19.3 Design Criteria

19.3.1 Design Water Levels

In designing a drainage canal, an engineer distinguishes two water levels:

- The water level at which the canal embankment is overtopped and the adjacent area is innundated. Whether this water level is exceeded depends upon the design discharge capacity of the canal reach and the related structure (Section 19.3.2);
- The water level that is needed to maintain a sufficiently low watertable during the drainage season. This water level is related to the depth of the watertable that is required to improve crop growth, allow farm machinery to work the land, limit subsidence, prevent salinity, etc. This water level is usually given as a value that, on the average, should not be exceeded during a number of days (say 10) per drainage season. It has a direct impact on the depth, f_n, of a drainage pipe or field ditch (Figure 19.6).

Hence, at 'normal discharge', the water level in the collector drain should be a distance, F_n, below the land surface about 10 days a year. This distance is often called freeboard. The freeboard equals

$$F_n = f_n + Ls/2 + 0.10 \tag{19.1}$$

where

F_n = required freeboard in a collector drain at normal discharge, Q_n, occurring about 10 days a year (m)
f_n = drain depth based on various design criteria (m)
$Ls/2$ = head loss due to the gradient, s, of the field drain over half its length, L, (m)
0.10 = a safety margin in metres that guarantees an undisturbed flow of Q_n most days of the year

To determine the related water levels in the drainage canals, one must have a good contour map of the area. The scale of this map should be 1:10 000 or larger, and

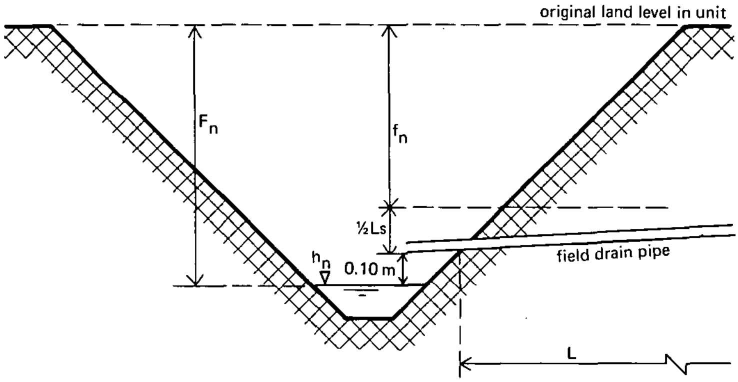


Figure 19.6 Freeboard in a collector drain at 'normal discharge'

the contour interval 0.50 m or less. On this map, 'land and level units' are drawn in which less than 10 per cent of the area is below a certain elevation. As a rule of thumb, the area of 'land level units' is as follows:

- In flat areas: greater than 200 ha, with a level interval of about 0.25 m;
- In sloping areas: greater than 50 ha, with a level interval of 0.50 m or more.

The elevation of each 'land level unit' should be decreased by the required freeboard, F_n, in the local collector drain to find the design water level for Q_n. The resulting water levels now can be written on the topographical map in each 'land level unit'. As mentioned earlier, this level, h_n, will be exceeded about 10 days a year. The h_n levels are used to determine the available hydraulic gradient for canal reaches.

19.3.2 Design Discharge Capacity

A major problem in designing a drainage canal system is determining the discharge capacity which various canal reaches have to handle without overtopping their embankments and innundating the adjacent areas. This is the design discharge for bank-full-flow. It depends on the construction cost of a canal reach and its related structures, and on the damage that will be inflicted if a discharge exceeds the design. These two factors can be combined if we assume that:

1) The probability of a certain discharge being exceeded can be described by a double exponential distribution;
2) Damages occur only if an existing, or studied discharge, capacity is exceeded;
3) If the discharge is exceeded, inundations damage buildings, infrastructures, crops, etc. in the area to be drained;
4) All damages can be repaired within one year.

Enlarging the capacity of the drainage canal system decreases the frequency of damage. But regardless of the planned capacity, there is always the chance that the design discharge will be exceeded and damages incurred. In this context, two questions arise: Is it better to use the existing, or presently studied, discharge capacity for the drainage canal system, or must the capacity be increased? And if it is economically justified to increase the capacity of the system, then by how much? We can answer these questions by applying the following procedure.

Determine the Investment Costs
As illustrated in Figure 19.7, increasing the discharge capacity of a drain requires higher investment costs. The example curve in the figure assumes a linear relationship between investment cost and discharge capacity, which only holds true if the same investment must be made along the entire canal system. In reality, one reach and/or structure of the drainage system may require a higher investment cost than another to increase its capacity. And an initial cost must be made to realize any discharge capacity of a canal.

