26

Tank Irrigation

26.1. Definition and General Introduction

Tank irrigation may be defined as the *storage irrigation scheme*, which utilises the water stored on the upstream side of a smaller* earth dam, called a *bund*. These earthen bund *reservoirs* are, thus, infact, called as *tanks*, specifically in South India, where such works are very common. This terminology is, therefore, limited to India only.

There is, thus, no technical difference between a 'reservoir' and a 'tank', except that a large-sized tank will be termed as a reservoir. Moreover, a reservoir will generally be formed by dams of any material (such as masonry dam, concrete dam, or earth dam, etc.) ; whereas, a tank is generally said to be formed by earth dams only (or strictly speaking by earthen bunds). These earthen bunds, spanning across the streams, are called *tank bunds* or *tank banks*.

Most of the existing tanks of south India possess a *maximum* depth of 4.5 m, while a few are as deep as 7.5 to 9 m, and only a few exceptional ones exceed 11 m in depth. When the depth of the tank exceeds 12 m or so, the tank is generally referred to as a *reservoir*.

Like all earth dams, tank bunds are generally provided with *sluices* or *outlets* for discharging water from the tank for irrigation or other purposes. These *tank sluices* may be pipes or rectangular or arched openings passing near the base of the bund and through the body of the bund, and carrying the water into the downstream channel below the bund or transporting at distances where required, through pipes or canals. Sometimes, the *supply sluices* may not be passed through the body of the bund, and may be carried adjacent to it through some hill side at one end of the bund.

Similarly, as in the case of all dam reservoir projects, tanks are provided with arrangements for spilling away the excess surplus water that may enter into the tank, so as to avoid over-topping of the tank bund. These *surplus escape arrangements* may be in the form of a *surplus escape weir*, provided in the body or at one end of the tank bund, or some other arrangement like a syphon spillway may be provided as is done in the case of earth dam projects. The surplus escape weir is a masonry weir (compared to an ogee spillway in an earth dam) with its top *i.e.* crest level at equal to *Full tank level* (F.T.L.). When tank is full upto FTL, and extra water comes in, it is discharged over the surplus escape weir. The length or capacity of this surplus escape weir will be so designed that water level in the tank does never exceed the *maximum water level* (M.W.L.). The top of the tank bund will be kept at a level, so as to provide a suitable free-board above this M.W.L.

Since the surplus escape weir is a masonry weir, it will have to be properly connected to the earthen bund by suitably designed bank connections.

* Generally less than 12 m or so in height.

26.2. Isolated Tanks and Tanks in Series

Most of the existing small sized tanks of south India form part of *groups of tanks*, which are connected together in series, such that any tank either receives the surplus water of the upper tank(s), or sends its own surplus into some lower tank(s), or do both. However, when a tank neither receives water from an upper tank nor discharges its own surplus into a lower tank, it is called an *isolated tank*. There do exist some isolated tanks also in South India.

Figure 26.1. shows a typical group of 15 tanks numbered 1 to 15, and an isolated tank A. It is evident that *considerable economy of water can be obtained from the system of grouping*, because the surplus water of the each tank and also the drainage of its wet cultivation are caught up by the next lower tank. Each tank of the group takes a share in the yield of the whole catchment above it, which can be classified as follows :

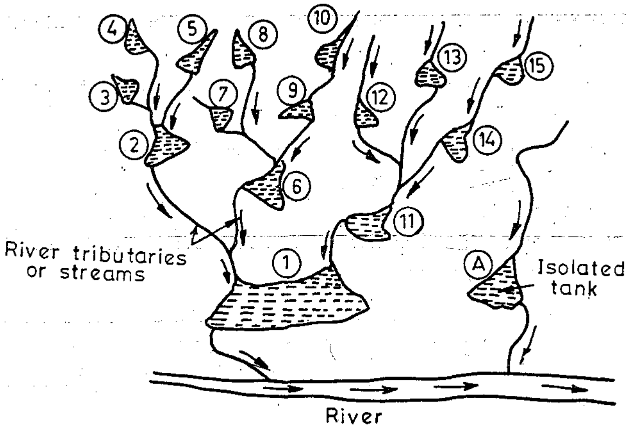


Fig. 26.1. Fig. showing isolated tanks and tanks grouped in series.

(*i*) the *free catchment*, which is the catchment area which only drains into the tank under consideration ; and

(*ii*) *the combined catchment*, which is the area of the whole catchment above the tank under consideration.

The difference between the combined and the free catchment, thus, gives the area of catchment intercepted by upper tanks. The whole catchment of the highest tank, on each drainage, shall be its free catchment. Moreover, each tank will receive the whole run- off from its free catchment ; but from the remainder of its catchment it will receive only the balance runoff which remains after the upper tanks have been filled.

One of the disadvantage of grouping of tanks, however, is that, if a breach occurs in an upper tank, it exposes all the tanks in the series below, to the risk of similar failures. Hence, while making repairs or doing restoration works in such groups of tanks, it is necessary to consider each system of tanks collectively as a whole, and to carry out repairs from the upper end of each group. The extent of danger to lower tanks due to breach of an upper tank, however, depends upon their relative capacities. For example, if a small upper tank breaches and passes its storage into lower large-capacity tank, it may pose little danger even if the breach may completely empty the small tank. However, the danger will be imminent if the case is opposite, and the large sized upper tank breaches and passes its storage into the lower small sized tank.

The provision of suitable *breaching sections** in tanks forming part of a group is, therefore, considered as a very desirable precaution against their failure by breaching. This is because, a breach occurring in a tank bund at a well selected point (at the place of breaching section) will not empty the tank, and indeed frequently does little more than supplement its surplusing power to a reasonable degree to the greater security both of the tank itself and those below it in the group.

26.3. Capacity of Water Spread of a Tank

The *gross capacity of a tank* may be defined as the cubic content of water stored in the tank upto F.T.L. The *effective capacity of a tank*, will, however, be the cubic content of water stored between F.T.L. and the bottom or sill level of the lowest supply sluice.

These storage capacities can be computed easily by using the contour plan of the area of the water-spread ; the total capacity being the sum of the capacities between successive contours. The smaller the contour interval (Δh), the more accurate the capacity computation will be. This is because, if A_1 and A_2 represent the areas enclosed between two successive contours, then the cubic content between these contours is roughly taken as $\frac{A_1 + A_2}{2}(\Delta h)$.

The summation of all cubic contents between the successive contours will be the required storage capacity of the tank.

When the contour plan is not available, and only the area of the tank at F.T.L. is known, then the effective cubic content of the tank may be roughly computed as follows

The area of tank at F.T.L. is multiplied by one- third of the depth from this level (F.T.L.) to the deep bed of the tank, or the level of the sill of the lowest sluice, whichever is higher of the two.

If the area (A_1) of the tank bed at the level of the sill of the lowest sluice, and the area (A_2) of the tank at F.T.L. are known even roughly, then the effective cubic content of the tank may be computed as $\frac{1}{3}[A_1 + A_2 + A_1 A_2] \times h$, where h is the height or difference in elevations between F.T.L. and sill level of the lowest sluice. This formula is based on the assumption that the water stored is in the shape of a frustum of a cone.

These principles on which the storage capacity of a reservoir is computed, were also discussed earlier under article 18.2.

26.4. Designing the Section of the Tank Bund

The tank bund, as you know, is nothing but a small-sized earth dam ; and hence, strictly speaking, its design and construction should be carried out in accordance with the principles applicable to earth dams (already discussed in details in chapter 20).

