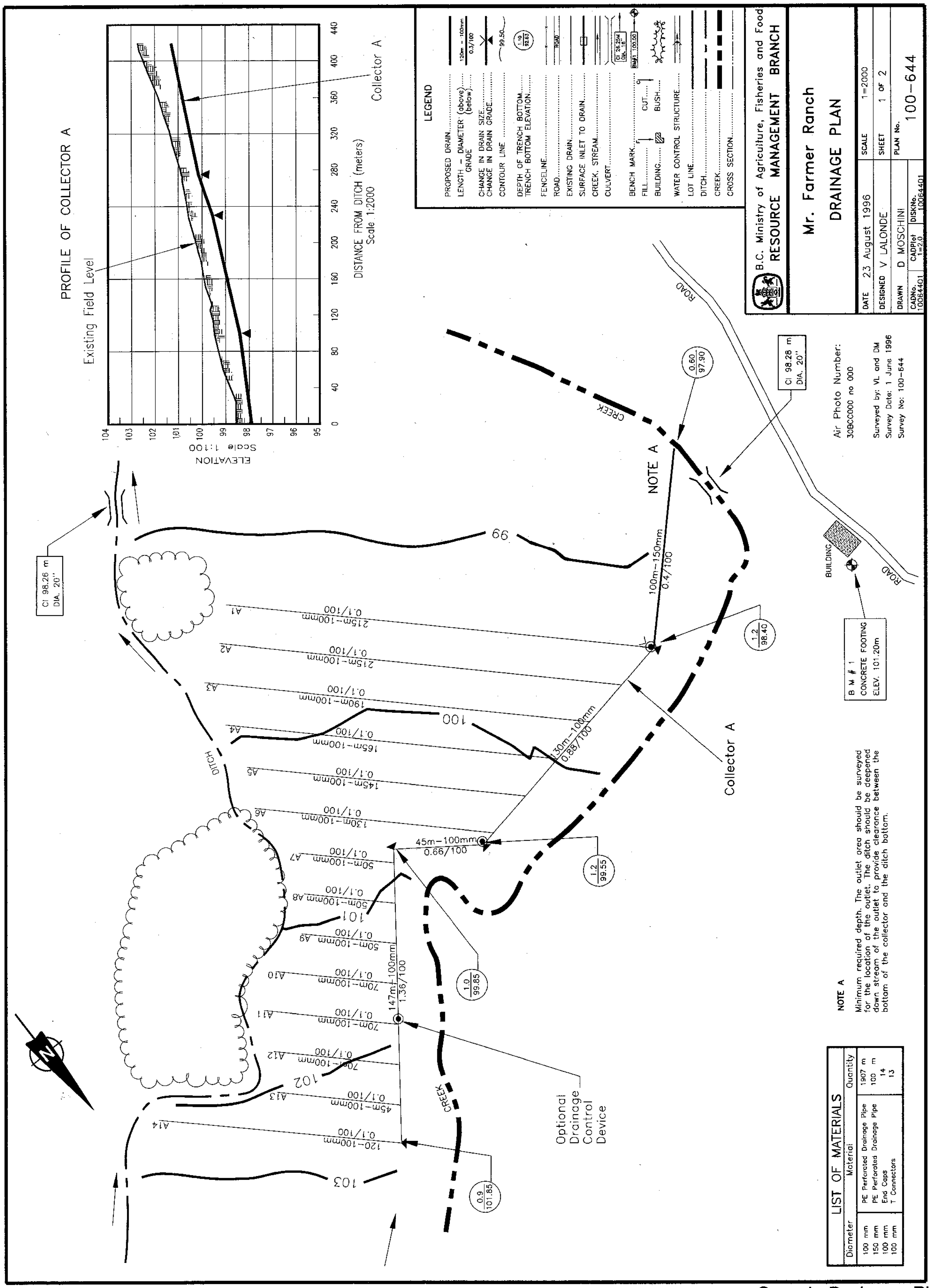


Figure 8.11 Sample Drainage Plan

8.4 Fisheries and Environmental Requirements

When planning to correct drainage problems on farmland, be aware that improvements may affect existing fisheries or water resources.

Before undertaking drainage improvements, approval must be obtained from the Water Management Branch of the B.C. Ministry of Environment, Lands and Parks. This ensures that planned improvements have considered the management and preservation of water and fisheries resources.

Usually a permit is not required to install subsurface drainage outlets unless modification of, or work in a stream, is required. (see Section 10.10.1). If the intention is to alter or maintain a stream to protect property, or to facilitate the reclamation, drainage or other improvements of land, permits are required from the Water Management Branch of the B.C. Ministry of Environment, Lands and Parks. Permits are issued under the Water Act. Annual improvements require a "land improvement license" whereas one-time improvements require an "approval".

Canada's Fisheries Act requires that any activity that may harmfully alter, disrupt or destroy fish habitat in a stream, ditch, diversion or any other water body must receive permission from the Department of Fisheries and Oceans.

Failure to comply with provisions of either of these Acts may result in significant fines and/or imprisonment. Questions regarding provisions of these Acts should be directed to your local office of the B.C. Ministry of Environment, Lands and Parks (MELP) or the Federal Department of Fisheries and Oceans (DFO).

In most cases, an approval will be granted by agencies if a well planned proposal for the development of a drainage system for farmland is provided. If necessary, terms and conditions may be set for the timing of improvements and measures required to reduce harmful effects such as siltation. The approval process may be lengthy, from 3 to 6 months. Due to spawning and rearing cycles of fish, work in and about a stream which could affect the fisheries resources may only be allowed during certain periods. Planning improvement programs at least one year in advance will allow for delays.

The exchange of information and communication among producers, government agencies and the public is important in improving mutual understanding. Open communication is in the best interest of all parties. Examples of good communication include the following:

- Consult the appropriate government agencies before undertaking activities for which the environmental implications are not clear (i.e. drainage outlet to a stream).
- Contact the responsible agencies promptly when accidents or unforeseen environmental impacts occur.