Determine the Damage due to Inundation
If, for example, the existing or presently studied discharge capacity of a drainage

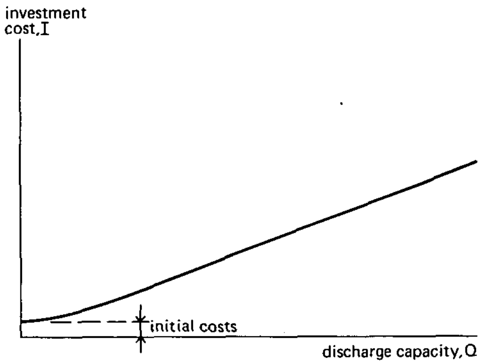


Figure 19.7 Investment cost as a function of canal discharge capacity

system is doubled from a Q_{10}, with a frequency of occurrence once every 10 years, to a Q_{20}, the damage from inundation decreases. To capitalize on the damages that occur if the discharge capacity is exceeded, we assume that they will be covered by a fictitious insurance company. Such a company is necessarily fictitious as there is usually no organization that is willing or able to offer insurance of this type. Damages include: repair or replacement of canals, structures, and pumping stations; loss of productivity of the land; damage to roads, buildings, and so on. The total damage, W, is expressed in monetary terms. Theoretically, the 'insurance company' would need to receive an annual premium equal to the product of the total damage, W, and its frequency of occurrence, F. This annual premium can be paid from the interest on a capital, R, deposited in a bank. The capitalized cost of damage, R, from exceeding a discharge capacity, Q, can be plotted as illustrated in Figure 19.8.

Hence, the total cost of a drainage canal system (and related structures) consists of:

- The construction cost of all canal reaches, related structures, pumping stations, sluices, and so forth;
- The capitalized cost of the 'insurance premium'.

Both costs are a function of the discharge capacity of the drainage system.

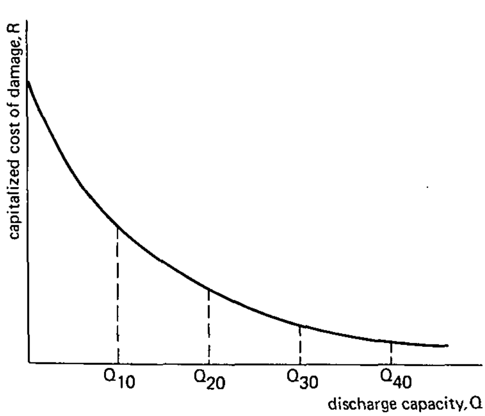


Figure 19.8 Capitalized cost of damage from inundation as a function of drain discharge capacity

The optimum design discharge capacity, Q_d, is obviously that capacity when the total costs, K = I + R, are minimal. Superposing the curves in Figures 19.7 and 19.8, we get the optimum, Q_d, as shown in Figure 19.9. For this optimum discharge capacity, the distance BC is the construction cost, I, and the distance AB the related capitalized cost of damage, R.

The capitalized cost of damage because of inundation of an area is strongly influenced by the land use in that area. For example, if only grassland is being drained damage will be low, but fairly high if there are villages, through roads, and so forth in the drained area. If part of the drained area is rural and another part is urban/industrial, different capitalized costs of damage must be determined for the related parts of the drainage system. Because of this influence of land use on the capitalized cost of damage, and thus on the design discharge, increased economic development in the drained area will call for a related increase of the discharge capacity of the drainage system.

Over the distance OC, the general R-Q curve falls sharply while the I-Q curve rises gradually, so the summarized K-Q curve is steeper to the left of A than to its right. This general shape of the K-Q curve has a significant consequence if the drainage canal system is not constructed to accommodate the optimum design discharge. Whether the actual design discharge is too high (OF) or too low (OF'), the total cost of the system will exceed AC. The difference in cost, either DE or D'E', is named 'regret', i.e. the capital lost because the optimum solution was not constructed. A closer look at Figure 19.9 shows that the regret DE is much smaller than D'E', indicating that it is more economical to 'overdesign' the system. This general rule is amplified as damages in the area increase with time because of future development.

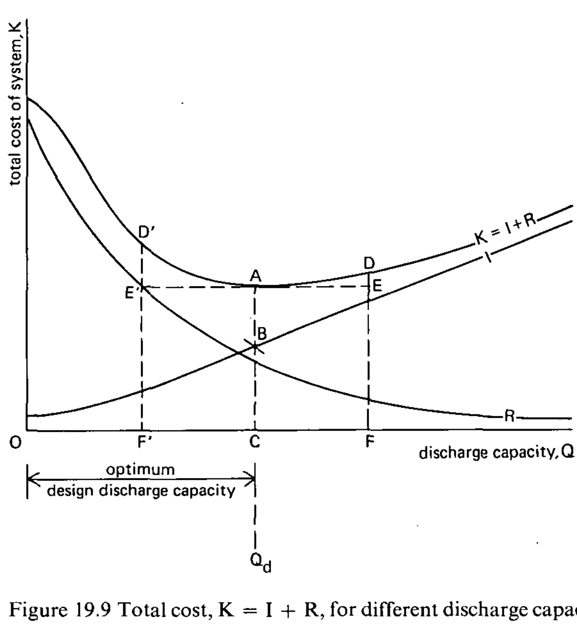


Figure 19.9 Total cost, K = I + R, for different discharge capacities of a drainage canal system

19.3.3 Influence of Storage on the Discharge Capacity

We can determine the available hydraulic gradient of the drainage canals with the procedure described in Section 19.3.1. Parallel to this gradient is a high-water-line related to the optimum design discharge capacity (Section 19.3.2) of the canal system. Above this high-water-line, there is often a natural freeboard in some canal reaches that allows water to be stored. Storage is also possible in small lakes or swamps that do not transport water. While these storage areas are being filled, the flow rate in downstream canal reaches and/or structures is reduced. To justify a reduction, storage capacity must be significant with respect to the volume of incoming flow and stored water must be discharged rapidly after a high water peak passed so that the storage capacity can be used again upon occurrence of the next peak. Suitable storage can be found in small lakes or swamps close to a drainage outlet, sluice, or pumping station, or in well drained permeable soils above design groundwater level. Also temporary inundation of low-lying rice fields, grassland, and so on, is a good method of storage.