In accordance with these very principles, the tank bunds may be of three types ; *i.e.*

Type A : *Homogeneous embankment type* (Fig. 20.1) ;

Type B : *Zoned embankment type* (Fig. 20.2) ; and

Type C : *Diaphragm type* (Fig. 20.3).

Most of the tank bunds of South India belong to type A, and they have been constructed with the soils excavated from pits in the immediate vicinity of each bund, and carried by head load to the bund.

* A 'breaching section' is a length kept lower and weaker than the remainder of the bound, so as to localise a breach in that length only.

As discussed in chapter 20, the large modern earth dams are designed after doing a lot of mathematical calculations for seepage and stability analysis, and keeping into consideration the latest advancements made in the field of soil mechanics. However, for small earthen bunds, generally no such calculations are carried out, and the sections are designed on the basis of practical considerations and experience derived from success and failure of similar works and of their working conditions.

The commonly adopted standards used for fixing the dimensions of tank bunds, in South India, are given in table 26.1.

Table 26.1. Common Dimensions of Tank Bunds

S. No.	*Depth of deep bed below F.T.L. i.e. maximum water depth in metres*	*Free board (in metres)*	*Width of top of bund (in metres)*
1.	1.5 to 3.0	0.9	1.2
2.	3.0 to 4.5	1.2	1.5
3.	4.5 to 6.0	1.5	1.8
4.	over 6.0	1.8	2.7

In favourable soils, such as red and white gravel, red and black loams, etc., the side slopes of the bund may be kept as $\frac{1}{2} : 1$ ($\frac{1}{2} H : 1 V$) for smaller tanks with water depths not exceeding 2.5 m, and 2 : 1 for larger ones up to about 5 m in depth. In light sandy, or black cotton, or clayey soils, however, the slopes may be kept between 2 : 1 to $2\frac{1}{2} : 1$.

The upstream face of the tank bund is generally rivetted with stone apron or riprap (Fig. 26.2) so as to protect it against erosion, and if this is done, then the upstream slope

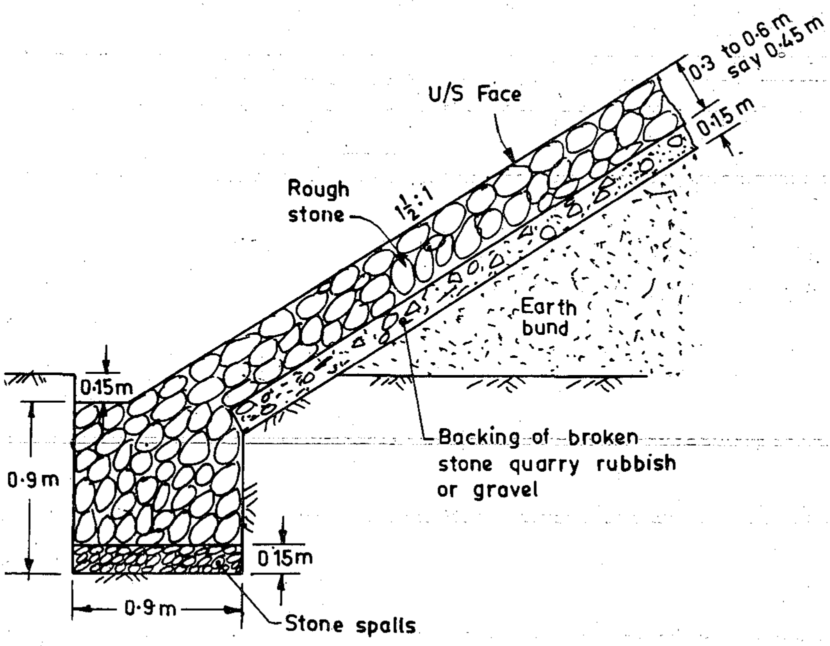


Fig. 26.2. Upstream Revetment of Tank Bunds.

is generally adopted is $1\frac{1}{2}:1$ even upto 6 m depth. For inferior soils, or greater depths, however, the rivetted slope may be made flatter, say 2 : 1.

In this way, for average cases, a $1\frac{1}{2}:1$ slope will generally be adopted for upstream face, and 2 : 1 slope for downstream face.

This practice is *contrary* to the standard recommendations adopted in various countries, where the upstream slope, even when revetted, is kept flatter than the downstream slope because of the soil being saturated. There are, however, thousands of tanks in Tamilnadu with water slopes of $1\frac{1}{2}:1$, and failure by slipping of this slope is rare ; and hence, in normal cases, the local practice in this respect can be easily adopted. In very small tanks, and in case the upstream slope is heavily revetted, upstream faces have been given 1 : 1 or even steeper slopes in actual practice, but such steeper slopes are not recommended.

26.5. The Tank Weirs or Surplus Escape Weirs and Their Design Principles.

26.5.1. Definition. As stated earlier, the excess surplus water is spilled from a tank, into the downstream channel, so as to avoid the rise of water in the tank above the M.W.L. In fact, the water will generally start spilling over the crest of this escape weir, as and when it rises above F.T.L. ; and the discharging capacity of this weir will be designed so as to pass the full maximum flood discharge (likely to enter the tank) with a depth over the weir equal to the difference between F.T.L. and M.W.L.

Although the effective storage capacity of a tank is limited by F.T.L., but the area submerged by the tank bund and revetment are all dependent on M.W.L. And hence, in order to restrict the dimensions of these, it is desirable to keep the difference between F.T.L. and M.W.L. to a smaller value. But, on the other hand, the smaller is this difference, the longer will be the surplus escape required in order to enable it to pass the given discharge. Hence, the difference (H) between F.T.L. and M.W.L. is fixed on a compromise basis, in each particular project, so as to obtain overall economy and efficiency. In small and medium sized tanks, the usual difference between F.T.L. and M.W.L. is kept from 0.3 to 0.6 metre, and it is rarely allowed to exceed 0.9 metre.

26.5.2. Types of Tank Weirs and Their Cross-sections. Tank escape weirs are similar to river-weirs (*i.e.* diversion weirs or anicuts), and hence, they may be classified into the following three general types :

Type A : *Masonry weirs with a vertical drop* ;

Type B : *Rockfill weirs with a sloping apron* ; and

Type C : *Masonry weirs with a sloping masonary apron (glacis).*

These three types of river weirs have already been discussed in article 9.3.1.

Besides these three important types of river weirs, which are used as tank weirs also, the fourth type of a tank weir which is a combination of type A and type C, may also be used. In such a *D type weir*, a number of vertical steps are made (as in the case of a stepped fall) instead of providing a horizontal or sloping downstream apron. Such weirs of type D are called *weirs with stepped aprons.* The A and D type of weirs are most widely adopted, although every type of weir has been used in South Indian tanks.

The A type of weir *i.e.* weir with a masonry pucca horizontal floor, may sometimes by provided with depressed floors, so as to provide sufficient water-cushion for absorbing the impact of high water falls. Typical sections of the two sub- types of A type, and

D type of weirs, and the conditions under which each is adopted are shown in Figs. 26.3 (*a*), 26.3 (*b*), and 26.4 respectively.

