Module 4

Hydraulic Structures for Flow Diversion and Storage

Lesson
9
Reservoir Outlet Works

Instructional objectives

On completion of this lesson, the student shall learn:

1. Functions of outlet works
2. Classification of outlet works
3. Determination of design discharge and elevation of outlet works
4. Choice of outlet works and their layout
5. Components of outlet works
6. Hydraulic design of outlet works

4.9.0 Introduction

Water from the reservoir of a dam is released through two principal types of structures:

1. Spillways, which are provided for storage and detention dams to release surplus water or floodwater that cannot be contained in the allotted storage space, and for diversion dams to bypass flows exceeding those turned into the diversion system.

2. Outlet works, which regulate or release water impounded by a dam. It can release incoming flows at a retarded rate, as does a detention dam; it can divert incoming flows into canals or pipelines, as does a diversion dam; or it can release stored waters at rates dictated by downstream needs, by evacuation considerations, or by a combination of multiple-purpose requirements.

Outlet works are so named because they release out water from the reservoir. Some of these are equipped with an Intake Structure if the water is fed into a canal or a conduit for serving some specific purpose like meeting irrigation water requirement or hydropower generation, etc.

Occasionally, the outlet works may be placed at a level high enough to deliver water to a canal, while a bypass is extended to the river to furnish necessary flows below the dam. Such bypass flows may be required to satisfy prior-right uses downstream or to maintain a live stream for abatement of stream pollution, preservation of aquatic life, or other purposes. Dams constructed to provide reservoirs principally for recreation or for fish and wildlife conservation require a fairly constant reservoir level. For such dams an outlet works may be needed only to release the minimum flows necessary to maintain a live stream below the dam. In certain cases, the outlet works of a dam may be used in lieu of a service spillway combined with an auxiliary or secondary spillway. In such a case, the usual outlet works installation might be modified to include a bypass overflow so that the structure can serve as both an outlet works and a spillway.

An outlet work may act as a flood control regulator to release waters temporarily stored in flood control storage space or to deplete the storage of a reservoir in anticipation of flood inflows. Furthermore, the outlets may be used to empty the reservoir to permit inspection, to allow needed repairs, or to maintain the upstream face of the dam or other structures normally inundated. The outlets may also aid in lowering the reservoir storage when controlling objectionable aquatic life in the reservoir is desired. Sometimes reservoirs are lowered and raised in a sequence to control the menace of malaria.

4.9.1 Classification of outlet works

Outlet works structures can be classified according to their purpose, their physical and structural arrangement, or their hydraulic operation. An outlet work that empties directly into a river could be designated a "river outlet"; one that discharges into a canal could be designated a "canal outlet"; and one that delivers water into a closed pipe system could be designated a "pressure pipe outlet." An outlet work may be described according to whether it consists of an open-channel or closed-conduit waterway, or whether the closed waterway is a conduit in cut-and-cover or in a tunnel. An outlet works may also be classified according to its hydraulic operation: whether it is gated or ungated or, for a closed conduit, whether it flows under pressure for part or all of its length or only as a free flow waterway.

Reservoir outlet works facilities may also be divided as those provided in concrete gravity dams or embankment dams. Outlet works through concrete gravity dams are usually called sluices while those through embankment dams are called conduits (if laid below an embankment dam or constructed by cut-and-cover procedure) or tunnels (if excavated through the abutment or foundation). Certain specific requirement of sluices through concrete gravity dams and embankment dams are given below:

a. Concrete Gravity Dams. Generally, sluices that traverse through concrete gravity dams have rectangular cross sections and are short in comparison with conduits through embankment dams of comparable height. Use of a number of small sluices, at one or more elevations provides flexibility in flow regulation and in quantity of water released downstream. Sluices are controlled by gates at the upstream face and/or by gates or valves operated from a gallery in the interior of the dam. Sluices are usually designed so that the outflow discharges onto the spillway face and/or directly into the stilling basin. When sluices traverse through non-overflow sections, a separate energy dissipator must be provided.

b. Embankment Dams. Conduits and/or tunnels for embankment dams may have circular, rectangular, horseshoe, or oblong cross sections and their length is primarily determined by the base width of the embankment. Due to the greater length, it is usually more economical to construct a single large conduit than a number of small conduits. Conduits should be tunneled through the abutment as far from the embankment as practicable, or placed in an open cut through rock in the abutment or on the valley floor. Gates and/or valves in an intake tower in the reservoir, in a central control shaft in the abutment or embankment, or at the outlet portal are used to control the flow. Generally, placement of the control device at the outlet portal should be avoided when the conduit passes through the embankment due to the inherent dangers of a possible rupture of a conduit subject to full reservoir head. Diversion during construction or reservoir evacuation requirements, especially on large streams, may govern the size and elevation of the conduit(s).

4.9.2 Functions of outlet works

1. **Flood Control.** Flood control outlets are designed for relatively large capacities where close regulation of flow is less important than are other requirements. Although control of the outflow by gates is usually provided, the conduits may be ungated, in which case the reservoir is low or empty except in time of flood. When large discharges must he released under high heads, the design of gates, water passages, and energy dissipator should be carefully developed. Multilevel release provisions are often necessary for water quality purposes.

2. **Navigation.** Reservoirs that store water for subsequent release to downstream navigation usually discharge at lower capacity than flood control reservoirs, but the need for close regulation of the flow is more important. The navigation season often coincides with the season of low rainfall, and close regulation aids in the conservation of water. Outlet works that control discharges for navigation purposes are required to operate continuously over long periods of time. The designer should consider the greater operation and maintenance problems involved in continuous operation.

3. **Irrigation.** The gates or valves for controlling irrigation flows are often basically different from those used for flood control due to the necessity for close regulation and conservation of water in arid regions. Irrigation discharge facilities are normally much smaller in size than flood regulation outlets. The irrigation outlet sometimes discharges into a canal or conduit rather than to the original riverbed. These canals or conduits are usually at a higher level than the bed of the stream. This has been implemented for the canal off-taking from the Sardar Sarovar Dam on River Narmada. At other times, irrigation releases are let down to the river from where a barrage downstream picks up the flow and diverts it into an irrigation canal. For example, Bhakra Dam and Nangal Barrage on River Sutlej, Maithon dam and Durgapur Barrage on River Damodar and Hirakud Dam and Mahanadi Barrage on River Mahanadi etc. were built in conjunction with one another to serve a similar purpose.