To illustrate the impact of storage capacity on the design discharge capacity of a structure or canal reach downstream of this storage, Figure 19.10 gives six drain

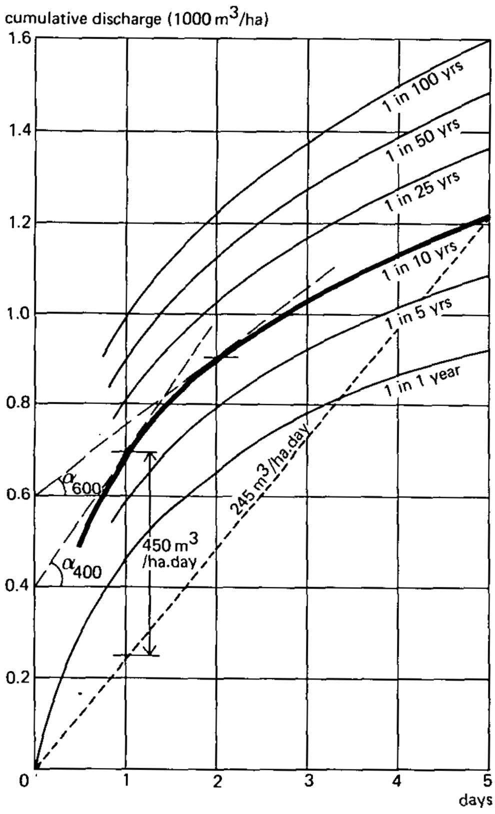


Figure 19.10 Discharge duration curves with varying frequencies of occurrence

discharge duration curves. Such a curve does not represent a 'maximum discharge' but the envelope of maximum discharged volumes (in m^3/ha) for various periods (in days), with a given frequency of occurrence. If we used the procedure in Section 19.3.2 to find an optimum design discharge with a frequency of occurrence of, say, once every 10 years, we can obtain the following information from Figure 19.10:

- If there is no significant storage capacity in the drainage system it must discharge over 700 m^3/d per ha in the first day;
- If there is an average storage capacity of 400 m^3/ha, the required discharge capacity for drains and structures equals the tangent of α_{400}, which is 300 m^3/d per ha. The storage capacity thus considerably reduces the required discharge capacity;
- More storage capacity, say 600 m^3/ha, would reduce the discharge capacity to a low figure of tan α_{600} = 150 m^3/d per ha. A serious disadvantage of such a low discharge capacity is that the storage cannot be emptied 'rapidly'. In this context, the term 'rapidly' generally means that the cumulative discharge of 5 days must be carried away in 5 days. In Figure 19.10, this rule of thumb would lead to a minimum discharge capacity of 245 m^3/d per ha, which would require an average storage capacity of 450 m^3/ha. If this storage capacity is not feasible, the discharge capacity must be correspondingly higher.