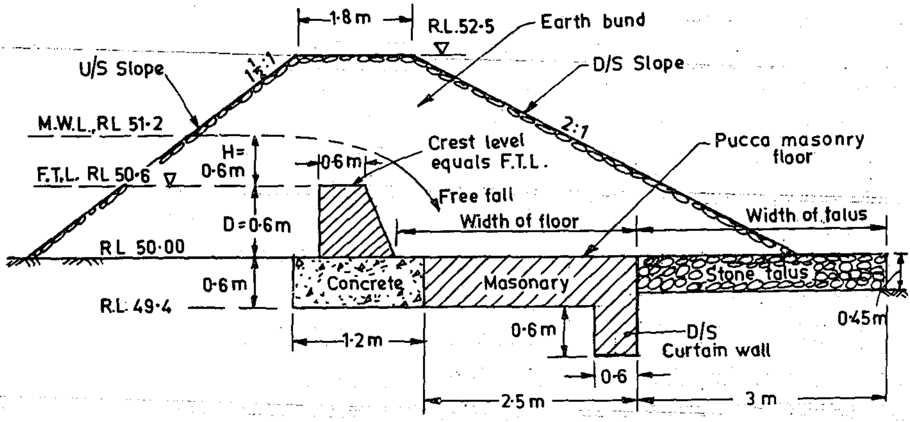


Fig. 26.3 (*a*) A typical masonry tank weir with a vertical drop, with a horizontal undepressed floor, suitable for low drops of 0.6 to 0.9 metre or for even higher drops when the soil is a rock.

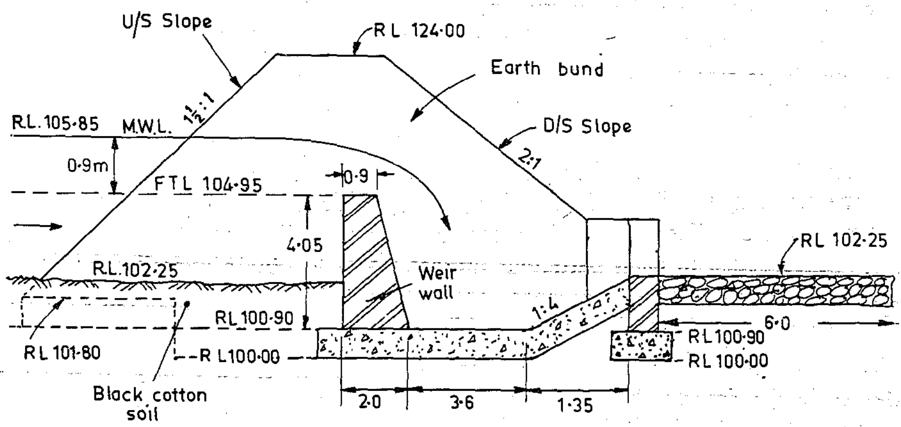


Fig. 26.3 (*b*) A typical masonry tank weir with a vertical drop with depressed floor, suitable for high drops (say 2.5 m upward) or in soft soils but only slightly pervious.

The general principles and considerations which guide the design of tank weir sections, are the same as in the case of river weirs founded on *rocks* or *loose pervious or impervious soils* But in case of tanks, the conditions regarding the *nature of foundation soil* and the *working conditions* are more varied than in the case of river weirs.

Say for example, the river weirs or anicuts are generally founded on soft sandy soils, whereas in tank weirs, almost every class of soil is occasionally to be built on, except this rarely met foundation sand.

Similarly, the tail water conditions in anicuts differ from those in tank weirs. This is because, the tail water backing up during floods and affording some protection to the talus and to the soil at the downstream toe of the apron, are absent in the majority of tank weirs ; and, therefore, the tank weirs built on soft soil would, other things being

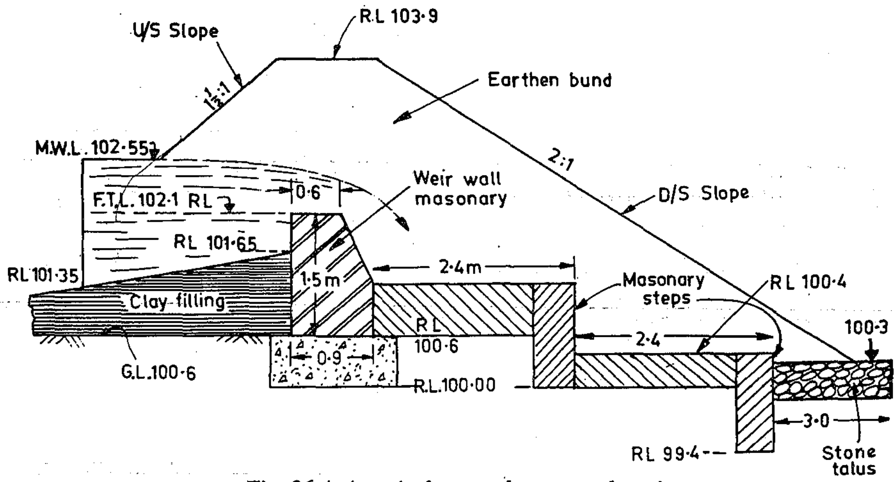


Fig. 26.4. A typical stepped-apron tank-weir, suitable for sites on soft soil when the drop exceeds 0.9 metre.

equal, be more exposed to damage by scour at the downstream toe of the apron and retrogression of levels than river weirs.

On the other hand, the depth of water passing over the crests of tank weirs is generally far less than that over anicuts, and in the case of very many tanks, it is only, on an average, for a few days each year, that any flow at all passes over the weir, and while the duration of continuous heavy flow is frequently limited to a maximum of two to three days. Tank weirs are, thus, usually worked, far less heavily and far less continuously than anicuts, and this fact may be duly considered while designing them.

Empirical Formulas for Determining Width of Floors of Tank Weirs. The width of the horizontal floors of type *A* and *D* weirs, from the foot of the drop wall to the downstream edge of the floor should never be less than 2 $(D+H)$ where D is the height of the drop wall, and H is the maximum water head over the wall. In important works, this width may be increased to 3 $(D+H)$. The rough stone apron forming a *talus* below the last curtain wall may be of varying widths depending on the nature of the soil and the velocity and annual probable quantity and intensity of runoff ; it would generally vary from 2.5 $(D+H)$ to 5 $(D+H)$ according to varying conditions.

26.5.3. Length of the Tank Weir. In order to determine the length of the escape weir, it is, first of all, necessary to determine the *maximum flood discharge* that may enter into a tank, after it is filled up to full tank level. This peak discharge that may come from the free catchment of a tank can be fairly estimated by using the empirical formulas applicable to the given region, as discussed earlier under article 7.9.2. Generally, in South India, all tank weirs have been designed on the basis of Ryve's formula (Refer equation 7.49). The formula is directly applicable for free catchments in all isolated tanks. However, for combined catchment of a tank forming a constituent unit of a group, the following modified formula is used for calculating peak discharge :

$$Q_p = C_1 \cdot A^{2/3} - c_1 a^{2/3} \qquad ...(26.1)$$

where C_1 is the coefficient in Ryve's formula (Refer Table 7.45)

A is the area of the combined catchment in sq. kilometres

c_1 is the coefficient from $\frac{1}{5}$th to $\frac{1}{3}$rd of C_1 and

a is the area in sq. kilometres of the catchment intercepted by upper tanks.

This formula is purely empirical, and should only be applied when the upper tanks are provided with adequate surplus works, and kept in good state of repairs.