4. **Water Supply.** Municipal water supply intakes are sometimes provided in dams built primarily for other purposes. Such problems as future water supply requirements and peak demands for a municipality or industry should be determined in cooperation with engineers representing local interests. Reliability of service and quality of water are of prime importance in water supply problems. Multiple intakes

and control mechanisms are often installed to assure reliability, to enable the water to be drawn from any selected reservoir level to obtain water of a desired temperature, and/or to draw from a stratum relatively free from silt or algae or other undesirable contents. Ease of maintenance repair without interruption of service is of primary importance. An emergency closure gate for priority use by the resident engineer is required for water supply conduits through the dam.

5. **Power.** For generation of hydropower, intake structures direct water from the reservoir into the penstock or power conduit. Gates or valves are used to shut off the flow of water to permit emergency unit shutdown or turbine and penstock maintenance. Racks or screens prevent trash and debris from entering the turbine units. Where the powerhouse is integral with the dam, the intake is part of the dam structure. Where the powerhouse is not part of the dam, a separate intake structure must be provided. Projects that are required to use water at a selected temperature must have multi-level intakes in order to control inlet water quality by mixing waters obtained from different levels.

6. **Low-Flow Requirements.** Continuous low-flow releases are required at some dams to satisfy environmental objectives, water supply, downstream water rights, etc. To meet these requirements multilevel intakes, skimmer weirs, or other provisions must be incorporated separately or in combination with other functions of the outlet works facility. Special provisions for these purposes have to be incorporated in concrete gravity dam non-overflow sections. Embankment dams with mid-tunnel control shafts also require special considerations for low-flow releases.

7. **Diversion.** Flood control outlets may be used for total or partial diversion of the stream from its natural channel during construction of the dam. Such use is especially adaptable for earth dams.

8. **Drawdown.** Requirements for low-level discharge facilities for drawdown of impoundments may also provide flexibility in future project operation for anticipated needs, such as major repairs of the structure, environmental controls, or changes in reservoir regulation.

4.9.3 Determination of design discharge capacities

Outlet works are designed to release water at specific rates. These rates are dictated by downstream needs, by flood control regulation, by storage considerations, by power generation needs (where the outlet works is used as the penstock for power plants), and by legal requirements. Delivery of irrigation water is usually determined from project or farm needs and is related to the consumptive use and to the special water requirements of the irrigation system. Delivery for domestic use can be similarly established. Releases of flows to satisfy prior rights must generally be included with other needed releases. Minimum downstream flows for pollution abatement, fish preservation, and associated needs are often accommodated through other required releases. A small bypass pipe is often used to provide these minimum releases. This pipe usually originates at the gate chamber or in the downstream control structure, depending on the type of outlet works.

Irrigation outlet capacities are determined from reservoir operation studies. They must be based on a consideration of a critical period of low runoff when reservoir storages are low and daily irrigation demands are at their peak. The most critical draft from the reservoir, considering such demands (commensurate with remaining reservoir storage) together with prior rights and other needed releases, generally determines the minimum irrigation outlet capacity. These requirements are stated in terms of discharge at either a given reservoir content or a given water surface elevation. Evacuation of water stored in an allocated flood control storage space of a reservoir can be accomplished through a gated spillway at the higher reservoir levels or through an outlet at the lower levels.

Flood control releases generally can be combined with the irrigation releases if the outlet empties into a river instead of into a canal. The capacity of a flood control outlet can be determined by the required time of evacuation of the given storage space, considering the inflow into the reservoir during the evacuation. Combined flood control and irrigation releases ordinarily must not exceed the safe channel capacity of the river downstream from the dam and must allow for all anticipated inflows immediately below the dam. These inflows may be natural run-offs, or the results of releases from storage developments along the river or from developments on tributaries emptying into the river.

If an outlet is to serve as a service spillway in releasing surplus inflows from the reservoir, the discharge required for this purpose may determine the outlet capacity. Similarly, the minimum outlet capacity can be determined by the discharge and the time required to empty the reservoir for inspection, maintenance, repair, or emergency drawdown. Here again, the inflow into the reservoir during the emptying period must be considered. The capacity at low reservoir level should be at least equal to the average inflow expected during the maintenance or repair period. It can, of course, be assumed that required repair will be delayed until service demands are light and that repairs will be made during low inflow and during seasons favorable to such construction.

An outlet works cut-and-cover conduit or tunnel is often used to divert the river flow during the construction period, precluding supplementary installations for that purpose. The outlet structure size dictated by this use, rather than the size dictated by ordinary outlet works requirements, may determine the final outlet works capacity. A diversion bypass pipe may be required to satisfy downstream requirements during placement of second-stage concrete and gates in the outlet works.

4.9.4 Position (elevation) of outlet works in relation to reservoir storage levels

The establishment of the intake level and the elevations of the outlet controls and the conveyance passageway, as they relate to the reservoir storage levels, are influenced by many factors. Primarily, to attain the required discharge capacity, the outlet must be placed sufficiently below the minimum reservoir operating level to provide the head required for outlet works flows.

Outlet works for small detention dams are generally constructed near riverbed level because permanent storage space, except for silt retention, is ordinarily not provided. These outlet works may be ungated to retard the outflow while the reservoir temporarily stores the bulk of the flood runoff, or they may be gated to regulate the releases of the temporarily stored waters. If the purpose of the dam is only to raise the reservoir and divert incoming flows at low heads, the main outlet works generally should be an intake or regulating structure at a high level. A sluiceway or small bypass outlet should also be provided to furnish water to the river downstream or to drain the water from behind the dam during off-season periods. Dams that impound water for irrigation, for domestic use, or for other conservation purposes, must have outlet works low enough to draw the reservoir down to the bottom of the allocated storage space; however, the outlet works may be placed above the riverbed, depending on the established minimum reservoir storage level. It is common practice to make an allowance in a storage reservoir for inactive storage to accommodate sediment deposition, for fish and wildlife conservation, and for recreation. The positioning of the intake sill then becomes an important consideration; it must be high enough to prevent interference from the sediment deposits, but at the same time, low enough to permit either a partial or a complete drawdown below the top of the inactive storage.