19.3.4 Suitability of Soil Material in Designing Canals

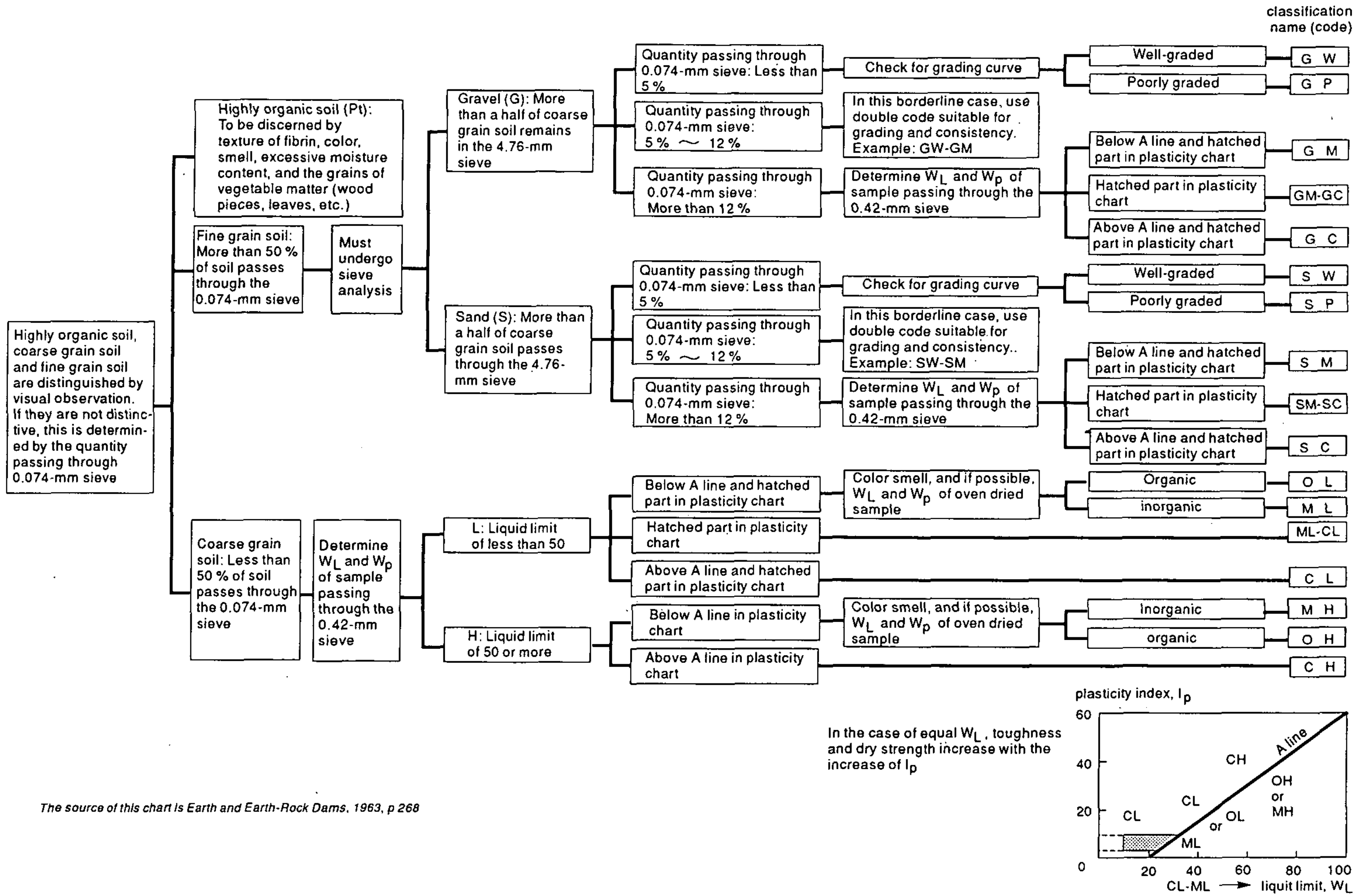
Unified Soil Classification System

To classify soil material as to its suitability in constructing canals, I advise using the 'Unified Soil Classification System', as adapted in 1952 by the U.S. Bureau of Reclamation and the U.S. Army Corps of Engineers. The laboratory work for the identification procedures of this classification system is given in Figure 19.11. In classifying soils, we must realize that with soils consisting largely of fine grains the amount of water present in the voids has a pronounced effect on the soil properties. Three main states of soil consistency are recognizable:

- The liquid state, in which the soil is either in suspension or behaves like a viscous fluid;
- The plastic state, in which the soil can be rapidly deformed or molded without rebounding elastically, changing volume, cracking, or crumbling;
- The solid state, in which the soil will crack when deformed or will exhibit elastic rebound.

When describing these states, we customarily consider only that fraction of the soil that is finer than the 0.4 mm sieve size (the upper limit of the fine sand component). For this fraction, the water content, expressed as a percent of dry mass, at which the soil passes from the liquid state into the plastic state is called the liquid limit, w_L. Similarly, the water content at which the soil passes from the plastic state to the solid state (or semi-solid state) is called the plastic limit, w_p. The difference between the liquid limit and the plastic limit corresponds to the range of the water content within which the soil remains plastic. This range is called the plasticity index, PI. Highly plastic soils have high PI values. In a non-plastic soil, the plastic limit and the liquid limit are the same, and the PI equals 0. These limits of consistency are called 'Atterberg limits', after a Swedish soil scientist.

LABORATORY WORK FOR UNIFIED SOIL CLASSIFICATION



The source of this chart Is Earth and Earth-Rock Dams, 1963, p 268

Figure 19.11 Laboratory work for Unified Soil Classification

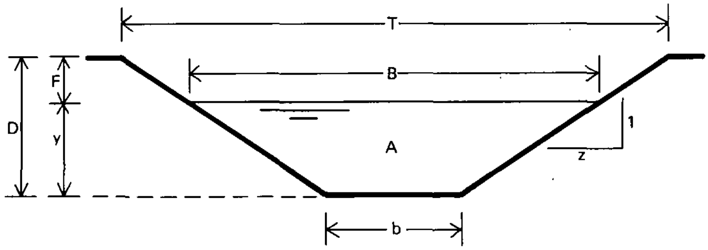


Figure 19.12 Terminology

Side Slope of the Canal

For an earthen canal, a designer usually assumes a trapezoidal cross-section (Figure 19.12). He makes the side slopes as steep as possible to limit excavation and expropriation costs. Side slopes depend on factors such as the soil in which the canal is excavated, canal depth, groundwater flow into the canal, surcharge onto the bank, and so on.

As mentioned earlier, canal depth influences the side slopes. A stable side slope must be flatter as canal depth increases. Table 19.2 gives minimum recommended side slopes (excluding rock). Depending on the soil in which the canal is planned to be excavated, the side slope may be flatter than those shown in Table 19.2.