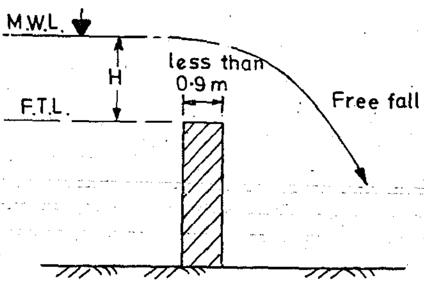
After the peak discharge is worked out and decided upon, the length of the weir can be worked out by using the appropriate discharge formula applicable to the weir type adopted in the project. In general, the discharge over a broad crested free weir and without any velocity of approach, is given as :

$$Q = C \cdot L \cdot H^{3/2} \qquad \ldots(26.2)$$

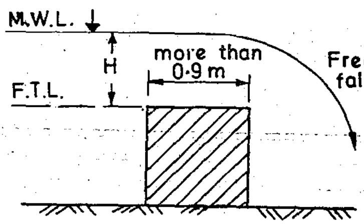
where L = the length of the weir ;

H = the head of water over the weir (*i.e.* the difference between M.W.L. and F.T.L.), and

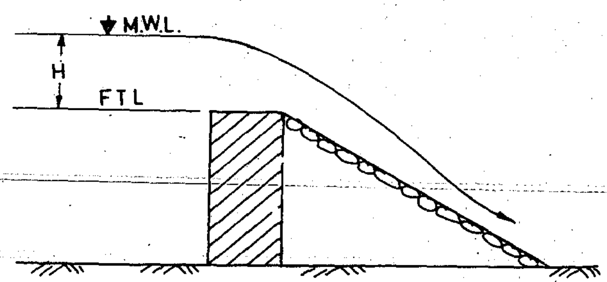
C = a constant, the common values of which for three commonly used types of weirs in South India, are shown in Fig. 26.5.



(*i*) Weirs with crests up to 0.9 m wide.



(*ii*) Weirs with crests over 0.9 m wide or weirs provided with dam-stones.*



(*iii*) Rough stone sloping escapes.

Fig. 26.5. Different types of Tank Weirs and the values of their coefficients in discharge formulas.

*A common practice which has been resorted to for centuries in South India is to fix **damstones** in the crest wall of the weir. these stones are generally about 15 cm × 15 cm in section, and 0.75 to 0.9 m high, built into the masonry weir wall at about 0.45 to 0.6 m clear interval ; projecting above the weir crest to a height of 0.3 to 0.6 metre, their tops being generally at M.W.L.

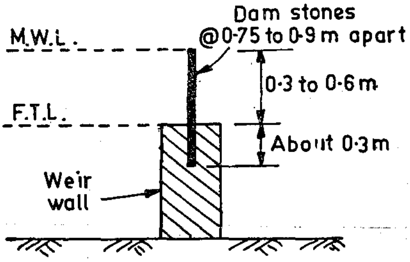


Fig. 26.6. Dam-stones.

The space between these stones are blocked up with clay and turf by cultivators, with the result that water can be held up in the tank up to M.W.L., before any surplusing takes place. When the tank receives more water, which just causes the water level in the tank to rise above M.W.L., the water over-tops the turf weir, which is rapidly washed away, and the surplus weir starts functioning with full head (H), without M.W.L. exceeding to any appreciable extent.

Whenever this occurs, all the water stored in the tank above the weir crest level, must however, be passed off before the turf dam can be rebuilt.

The dam stones cause obstruction to the discharge, and when they are installed, the length of the weir must be correspondingly increased, *i.e.* constant (C) in weir discharge formula reduced from 1.84 to 1.66.

Sometimes, instead of damstones, shutters may be provided between F.T.L. and M.W.L., so that they can be lowered and raised as and when needed, thus serving the purpose of giving full pondage up to M.W.L. before the worst flood arrives for surplus disposal. They may, however, create operational problems, and necessitate special establishment.

If no damstones or shutters are provided above F.T.L., and flood water starts spilling over the surplus work immediately after the tank water level exceeds F.T.L., then *strictly speaking*, the computed peak flood discharge should not be used to directly work out the length of the weir by the above simple and straight formulas. This is because of the fact that certain flood discharge will be absorbed between F.T.L. and M.W.L. This *flood absorption capacity* of a tank is, however, considered only in very big tanks or in large-sized tanks, and this is kept unaccounted as a further measure of safety in such works. A method of computing the allowance which may be made for the absorption capacity of big tanks has been worked out by Capt. Garret, and is given in his paper on the "General Theory of the Storage Capacity and Flood Regulation of Reservoirs" published in 1912 by the Government of India. The same may be referred to if needed along with its original tables given in the same paper.

26.5.4. Choice of a Suitable Site for Locating a Tank Weir. As pointed out earlier, a surplus weir can be located either in the body of the tank bund or at one end of it. When a saddle, disconnected with the tank bund is available, it must be preferred for locating the surplus weir, as compared to providing it within the bund body, but even in such a case, it will be necessary to locate it at one flank of the bund and connected with it.

If all the cultivation is on one side of the stream which is dammed by the bund, then it is preferable to locate the surplus weir on the other flank ; otherwise it would be necessary in many cases, to carry the distributary channels across the surplus channel, and there may also be danger of cultivation being damaged by the surplus water when the tank surpluses freely.

Besides these considerations, the most favourable sites for surplus weirs are at places ;

(*i*) where the N.S.L. along the line of the weir approximately equals F.T.L.

(*ii*) when the foundation soil is hard both on the weir site and along the runoff channel, and where the ground contours are such as to give clear approach to the weir site and a suitable course for the surplus water.

26.6. Tank Outlets or Tank Sluices and their Design Principles

As stated earlier, a *tank sluice* is an opening in the form of a culvert or a pipe running through or under the tank bund, and supplying water from the tank to the distributary channel below, to meet the irrigation or other water requirements, as and when needed. Suitable wing walls and other bank connections are also provided as required at the head and tail end of the culvert.

In ordinary medium-sized sluices, masonry culverts with or without arch roofs are generally constructed (Refer Fig. 26.7). The size of the culvert (*i.e.* its cross-section) will depend upon the maximum quantity of water (Q)* it is required to convey, but in no case should be less than 0.6 metre wide and 0.75 metre high, so as to allow a man to enter it for examination and repairs or removal of obstructions. The size of the barrel should also be such as to limit the velocity through the sluice barrel to a maximum of 4.5 m/sec*, under the condition of plug hole being fully open and with the water at full tank level.

In case of very small sluices, earthen ware or cement or cast iron pipes may be used to take the place of masonry culverts. (Refer Fig. 26.8). Such sluices are called *pipe sluices*. They are generally not adopted in tank bunds, where the depth below F.T.L. exceeds 2.5 metre or so. This is because, in such cases, the earthen ware pipes may get fractured, or leakage through their joints may take place, resulting in a breach, as the pipes can neither be examined nor repaired easily without cutting open the bund. Moreover, these pipes and especially the cast iron pipes are rarely found to be economical compared to masonry sluices.

Besides the above types of tank sluices, one more type of sluice *i.e. a sluice with a tower head* (Refer Fig. 26.9) is also sometimes provided. This form is sometimes found more economical than the types previously referred to, owing to the saving obtained by avoiding the heavy wing walls of the previous type. Moreover, here there is lesser danger of failure by cracking and bulging which frequently occurs in the wings of the other type. But, on the other hand, with such a sluice, additional length of the barrel is required. Tower-heads or wells are generally placed in the water slope of the bund, as thereby, the expanse of a bridge or causeway leading from the bank to the regulation

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$$^*V = \frac{Q}{A} = \frac{\text{Discharge}}{\text{Area of barrel}} = Cd \cdot \sqrt{2g \cdot h}$$

where h is the height of the F.T.L. above the sill level of the sluice.

Cd = 0.63 for free fall.