Where an outlet is placed at riverbed level to accommodate the construction diversion plan or to drain the reservoir, the operating sill may be placed at a higher level to provide a sediment and debris basin and other desired inactive storage space, or the intake may be designed to permit raising the sill as sediment accumulates. During construction, a temporary diversion opening may be formed in the base of the intake to handle diversion flows. Later, this opening may be plugged. For emptying the reservoir, a bypass around the intake may be installed at riverbed level. This bypass may either empty into the lower portion of the conduit or pass under it. Water can be delivered to a canal at a higher level by a pressure riser pipe connecting the conduit to the canal.

4.9.5 Choice of outlet works and their layout

The layout of an outlet work is influenced by many conditions relating to the hydraulic requirements, to the site adaptability, to the interrelation of the outlet works and the construction procedures, and to the other appurtenances of the development. Thus, an outlet work leading to a high-level canal or into a closed pipeline might differ from one emptying into the river. Similarly, a scheme in which the outlet works is used for diversion might vary from one where diversion is effected by other means. In certain instances, the proximity of the spillway may permit combining some of the outlet works and spillway components in a single structure. For example, the spillway and outlet works layout might be arranged so that discharges from both empty into a common stilling basin.

The topography and geology of a site may have a great influence on the layout selection. Some sites may be suited only for a cut-and-cover conduit type of outlet works; whereas, at other sites, either a cut-and-cover conduit or a tunnel may be selected. Unfavorable foundation geology, such as deep over-burdens or inferior foundation rock, precludes the selection of a tunnel scheme. On the other hand, sites in narrow canyons with steep abutments may make a tunnel outlet the only choice. Because of confined working space and excessive costs where hand-construction methods must be used, building a tunnel smaller than about 2 metre in diameter is not practicable. However, a cut-and-cover conduit can be built to almost any size if it is precast or cast-in-place with the inside bore formed by a pre-fabricated liner. Thus, the minimum size dictated by construction conditions, more than the size dictated by hydraulic requirements, influences the choice of either the cut-and-cover conduit or the tunnel scheme. The amount of load to be taken by a conduit will also affect this choice.

The outlet works for a low dam, whether it is to divert water into a canal or release it to the river, often consists of an open-channel or cut-and-cover structure at the dam abutment. The structure may consist of a conventional open flume or rectangular channel with a gate similar to that used for ordinary spillway installations, or it may be regulated by a submerged gate placed to close off openings in a curtain or headwall. Where the outlet is to be placed through a low earthfill embankment, a closed structure may be used. This structure may consist of single or multiple units of buried pipe or box culverts placed through or under the embankment. Flow for such an installation could be controlled by gates placed at the inlet or at an intermediate point along the conduit, such as at the crest of the embankment, where a shaft would be provided for gate operation. Downstream from the control structure, the channel would continue to the canal or to the river where, depending on the exit velocities, a stilling device. Figure I shows typical installations of the arrangements described above.

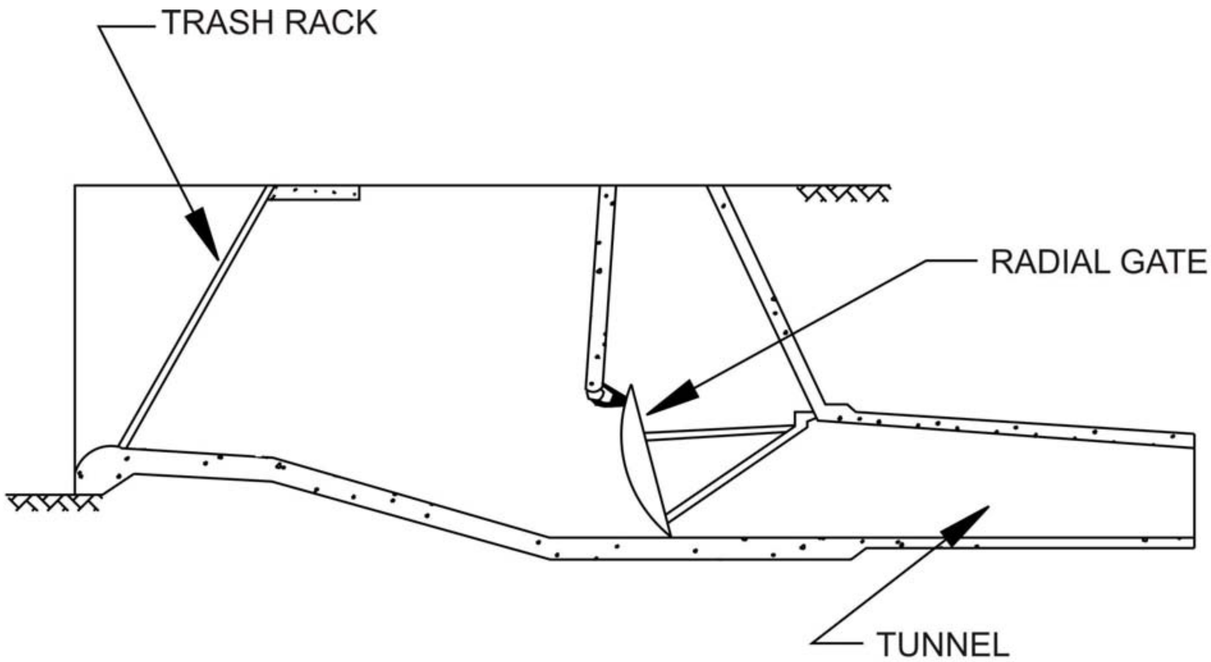

FIGURE 1. OUTLET FOR LOW-HEAD INSTALLATION WITH FREE-FLOW DOWNSTREAM TUNNEL

For higher earthfill dams, where an open-channel outlet structure would not prove feasible, the outlet might be carried through, under, or around the dam as a cut-and-cover conduit or through the abutment as a tunnel. Depending on the position of the control device, the conduit or tunnel may be free flowing, flowing under pressure for a portion of its length, or flowing under pressure for its entire length. Intakes may be arranged to draw water from the bottom of the reservoir, or the inlet sills may be placed at some higher reservoir level. Dissipating devices may be used at the downstream end of the conduit. The outlet works also may discharge into the spillway stilling basin. Depending on the method of control and the flow conditions in the structure, access to the operating gates may be by bridge to an upstream intake tower, by shaft from the crest level of the dam, by walkway within the conduit or tunnel with entrance from the downstream end, or by a separate conduit or tunnel access adit. Arrangements typical of those described above are shown on Figures 2 through 5.