Table 19.3 lists minimum side slope ratios (z = horz/vert) for canals in different soils. Use flatter side slopes if groundwater seeps through the canal banks or if a public road runs along the canal.

A designer usually determines the side slopes not on the basis of extensive studies

Photo 19.2 Localized failure of a side slope upon construction (Courtesy, L. Molenaar)

Table 19.2 Minimum side slope ratios for various depths of earthen canals

Canal depth, D	Minumum side slope ratio, z = horz./vert.
D ≤ 1 m	1.0
1 < D < 2	1.5
D ≥ 2 m	2.0

of soil mechanics, but on the interpretation of soil samples taken along the center line of the planned canal. For a given canal reach, he selects one side slope which, upon construction, may prove to be too steep for a short length of canal (see Photo 19.2). To correct such localized failures, newly constructed systems must be reconstructed after the first drainage season.

Table 19.3 Minimum side slopes for earthen canals in different soil materials

Group symbol	Typical names		Minimum side slope ratio (horz./vert.)
Rk	Rock		0.25
GW	Well-graded gravels, gravel-sand mixtures, little or no fines		2.5
GP	Poorly graded gravels, gravel-sand mixtures, little or no fines		2.5
GM	Silty gravels, poorly graded gravel-sand-silt mixtures		1.5
GC	Clayey gravels, poorly graded gravel-sand-clay mixtures		1.0
SW	Well-graded sands, gravelly sands, little or no fines		2.5
SP	Poorly graded sands, gravelly sands, little or no fines		2.5
SM	Silty sands, poorly graded sand-silt mixtures		2.0
SC	Clayey sands, poorly graded sand-clay mixtures		2.5
ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity		1.5
CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays		2.0
OL	Organic silts and organic silt-clays of low plasticity		2.0
MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts		3.0
CH	Inorganic clays of high plasticity, fat clays		3.0
OH	Organic clays of medium to high plasticity		3.0
Pt	Peat and other highly organic soils	stiff	1.0
		soft	3.0

classification		water permeability characteristic				compaction characteristic				shearing characteristic				erosion resistance		expansion / shrinkage		freezing		suitability as banking mat.				suitab. foundation mat.			
																				earth lining		canal banking		canal foundation		structure foundation	
code	illustration	order	in time of compaction	coeff. in cm/s	necessity of lining	order	workability	dry density t/m^3	suitable for machine	order	shearing strength	cohesion	angle of internal friction	order	resistivity	order	character	order	character	order	suitability	order	suitability	order	suitability	order	suitability
GW		14	very large	$>10^{-2}$	yes	15	very good	2.0 to 2.1	tractor, rubber tire, vibration	1	very large	small	very large	2	very large	14	hardly any	15	none to very small	-	unsuitable	-	unsuitable	-	low	1	high to low
GP		16	very large	$>10^{-2}$	yes	8	good	1.8 to 2.0	tractor, rubber tire, *vibration*	3	large	small	large	3	very large	16	hardly any	17	none to very small	-	unsuitable	-	unsuitable	-	low	3	highest
GM		12	medium to small	10^{-3} to 10^{-6}	yes to no	12	good	1.9 to 2.1	rubber tire, sheep's foot vibration	7	large	ordinary	large	5	large	12	very small	10	small to ordinary	6	somewhat	5	suitable	3	high	4	high
GC		6	small	10^{-6} to 10^{-8}	no	11	good	1.8 to 2.1	rubber tire, sheep's foot	9	large	ordinary	ordinary	4	large	10	small	11	small to ordinary	2	most suitable	2	most suitable	4	high	6	high
GW-GC		8	small	10^{-5} to 10^{-7}	no	16	good	1.8 to 2.1	rubber tire, sheep's foot	4	large	ordinary	large	1	very large	11	small	12	small to ordinary	1	most suitable	1	most suitable	1	highest	5	high
SW		13	large	$>10^{-3}$	yes	13	very good	1.8 to 2.1	tractor, vibration	2	very large	small	very large	8	ordinary	13	hardly any	14	none to very small	-	unsuitable	9	ordinary, high grade pavement	-	low	2	highest
SP		15	very large	$>10^{-3}$	yes	13	ordinary	1.6 to 1.9	tractor, vibration	6	large	small	large	9	ordinary	15	hardly any	16	*none to* very small	-	unsuitable	9	ordinary, high grade pavement	-	low	7	high
SM		11	medium to large	10^{-3} to 10^{-6}	yes to no	10	ordinary	1.8 to 2.0	rubber tire, sheep's foot vibration	8	large	small	large	10	small	9	very small-ordinary	7	small to large	7	ordinary (erosion limit)	6	suitable	5	high	10	high to low
SC		5	small	10^{-6} to 10^{-8}	no	9	ordinary	1.7 to 2.0	rubber tire, sheep's foot	10	ordinary	ordinary	ordinary	7	ordinary	7	small to ordinary	8	small to large	4	suitable	4	suitable	6	high	9	high to low
SW-SC		7	small	10^{-5} to 10^{-7}	no	14	good	1.7 to 2.1	rubber tire, sheep's foot	5	large	ordinary	large	6	large	8	small to ordinary	9	small to large	3	most suitable	3	most suitable	2	highest	8	high to low
ML		10	medium to small	10^{-3} to 10^{-6}	yes to no	5	*ordinary*	1.5 to 1.9	*rubber tire,* sheep's foot	12	ordinary	small	ordinary	-	very large	6	small to ordinary	1	ordinary to very large	8	ordinary (erosion limit)	8	somewhat suitable	8	high to low	12	high to low
CL		3	small	10^{-6} to 10^{-8}	no	6	ordinary	1.5 to 1.9	rubber tire, sheep's foot	11	ordinary	large	small	11	small	5	ordinary	3	ordinary to large	5	somewhat suitable	7	somewhat suitable	7	high to low	11	high to low
OL		4	medium to small	10^{-4} to 10^{-6}	no	3	bad	1.3 to 1.6	rubber tire, sheep's foot	15	small	unknown	unknown	-	very small	4	ordinary to large	4	ordinary to large	9	ordinary (erosion limit)	12	ordinary	9	high to low	13	low
MH		9	medium to small	10^{-4} to 10^{-6}	no	2	bad	1.1 to 1.5	sheep's foot	14	ordinary to small	large	small	-	very small	3	large	2	ordinary to very large	-	unsuitable	13	ordinary	10	high to low	14	low
CH		1	small	10^{-6} to 10^{-8}	no	4	bad	1.2 *to* 1.7	sheep's foot	13	ordinary to small	large	small	12	small	2	large	5	ordinary	10	unsuitable	11	ordinary	11	high to *low*	15	low
OH		2	small	10^{-6} to 10^{-8}	no	1	bad	1.0 to 1.6	sheep's foot	16	small	unknown	unknown	-	very small	1	large	6	ordinary	-	unsuitable	14	unsuitable	12	high to low	16	low
Pt		-	-	-	-	-	-	-	-	-	small	-	-	-	very *small*	-	very large	13	small	-	unsuitable	banking for surfaced-lined *canal*		-	low	-	low
remarks			order: in order of coefficients of water permeability			order: in order of densities																					