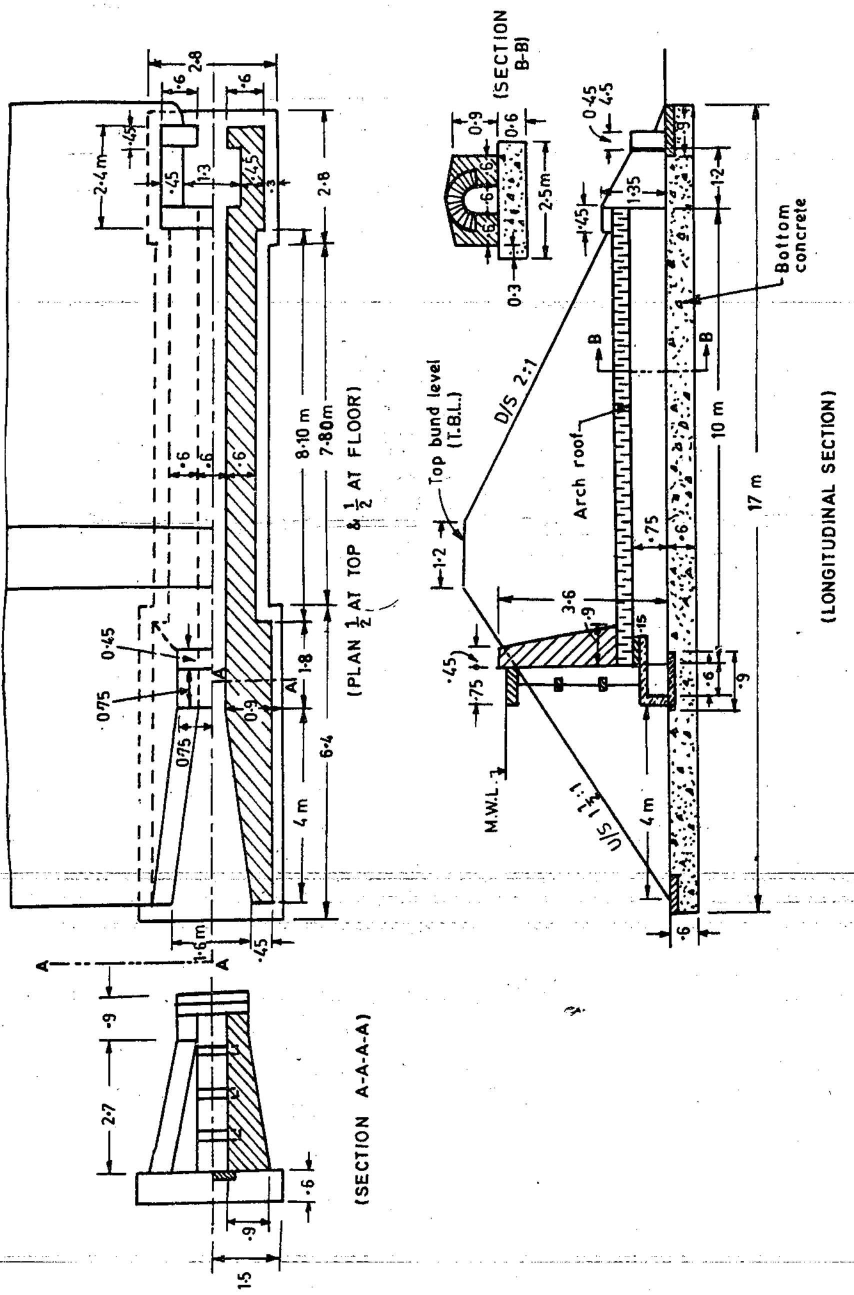

Fig. 26.7. Masonry supply sluice for a medium-sized tank.

platform is saved. But this has the disadvantage of making it impossible, while the tank has water, to have access to the portion of the barrel upstream of the well.

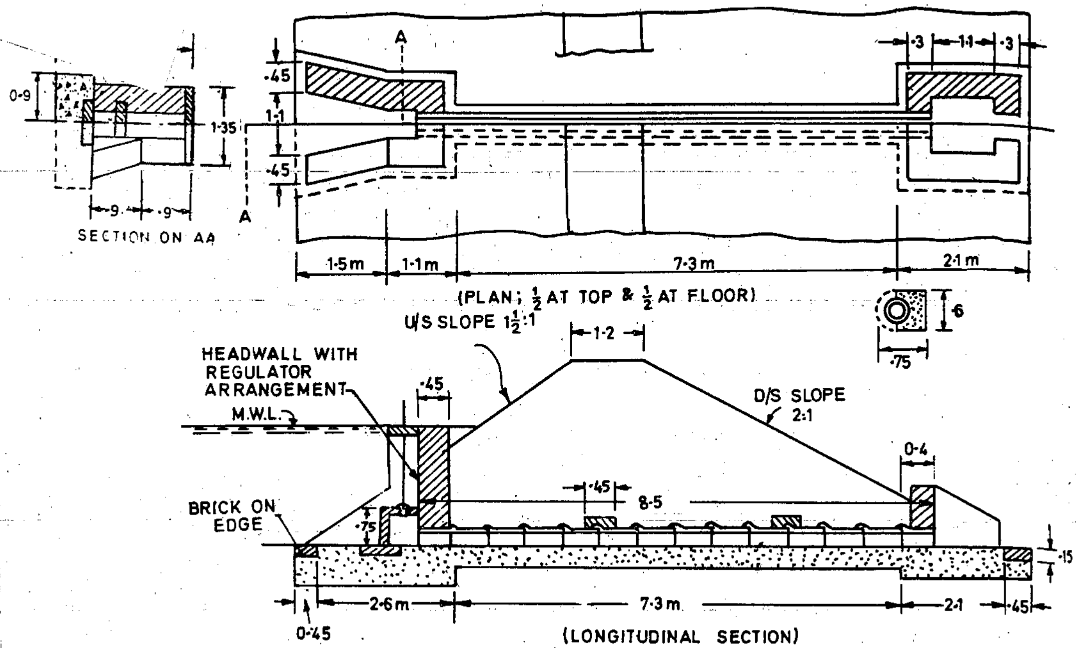

Fig. 26.8. Earthern ware pipe-sluice for a very small tank.