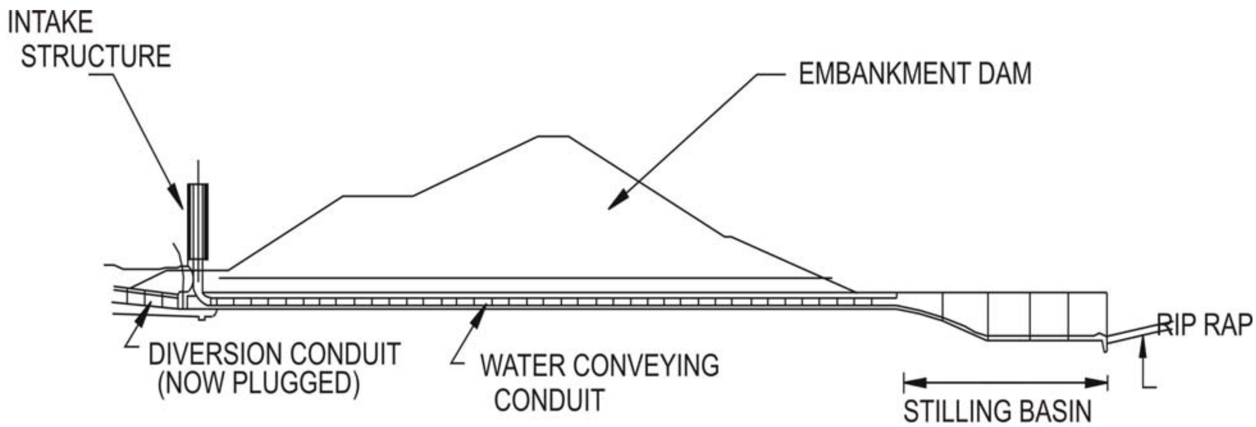

FIG2. OUTLET FOR INTAKES OF MEDIUM HEAD INSTALLATION WITH FREE-FLOW CONDUIT AND HYDRAULIC JUMP STILLING BASIN

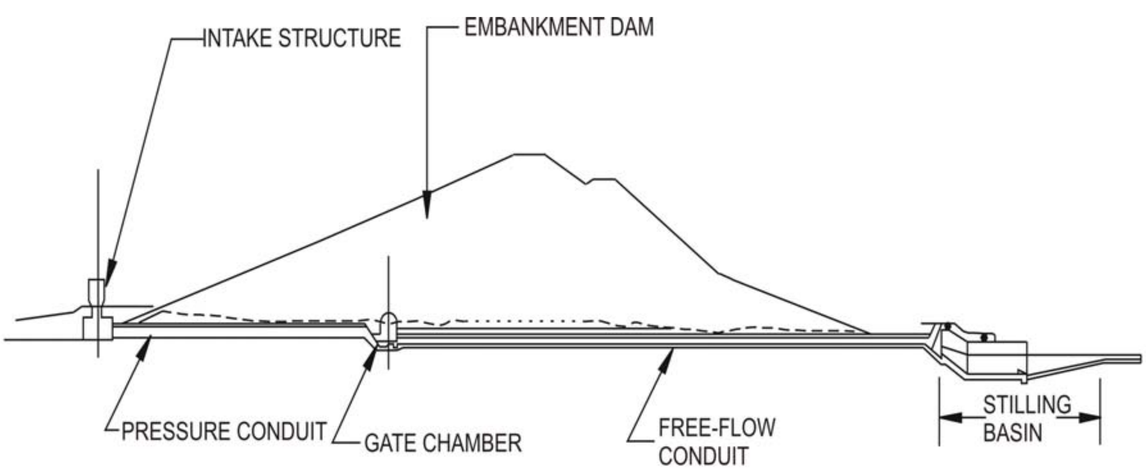

FIG3. OUTLET WIYH A PRESSURE CONDUIT UPSTREAM OF GATE CHAMBER AND FREE-FLOW PIPE IN DOWNSTREAM

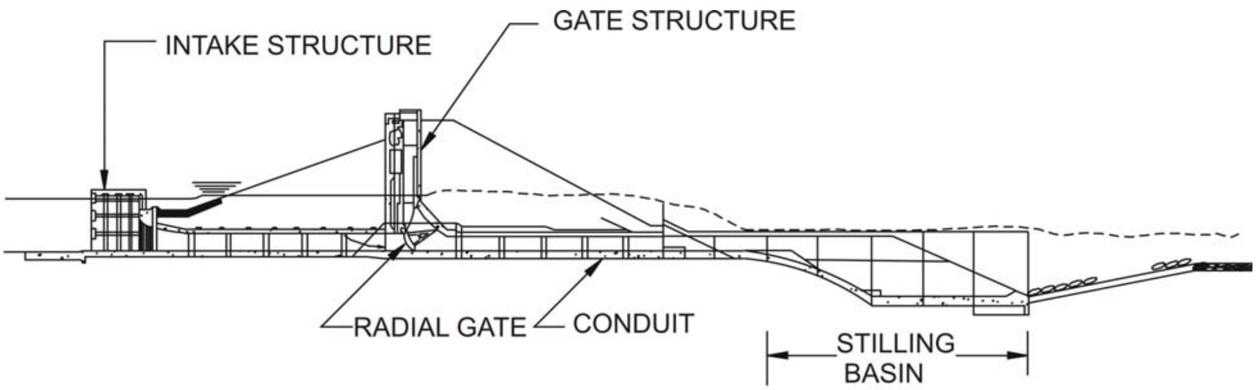

FIG4. OUTLET EITH A TRASH-RACK BOX INTAKE,PRESSURE CONDUIT ON UPSTREAM AND FREE FLOW CONDUIT ON DOWNSTREAM

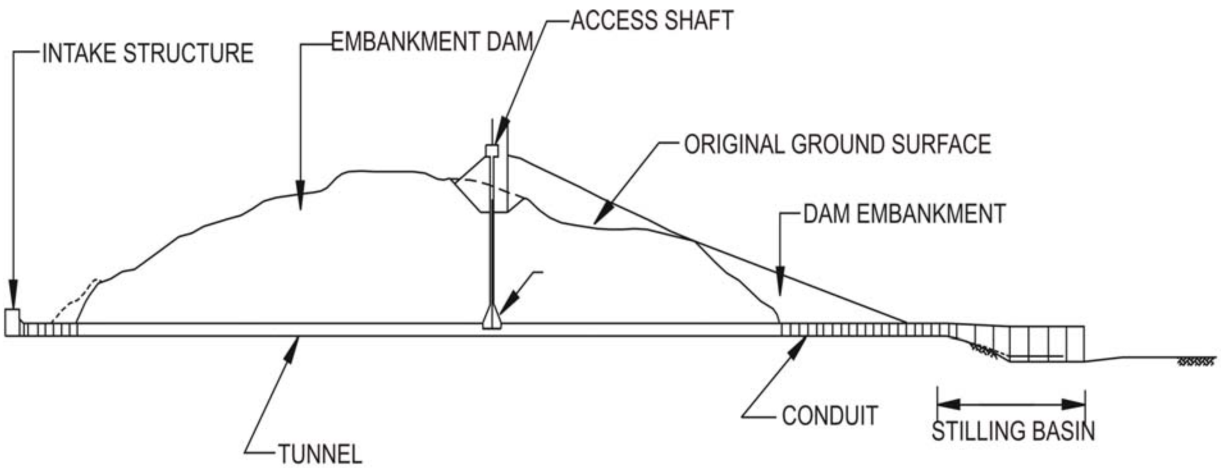

FIG5. OUTLET WITH TRASHRACK INTAKE STRUCTURE,PRESSURE TUNNEL UPSTREAM OF GATE CHAMBER,FREE TUNNEL AND CONDUIT ON DOWNSTREAM

For a concrete dam, the outlet works installation should usually be carried through the dam as a formed conduit or a sluice, or as a pipe embedded in the concrete mass. Intakes and terminal devices may be attached to the upstream and downstream faces of the dam. Often, the outlet is formed through the spillway overflow section using a common stilling basin to dissipate both spillway and outlet works flows. Where an outlet works conduit is installed in the non-overflow section of the dam or where an outlet must empty into a canal, a separate dissipating device will, of course, be necessary. Instead of one large conduit, several smaller conduits may be used in a concrete dam to provide a less expensive and more feasible arrangement for handling the outlet works releases. The multiple conduits may be placed at a single level or, for added flexibility, at several levels. Such an arrangement would reduce the cost of the control gates because of the lower heads on the upper-level gates. Details of typical outlet works installations for the concrete dam at Bhakra are shown in Figures 6 and 7.

A diversion tunnel used during the construction of a concrete dam can often be converted into a permanent outlet works by providing outlet sluices or conduits through the tunnel plug. Ordinarily, the diversion tunnel for a concrete dam will be in good quality rock and will therefore require little lining protection. Furthermore, the outlet portal of the tunnel will generally be located far enough downstream from the dam so that no dissipating structure will be needed or, at most, only a deflector will be required to direct the flow to the downstream river channel.