Table 19.4 Suitability of soil material in designing canals (the codes in the first column are explained in Table 19.3)

Suitability of a Soil as Construction Material
Soil classification is a major factor influencing the construction of earthen canals, embankments, and dikes. Table 19.4 lists the suitability of the different soil classes as construction material for canals. Data are included that are not relevant for drainage canals, but as most of this chapter also applies to un-lined irrigation canals, this additional information has been given as well.

19.3.5 Depth of the Canal Versus Width

An important criterion that influences the shape of the canal cross section is the ratio between bottom width, b, and canal depth, D. In selecting the ratio, b/D, we must take the following points into consideration:
1) Cost of construction, including expropriation of land;
2) Methods of maintenance;
3) Permissible fluctuation of the water level and minimum water depth;
4) Available or permissible hydraulic gradient;
5) Function of the canal.

Re 1: The water level in canals that collect water from the adjacent area always lies below the original land surface. As shown in Figure 19.13A, such wide and shallow canals require more excavation and expropriation than deeper canals, where water flows at a similar average velocity.

Conveyance drains that transport flood water through a low-lying area with the water

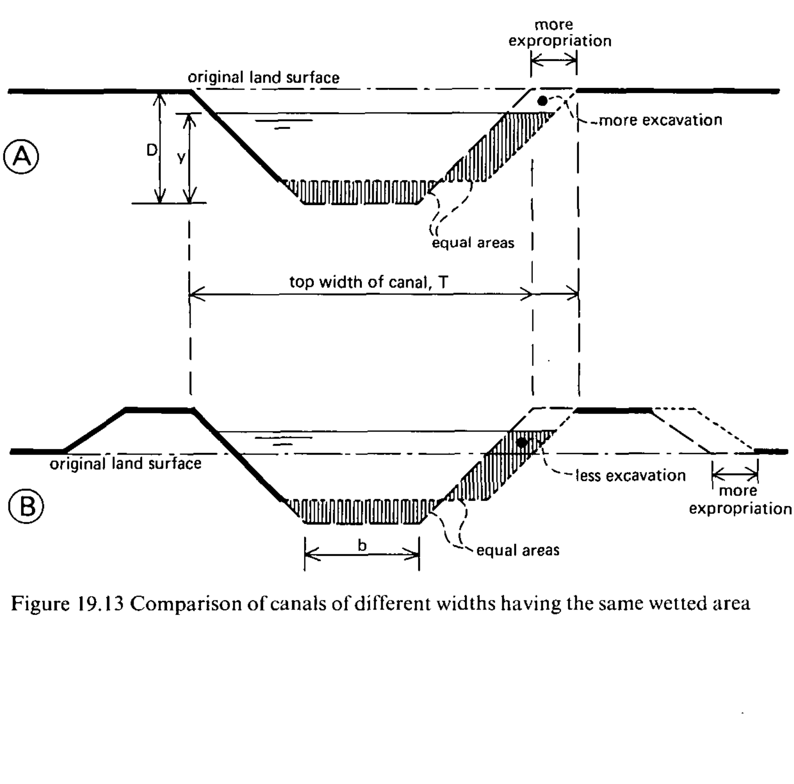


Figure 19.13 Comparison of canals of different widths having the same wetted area

surface above land level (Figure 19.13B) require less excavation if the canals are wide, but more expropriation. If the design water level is at land surface, the excavation of narrow deep canals is equal to that of wide shallow canals, where water flows at the same average velocity. To minimize construction cost, the designer will try to balance excavation and backfill along a canal reach.