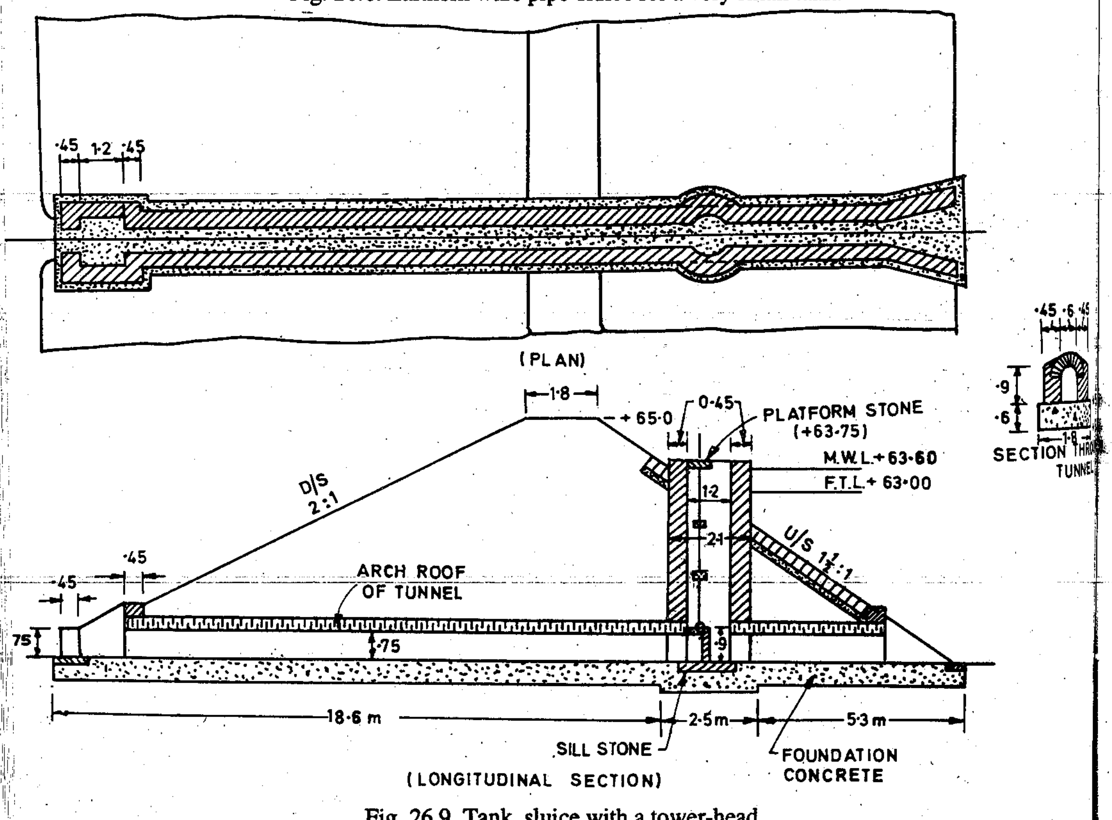

Fig. 26.9. Tank sluice with a tower-head.

26.6.1. Method of Regulation of Tank Sluices. The generally used vents for medium-sized tank sluices consist of one or more circular orifices of suitable size made in a horizontal stone, and the area of the opening is regulated by a long coned plug, the wider end of which is of the same diameter (allowing for clearance) as the vent (Refer Fig. 26.10). The vent is termed as the *plug-hole*. As the plug is raised, the hole or orifice is opened more and more, and when the plug is raised altogether clear of the plug hole by an amount not less than the diameter of the hole, the full discharge from the orifice will pass. This arrangement is both simple and economical, and affords an easily adjustable means of regulation to suit the varying conditions of water level which are inseparable from the reservoirs, and this arrangement is, thus, more suitable for tank sluices than the flat shutters which are generally used for canal sluices.

Details of plugs for tank-sluices are shown in Fig. 26.10, the standard sizes being 100, 150, 200, 250 and 300 mm dia, this being the size of the hole in the plug stone, the largest size of the cone part of the plug being about 6 mm less ; the width of the

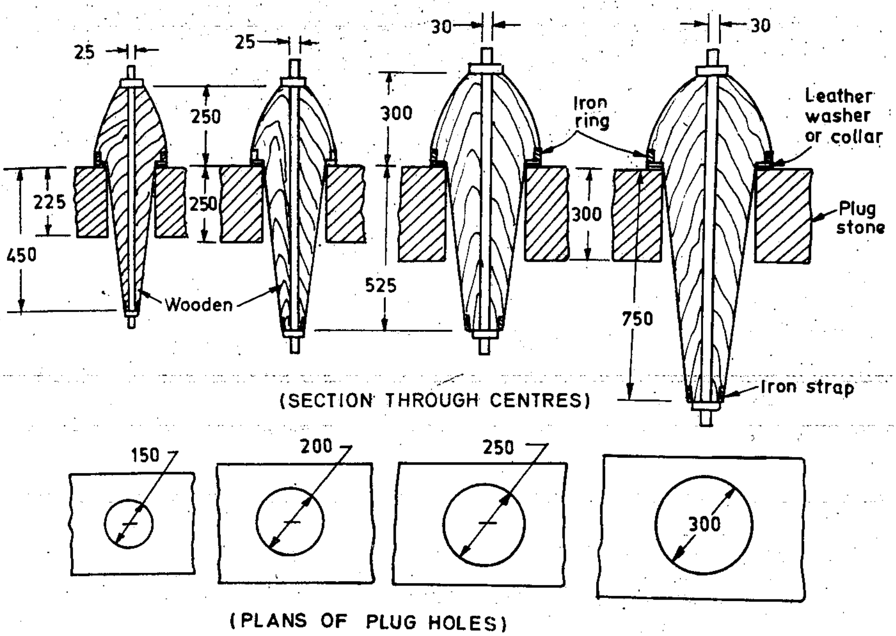

Fig. 26.10. Typical standard sized plugs for tank sluices.

seating should be from 25 mm to 30 mm. The cones should have a taper of one to four, and be made of hard wood ; the smaller end of cone and the greatest dia. of the plug should be cut cylindrical to take countersunk iron straps which should be shrunk on to prevent the plug from splitting. The lifting rod should be round iron, and secured by a split cotter pin at each end of the plug. When the rod is long, it should be passed through holes in guide beams fixed at intervals. The top end of the rod passes through a hole in the regulation platform ; it should be flat iron with holes at about 75 mm interval through which an iron pin is passed to keep the plug suspended at whatever height it gives suitable elevation.

When the computed size of a tank sluice or plug hole is more than 250 to 300 mm, in diameter, then it is generally advisable to provide two or more holes and plugs in the plug platform stone ; while for deep sluices, say over 7.5 m depth, two or more plug stones at different levels, each with separated plug holes, provide greater facility for easy regulation, and hence adopted.

The size of the orifices in the plug stone are generally calculated so as to pass the full supply with vents fully open and with 0.3 m of water standing over the plug stone platform. For regulation below this level, a rectangular vertical vent is provided which is closed by a shutter, which may be wooden but is generally a slab of stone. This vent is made of sufficient size to pass full supply with 0.15 m head. This shutter is brought into use only when the water in the tank is less than 1.2 m over the floor of the sluice; and at other times, the shutter is kept completely covering the orifice, and leakage past it, should be stopped by filling silt against its upstream face. This vent will be regulated by men standing on the plug stone.

In case of large tanks, where the quantity of water to be released is great, and where adequate establishment is maintained, flat shutters working in grooves, and regulated by screw spears, may be installed.

For heads of over 9 m or so, special balanced valves or shutters moving on rollers are generally installed.

Example 26.1. *Design a vertical drop horizontal floor tank surplus weir with the following data. Draw a neat sketch indicating the salient dimensions of the weir and bund section, and work out the length of the weir required with the following given data:*

Combined catchment	*= 26 sq. km.*
Intercepted catchment	*= 20 sq. km.*
Maximum water level	*= + 7.50 (m)*
Full tank level	*= + 6.70*
Ground level	*= + 5.80*
Tank bund level	*= + 1.80*
Slope on either side of bund	*= 2 : 1*
Ryve's coefficient for combined catchment	*= 9.0*
Ryve's coefficient intercepted	*= 1.8*

Solution. Using equation (26.1), we have

Q_P = peak flood discharge

$$= C_1 A^{2/3} - c_1 a^{2/3}$$

where $C_1 = 9.0,\ \ c_1 = 1.8$

$A = 26$ sq. km., $a = 20$ sq. km.

$$Q = 9.0\,(26)^{2/3} - 1.8\,(20)^{2/3} = 79.2 - 13.3 = 65.9 \text{ cumecs.}$$

or $\quad Q_p = 65.9$ cumecs.

Now, M.W.L. = 7.50 m

F.T.L. = 6.70 m

Ground level = 5.80 m

∴ Difference between MWL & FTL *i.e.* maximum

head of water over surplus weir = $H = 7.50 - 6.70 = 0.8$ m.
crest of weir is kept at F.T.L.