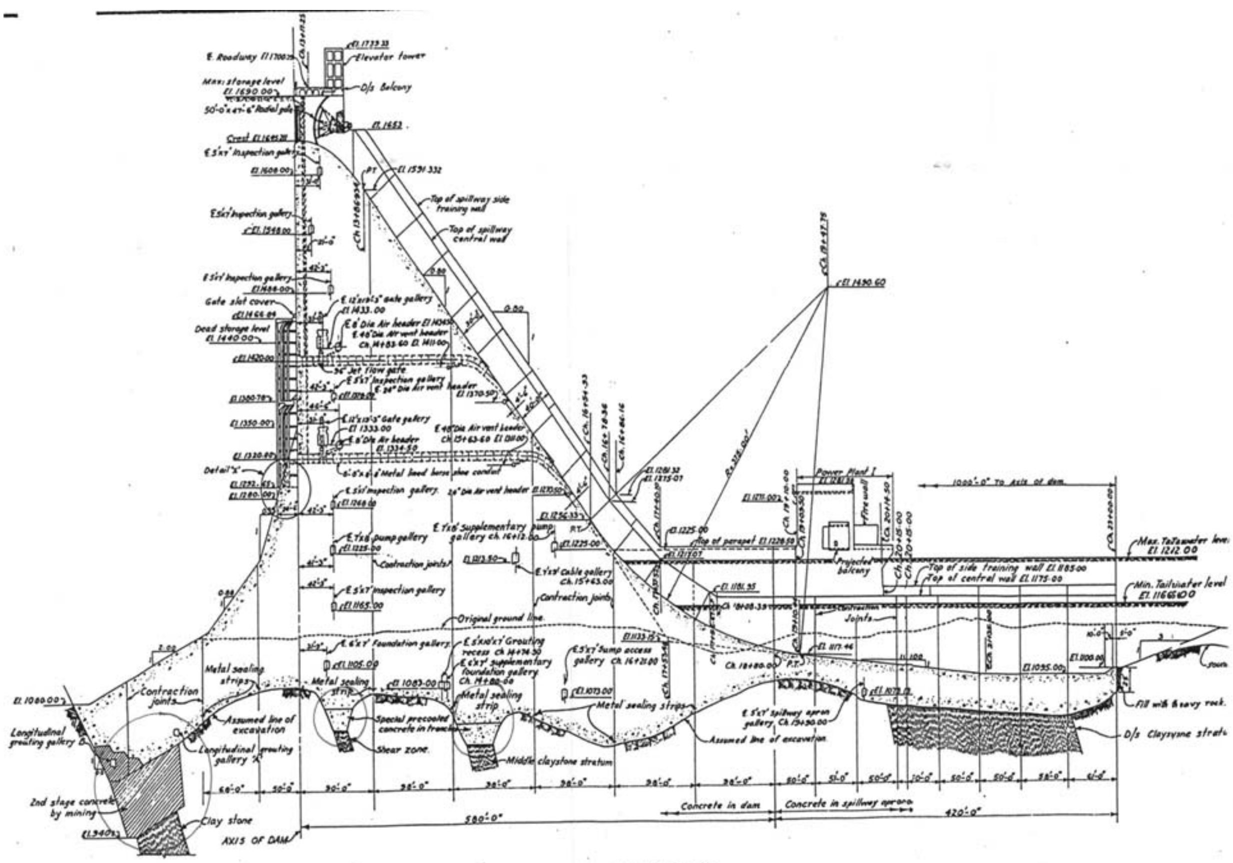

FIGURE 6. MAXIMUM SPILLWAY SECTION OF BHAKRA DAM SHOWING RIVER OUTLETS

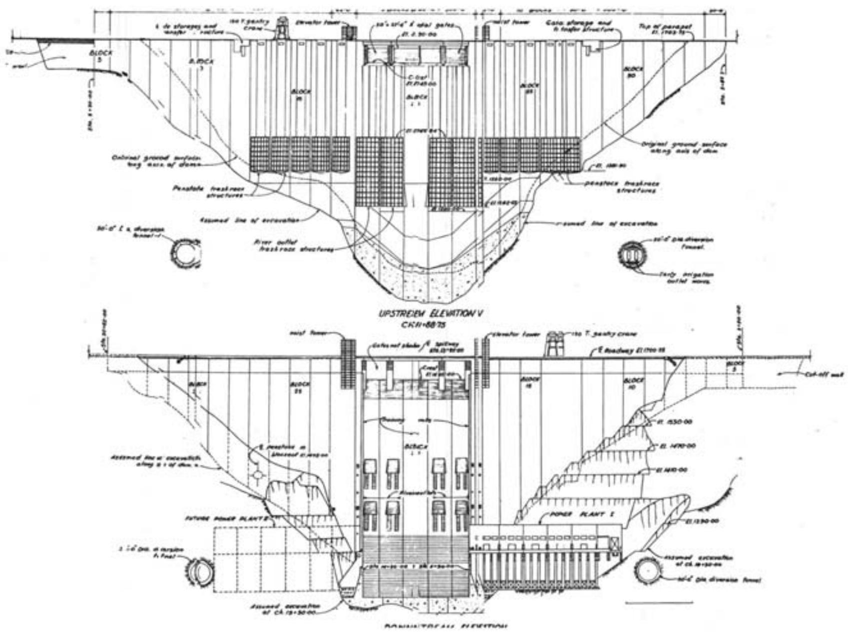

FIGURE 7. UPSTREAM AND DOWNSTREAM ELEVATION OF BHAKRA DAM SHEARING POSITION OF RIVERS OUTLETS

4.9.6 Components of outlet works

For an open-channel outlet works or for a conduit-type outlet where partial full flow prevails, the control gates or valves should determine the outlet works capacity. Where an outlet works operates as a pressure pipe, the size of the waterway and that of the control device should determine the capacity. The overall size of an outlet works is determined by its hydraulic head and the required discharge. The selection of the size of some of the component parts of the structure, such as the tunnel, is dictated by practical considerations or by interrelated requirements such as diversion, reservoir evacuation, and initial filling.

When the type of waterway has been chosen and the method of control established, the associated structures to complete the layout can be selected. The type of intake structure depends on its location and function and on the various appurtenances, such as fish-screens, trash racks, stop log arrangements, or operating platforms that must be furnished. A means for dissipating the energy of flow before returning the discharge to the river should normally be provided. This can be accomplished by a flip bucket, a stilling basin, a baffled apron drop, a stilling well, or a similar dissipation device. Gate chambers, control platforms, or enclosures may be required to provide operating space and protective housing for the control devices. An outlet works may also require an outlet channel to return releases to the river and an entrance channel to lead diversion flows or low-reservoir flows to the intake structure.

Tunnels

Because of its inherent advantages, a tunnel outlet works is preferred where abutment and foundation conditions permit its use and it is more economical than the other types of outlet works. A tunnel is not in direct contact with the dam embankment and, therefore, provides a much safer and more durable layout than can be achieved with a cut-and-cover conduit. Little foundation settlement, differential movement, and structural displacement is experienced with a tunnel that has been bored through competent abutment material, and seepage along the outer surfaces of the tunnel lining or leakage into the material surrounding the tunnel is less serious. Furthermore, it is less likely that failure of some portion of a tunnel would cause failure of the dam than the failure of a cut-and-cover conduit that passes under or through the dam.

Cut-and-Cover Conduits

If a closed conduit is to be provided and foundation conditions are not suitable for a tunnel, or if the required size of the waterway is too small to justify the minimum sized tunnel, a cut-and-cover conduit should be used. Because this type of conduit passes through or under the dam, conservative and safe designs must be used. Numerous failures of earthfill dams caused by improperly designed or constructed cut-and-cover outlet conduits have demonstrated the need for conservative procedures.

Control Devices

Selection of the outlet works arrangement should be based on the use of commercially available gates and valves or relatively simple gate designs where possible. The use of special devices that involve expensive design and fabrication costs should be avoided. Cast iron slide gates, which may be used for control and guard gates, are available for both rectangular and circular openings and for design heads up to about 15 metre. However, higher head installations require special gate designs. Simple radial gates are available for ordinary surface installations, and top-seal radial gates can be secured from manufacturers on the basis of simple designs and specifications. For low heads up to about 15 metre, commercial gate and butterfly valves are suitable for control at the downstream end of pressure pipes if they are designed to operate under free discharge conditions with the jet well aerated all around. Gate and butterfly valves are also suitable for use as inline guard valves and can be adapted for inline control valves if air venting and adequate aeration of the discharge jet are provided immediately downstream from the valve.