Re 2: The method chosen to remove aquatic weeds and silt from a canal to maintain the cross-section and keep the hydraulic resistance (Manning's n-value) below the design value influences the design. Specialized maintenance equipment usually is mounted on a tractor or hydraulic excavator. Figure 19.14 gives an example of how the reach of the equipment influences the top width and depth of a canal. If the permitted depth is exceeded, a berm of sufficient width (> 3.50 m) must be designed to accommodate the machinery. Photo 19.3 gives an example of how a machine can clean an entire canal just by working from the maintenance track on one side. If the top width of the canal were, say, 1 m wider, the machine would have to make a second run through the field on the left, making maintenance almost twice as costly.

Re 3: The water levels of narrow, deep canals fluctuate strongly with different actual flow rates. This fluctuation may damage side slopes if it occurs rapidly and creates a steep watertable gradient. If storage capacity is needed in a drainage system that discharges through a tidal gate or pumping station, wide canals with little fluctuation are advantageous.

Photo 19.3 This machine can clean a drain with this top-width by working from one side only.

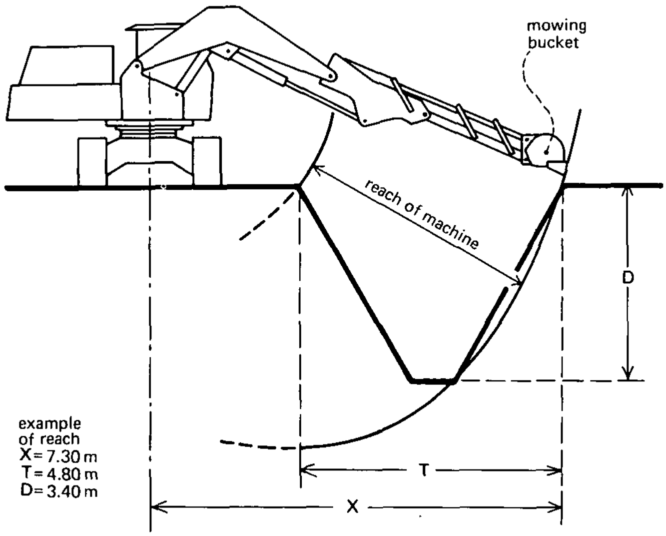


Figure 19.14 Relation between the reach of a machine and the size of canal that can be maintained

Re 4: As a preliminary to Section 19.5, note that we commonly use Manning's equation to calculate the average velocity in canals with uniform flow

$$v = \frac{1}{n} R^{2/3} s^{1/2} \tag{19.2}$$

where

v = average flow velocity (m/s)
n = resistance coefficient (–)
R = hydraulic radius ($R = A/P$) (m)
A = cross-sectional area of flow (m^2)
P = wetted perimeter (m)
s = hydraulic gradient (–)

Many areas to be drained have a rather flat topography so that the hydraulic gradient is limited. Rewriting of Equation 19.2 to

$$s = \frac{v^2 n^2}{R^{4/3}} \tag{19.3}$$

we see that, with a constant value for v, the hydraulic gradient is at a minimum if $R = A/P$ is at a maximum. Hence, the wetted perimeter must be as small as possible. As illustrated in Figure 19.15, this is true if the bottom and side slopes of the canal are tangent to a circle. These requirements indicate rather narrow, deep canals, and hold for concrete lined irrigation canals and small earthen canals. Larger earthen canals usually have a larger b/D ratio.

Re 5: Small-capacity collector drains, as illustrated in Figure 19.6, usually have the smallest practical bottom width of b = 0.50 m. The excavated soil is spread over

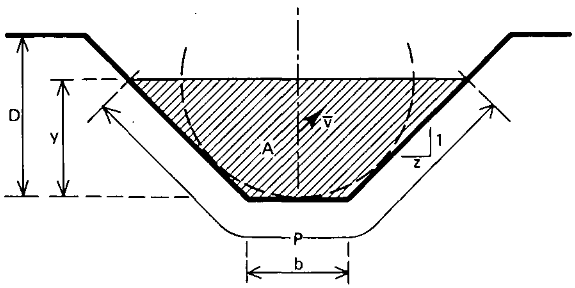


Figure 19.15 Best hydraulic section

the adjacent fields or removed, so that a simple trapezoidal cross section is commonly used for such collector drains.

The large-capacity main drains, or interceptor drains, often have a spoil bank and berms, which are also used as maintenance tracks (Figure 19.16A). Interceptor drains always have an asymmetrical cross section. The uphill side slope is relatively flat. On the downhill side of the drain there is a maintenance berm and spoil bank (Figure 19.16B).