∴ Depth of drop *i.e.* height of weir crest

$$D = 6.7 - 5.8 = 0.9 \text{ m.}$$

Since the drop is small, we can adopt a masonry weir with a horizontal masonry floor (without depressed floor) *i.e.* type A, Fig. 26.3 (*a*), easily.

The widths of horizontal pucca floor and talus are calculated below :

The width of horizontal masonry floor $= 2\,(D + H) = 2\,(0.9 + 0.8) = 3.4$ m.

The width of rough stone talus $= 4\,(D + H) = 4\,(0.9 + 0.8) = 6.8$ m.

Use the top crest width equal to 0.6 m, and draw the sketch as shown in Fig. 26.11.

The length of the weir can be determined by using equation (26.2) as below :

$$Q_p = C \cdot LH^{3/2}$$

where Q_p = 65.9 cumecs (calculated above)
L = ?
H = 0.8 m.
C = 1.84 for weirs with crests upto 0.9 m wide.

∴ $65.9 = 1.84 \times L \times (0.8)^{3/2}$

or $L = \dfrac{65.9}{1.84 \times 0.716}$ m = **50 m. Ans.**

Example 26.2. *A waste weir of a tank has the following details :*

Combined catchment	*= 26 sq. km.*
Intercepted catchment	*= 20 sq. km.*
F.T.L. of tank	*= + 12.70 m.*
Crest level of tank	*= + 12.70*
M.W.L. of tank	*= 13.4*
G.L.	*= 10.00*
Ryve's coefficient for combined catchment	*= 9*
Ryve's coefficient intercepted	*= 1.5.*

Design the length and cross-section of the body wall of the surplus work, assuming the foundation soil to be soft but only slightly pervious.

Solution. Depth of water over weir crest

$$= H = MWL - FTL = 13.4 - 12.7 = 0.7 \text{ metre}$$

The Depth of fall (D) = F.T.L. − G.L. = 12.7 − 10.0 = 2.7 m.

The choice is obviously a vertical drop fall with a water cistern.

Total length of horizontal floor

$$= 3\,(D + H) = 3\,(2.7 + 0.7) = 3 \times 3.4 = \mathbf{10.2\ m.}$$

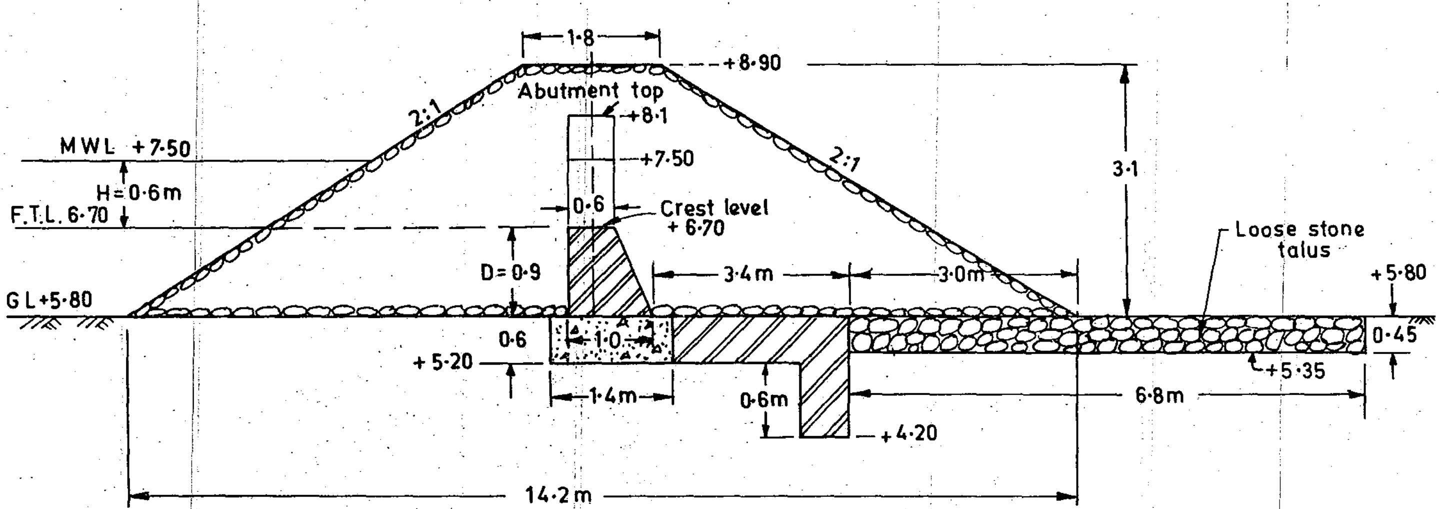

Fig. 26.11. Section of the designed Tank Surplus Weir in example 26.1.

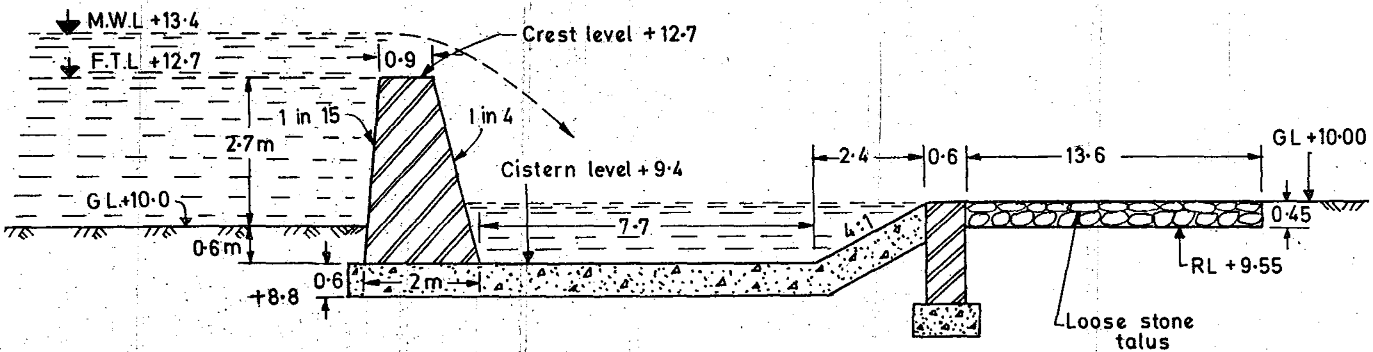

Fig. 26.12. Section of the designed Tank Weir in example 26.2.

Length of d/s talus = $4(D+H) = 4(2.7+0.7) = 4 \times 3.4 =$ **13.6 m.**

The depth to which the horizontal floor is depressed is given by equation (12.9) as $X = \frac{1}{4}(H \cdot H_L)^{2/3}$, where H_L is the difference in u/s and d/s water levels *i.e.* $(H+D)$ in this case.

or $$X = \frac{1}{4}(0.7 \times 3.4)^{2/3}$$

$= 0.5$; So let us use 0.6 m depth of cistern

Length of cistern is given by equation (12.8) as

$$L_C = 5 \cdot \sqrt{H \cdot H_L} = 5 \cdot \sqrt{0.7 \times 3.4} = 7.7 \text{ m.}$$

The slope length of concrete floor in a slope of 4 : 1 will be $= 4 \times 0.6 = 2.4$ m.

d/s cut-off wall thickness $= 0.6$ m

In this way, total length of floor provided

$= 7.7 + 2.4 + 0.6 = 10.7 > 10.1$; safe.

Hence, provide the section of the waste weir, as shown in Fig. 26.12.

Length of weir

$$Q_p = C_1 A^{2/3} - c_1 a^{2/3}$$

where $C_1 = 9.0$

$c_1 = 1.5$

$A = 36$ sq. km.