The control gate for an outlet works may be placed at the upstream end of the conduit, at an intermediate point along its length, or at the lower end of the structure. Where flow from a control gate is released directly into the open as free discharge, only that portion of the conduit upstream from the gate is under pressure. Where a control gate or valve is placed at the lower end of the structure, full internal pressure should be considered in the design of the conduit tunnel or pipe. However, when a control discharges into a free-flow conduit, the location of the control gate becomes important in the design of the outlet. Upstream gate controls for conduits are generally placed in a tower structure with the gate hoists mounted on the operating deck (Figure 2). With this arrangement, the tower must extend above the maximum water surface. If controls are to be located at some intermediate point along the conduit, high-pressure gates, slide gates, and top-seal radial gates may be used. These controls may be located in a wet-well shaft that extends vertically from the conduit level to the crest of the dam. Typical arrangements of these installations are shown in Figures 1 to 4.

Intake Structures

In addition to forming the entrance to the outlet works, an intake structure may accommodate control devices. It also supports necessary auxiliary appurtenances (such as trashracks, fishscreens, and bypass devices), and it may include temporary diversion openings and provisions for installation of bulkhead or stoplog closure devices. Intake structures may appear in many forms. The type of intake structure selected should be based on several factors: the functions it must serve, the range in reservoir head under which it must operate, the discharge it must handle, the frequency of reservoir drawdown, the trash conditions in the reservoir (which will determine the need for or the frequency of cleaning of the trashracks), reservoir wave action that could affect the stability, and other similar considerations. Depending on its function, an intake structure may be either submerged or extended in the form of a tower above the maximum reservoir water surface. A tower must be provided if the controls are placed at the intake, or if an operating platform is needed for trash removal, maintaining and cleaning fish-screens, or installing stoplogs. Where the structure serves only as an entrance to the outlet conduit and where trash cleaning is ordinarily not required, a submerged structure may be adopted.

The necessity for trashracks on an outlet works depends on the size of the sluice or conduit, the type of control device used, the nature of the trash burden in the reservoir, the use of the water, the need for excluding small trash from the outflow, and other factors. These factors determine the type of trashracks and the size of the openings. Where an outlet consists of a small conduit with valve controls, closely spaced trash bars are needed to exclude small trash. Where an outlet involves a large conduit with large slide-gate controls, the racks can be more widely spaced. If there is no danger of clogging or damage from small trash, a trashrack may consist simply of struts and beams placed to exclude only larger trees and similarly sized floating debris. The rack arrangement should also be based on the accessibility for removing accumulated trash. Thus, a submerged rack that seldom will be dewatered must be more substantial than one at or near the surface. Similarly, an outlet with controls at the entrance, where the gates can be jammed by trash protruding through the rack bars, must have a more substantial rack arrangement than one whose controls are not at the entrance.

Energy Dissipating Arrangements

The discharge from an outlet, whether of a gate valve, or free flow conduit, will emerge at a high velocity, usually in a nearly horizontal direction. If erosion-resistant bedrock exists at shallow depths, the flow may be discharged directly into the river. Otherwise, it should be directed away from the toe of the dam by a deflector. Where erosion is to be minimized, a plunge basin may be excavated and lined with riprap or concrete. When more energy dissipation is required for free flow conduits, the terminal structures described for spillways may be used. The hydraulic-jump basin is most often used for energy dissipation of outlet works discharges. However, flow that emerges from the outlet in the form of a free jet, as is the case for valve-controlled outlets of pressure conduits, must be directed onto the transition floor approaching the basin so it will become uniformly distributed before entering the basin. Otherwise, proper energy dissipation will not be obtained.

Entrance and Outlet Channels

An entrance channel and an outlet channel are often required for a tunnel or cut-and-cover conduit layout. An entrance channel may be required to convey diversion flows to a conduit in an abutment or to deliver water to the outlet works intake during low reservoir stage. And an outlet channel may be required to convey discharges from the end of the outlet works to the river downstream or to a canal.

4.9.7 Hydraulic design of outlets

The hydraulics of outlet works usually involves either open-channel (free) flow or full conduit (pressure) flow. Analysis of open-channel flow in outlet works, either in an open waterway or in a partly-full conduit, is based on the principle of steady nonuniform flow conforming to the law of conservation of energy. Full-pipe flow in closed conduits is based on pressure flow, which involves a study of hydraulic losses to determine the total heads needed to produce the required discharges.

Three types of outlet works are briefly discussed below which are commonly provided in river valley projects.

Sluices in concrete dams

Sluices are provided in the body of the dam to release regulated supplies of water for a variety of purposes which are briefly listed below:

1. River diversion
2. Irrigation
3. Generation of hydro-electric power
4. Water supply for municipal or industrial uses
5. To pass the flood discharge in conjunction with the spillway
6. Flood control regulation to release water temporarily stored in flood control storage space or to evacuate the storage in anticipation of flood inflows
7. Depletion of the reservoir in order to facilitate inspection of the reservoir rim and the upstream face of the dam for carrying out remedial measures, if necessary
8. To furnish necessary flows for satisfying prior right uses downstream
9. For maintenance of a live stream for abatement of stream polation, preservation of aquatic life, etc.

The flow through a sluice may be either pressure flow or free flow along its entire length or a combination of pressure flow in part length and free flow in the remainder part. Sluices are also classified based upon their alignment as:

1. *Straight Barrel Sluice* - The barrel of this sluice is kept nearly horizontal between the entry and exit transitions (Figure 8). This sluice has the advantage of having minimum length due to which lesser friction losses take place. Horizontal sluices are generally used under the following conditions:
   a) When the sluices are drowned at the exit; and
   b) When they have to be located at or near the river bed level, for example, in construction sluices for river diversion.

   The width of the sluice barrel is generally kept uniform throughout the length except in the entry transaction. If the sluice is designed for pressure flow conditions then the top profile of the sluice may be given a slight constriction. On the other hand, if free flow conditions prevail then no such constriction is required.