From the above, it will be clear that it is not practical to give simple design criteria for a b/D ratio. The matter becomes even more complicated if the canal is excavated in a layered soil, or if it is used for navigation, dry season irrigation, and so forth. To minimize the cost of excavation, land expropriation, and maintenance, modern earthern canals tend to be as narrow as possible. In practice, however, it is recommended to exceed the b/D ratios given in Figure 19.17.

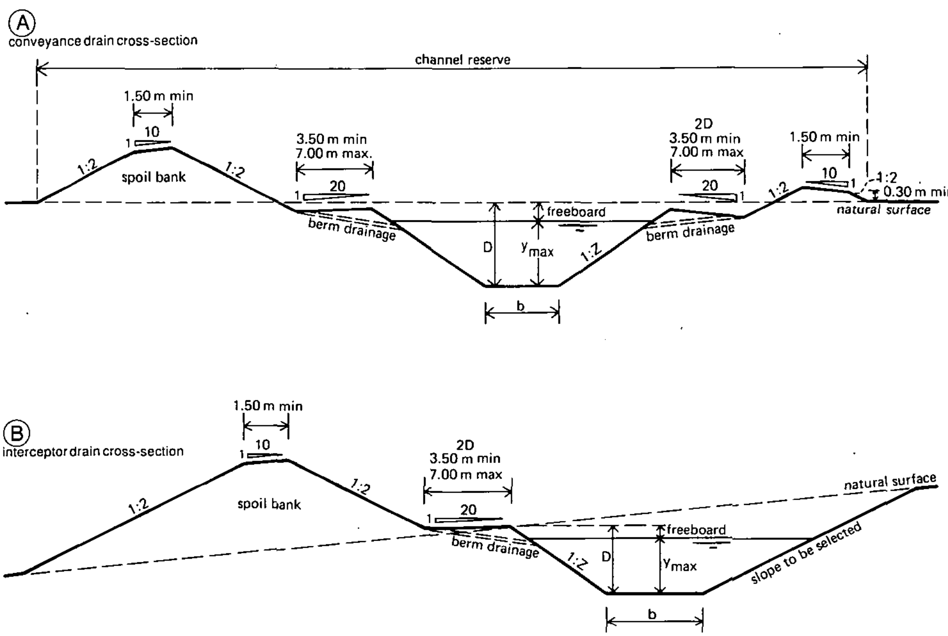


Figure 19.16 Examples of cross sections over drains

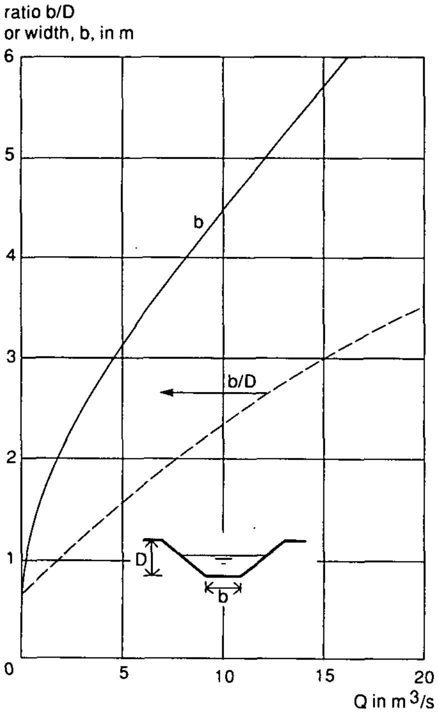


Figure 19.17 Minimum recommended values for earthen canal dimensions (after Bos, Replogle, and Clemmens 1984)

19.3.6 Canal Curvature

The alignment of a drainage canal consists of straight and curved reaches. The radius of curvature at changes of alignment is a function of the canal capacity as shown in Table 19.5. If the required radius cannot be achieved, it can be reduced to as low as 3 times the canal's bottom width, if lining for the outer curve or the entire canal is installed (Photo 19.4). This minimized radius, however, should be adopted only in exceptional circumstances.

Table 19.5 Radius of curvature of earthen canals

Canal capacity in m^3/s	Minimum radius*
up to 5	3 × bottom width (5 m min)
5 to 7.5	4
7.5 to 10	5
10 to 15	6
15 and over	7

* Round up to next highest metre

Photo 19.4 Local failure of side slope upon construction (courtesy, L Molenaar).

19.3.7 Canal Profiles

Following the field check of the canal center line on the photo mosaic, the selection of the alignment should be based on all the cross sections, and geologic and environmental data.

In addition to the survey data collected and mapped, the following design data should be included in the report on the drainage system:

1) Profiles of canals, showing alignment with bearings or an azimuth for each tangent. Length of canal reaches and radii of curves should be given;
2) Proposed hydraulic gradient, including elevation of canal bottom;
3) Typical cross sections, showing existing and proposed sections; one cross section for each type or size of the proposed section should be included on each sheet of corresponding canal reach. Average flow velocities should be given for normal (base) flow and for (high) design flow;
4) If structures are proposed for a canal reach, a drawing of a typical structure showing full dimensions should be included. Head loss over the structures at design (high) flow must be given;
5) Canal reaches through or along valuable landscapes must be illustrated with drawings, sketches or photo montages showing how the canal and structures will look in the surrounding landscape.

An example of a longitudal profile is shown in Figure 19.18.