$a = 20$ sq. km.

$$Q_p = 9(36)^{2/3} - 1.5(20)^{2/3}$$

$= 9 \times 10.9 - 1.5 \times 7.4 = 98.1 - 11.1 =$ **87 cumecs**

Now $$Q_p = CLH^{3/2}$$

$$87 = 1.84 \times L \cdot (0.7)^{3/2}$$

$\therefore$ $$L = \frac{87}{1.84 \times 0.948} = 49.8 \text{ m ; } \textbf{say 50 m}$$

Hence, use 50 m length of weir. **Ans.**

Example 26.3. *A tank has a catchment area of 120 sq. km. ; out of which 20 sq. km. make free catchment. Average annual rainfall on catchment is 75 cm. What should be the desirable gross storage for the tank ? If rice crop, with a duty of 640 hectares per cumec at the head of main canal and a crop period of 120 days, is to be irrigated from the water of this tank, find the area under the rice crop.*

What should be the length of the waste weir to dispose of safely the high flood discharge, with a head of 0.6 m on the crest of the weir ? Use Ryve's formula, with coefficient as 7.5.

How will the live storage be affected if the tank gets filled $1\frac{1}{2}$ times in a year.

Solution. Average annual rainfall = 75 cm.

The rainfall of average bad year = $\frac{2}{3}$rd of the average annual rainfall(say).

$$= \frac{2}{3} \times 75 = 50 \text{ cm.}$$

Runoff (as depth of water over the catchment) of this average bad year

$$= 20\% \text{ (say) of rainfall} = \frac{20}{100} \times 50 = 10 \text{ cm.}$$

The total catchment area of 120 sq. km. consists of independent catchment of 20 sq. km. and intercepted catchment of 100 sq. km.

Total volume of runoff in average bad year from free as well as intercepted catchment of the given tank

= full runoff from the free catchment + $\frac{1}{7}$th of the runoff from the intercepted catchment on the assumption that $\frac{6}{7}$ of the runoff from the intercepted catchment is impounded in the upper tanks.

$$= \left[20\,(1000 \times 1000) \times \left(\frac{10}{100}\right) + \frac{1}{7} \times 100\,(1000 \times 1000)\,\frac{10}{100}\right] \text{m}^3.$$

$$= \left[\frac{20 \times 10^6}{10} + \frac{1}{7} \times 100 \times 10^6 \times \frac{1}{10}\right] \text{m}^3$$

$$= 10^6\,[2 + 1.43] = 3.43 \times 10^6 \text{ m}^3 = 3.43 \text{ million cubic metre.}$$

$\therefore$ Live storage $= 1.1 \times 3.43 = 3.77$ M.m^3

and, Gross storage $= \left(\frac{10}{9}\right) 3.77 = \mathbf{4.19\ M.m^3}$ **Ans.**

Water required at the head of the main canal to irrigate 640 hectares of rice crop

$$= 1 \text{ cumec for 120 days.} = 1 \times (120 \times 24 \times 60 \times 60) \text{ cu.m.}$$
$$= 10.37 \times 10^6 \text{ cu.m.} = 10.37 \text{ M.m}^3$$

Hence, the area of rice crop which can be irrigated from the full tank water

$$= \frac{\text{Effective storage of the tank}}{10.37} \times 640 \text{ hectares}$$

$$= \frac{0.9 \times \text{Live storage}}{10.37} \times 640 \text{ hectares}$$

(assuming the losses in the tank to be 10% of live storage).

$$= \frac{0.9 \times 3.77}{10.37} \times 640 = \mathbf{209.4\ hectares.} \quad \textbf{Ans.}$$

Now, the high flood discharge from the catchment into this tank (after the tank is full) is given by equation (26.2) as

$$Q_p = C_1 A^{2/3} - c_1 a^{2/3},$$

where $C_1 = 7.5$ (given)

$c_1 = \frac{1}{5} C_1$ (assumed) $= 1.5$

A = Full combined catchment = 120 sp. km. (given)

a = Intercepted catchment = 100 sq. km. (given)

$\therefore \quad Q_p = 7.5\,(120)^{2/3} - 1.5\,(100)^{2/3} = 183 - 32.4 = 150.6$ cumecs.

Now, if L is the length of the waste weir, then

$$Q_p = C \cdot L \cdot H^{3/2} = 1.84 \cdot L \cdot H^{3/2}$$

$$\therefore \quad 150.6 = 1.84 \times L \times (0.6)^{3/2}$$

or $$L = \mathbf{176\ m.} \quad \textbf{Ans.}$$

If the tank fills $1\frac{1}{2}$ times in a year, then the live storage

$$= \frac{3.77}{1.5} = \mathbf{2.51\ M.m^3} \quad \textbf{Ans.}$$

PROBLEMS

1. What is an irrigation tanks ? Differentiate between isolated tanks and group of tanks. how can your compute the storage capacity of an irrigation tank ?

2. (*a*) What are the causes of failure of tank bunds ?

[**Hint.** Refer article 20.7]

(*b*) Sketch a typical cross-section of a tank bund of type C. Under what circumstances such sections are chosen ?

(*c*) Explain briefly the fūnction of a breaching section in a tank bund.

3. Design a tank surplus weir with the following data. Draw a neat sketch (not to scale) indicating the salient dimensions.

Combined catchment	= 26 sq. km
Intercepted catchment	= 20 sq. km.
Full tank level	= + 6.70 (m)
Maximum water level	= + 7.50 m
Ground level	= + 5.80 m
Foundation level	= + 4.20 m
Tank bund level	= + 8.90 m
Top width of bund	= 1.8 m
Slope on either side of bund	= 2 : 1

Downstream level is + 4.80 in a distance of 8 m.

4. A tank surplus work has the following details :

Combined catchment	= 26 sq. km.
Intercepted catchment	= 20 sq. km.
F.T.L. of tank	= 12.00 m.
Crest level of weir	= 12.00 m.
M.W.L. of tank	= 12.75 m.
G.L.	= 11.00 m.
Top of foundation concrete	= 9.60 m
Ryve's coefficient for combined catchment	= 9
Ryve's coefficient intercepted	= 1.5

Design the length and cross-section of the body wall of the surplus work.

5. What is a waste weir, and where is it installed in a project of an irrigation tank ? Discuss its importance, and principles involved in designing such a work.

6. (*a*) What is a tank weir, and what are its types ? Discuss the conditions favourable to the selection of a particular type.

(*b*) How does the foundation and working conditions differ for a tank weir as against a river weir.

(*c*) Where should a tank weir be located in a tank irrigation project ?

7. (*a*) What are dam-stones and where are they installed ? What are their advantages and disadvantages ?

8. What is a surplus weir and its types in an irrigation tank project ? Draw net sketches of the sections of A type weirs with and without water cushion provision.

9. (*a*) What do you mean by a tank sluice, and where is it installed ?

(*b*) Describe the different types of tank sluices indicating the regulation arrangements.

(*c*) For the data given below, design and sketch a tank sluice :

Discharge	= 0.25 cumec
Sill level of sluice	= + 20.00 m.
Top of bank	= + 56.00 m.
Assumed head of discharge	= 0.3 m.
Side slopes of banks in front and rear	= $1\frac{1}{2}:1$

Assume any other data, if required.

10. Write short notes on :

(*i*) Free catchment and combined catchment
(*ii*) Isolated tanks and tanks in series :
(*iii*) Tank bunds
(*iv*) Tank sluices ; and
(*v*) Tank weirs.