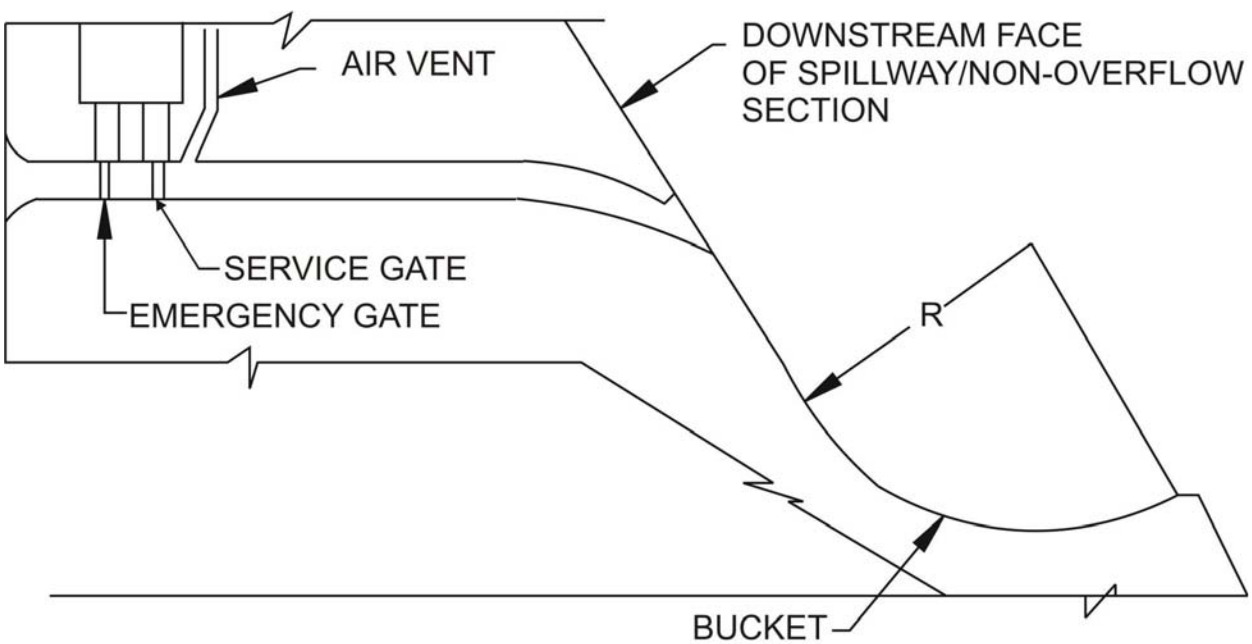

FIGURE 8. STRAIGHT BARREL LUICE

2. Trajectory Type Sluice - The barrel of this sluice is generally kept horizontal downstream of the entry transition up to the service gate to facilitate resting of the latter. Beyond the service gate the bottom of the sluice conforms to the parabolic path of the trajectory and meets the downstream face of the dam section tangentially (Figure 9).

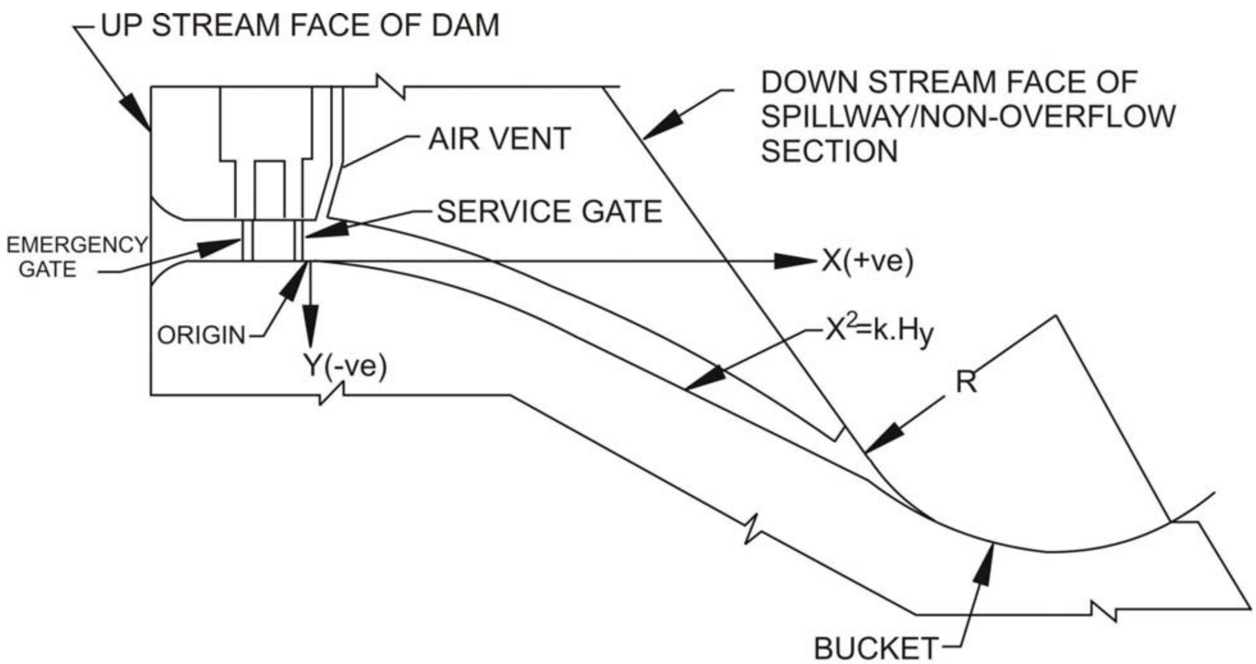

FIGURE 9 . TRAJECTORY TYPE SLUICE

For deciding upon the number and size of sluices, one has to consider the design discharge at a predetermined reservoir elevation. Details of this may be had from the Bureau of Indian Standards code IS: 11485-1985 “Criteria for hydraulic design of sluices in concrete and masonry dams”.

Intakes for irrigation

Two types of intakes are generally used for outlet works meant for releasing irrigation water. These are:

1. Run-of-the-river type intakes, and
2. Reservoir type intakes.

Run-of-the-river type intakes are those which draw water from the fresh continuous river inflows without any appreciable storage upstream of the diversion structure. A typical sketch of intake to meet special characteristics, such as steep slopes, high peaks and short duration flood flows and high sediment loads, is shown in Figure 10. A canal head regulator (discussed in Lesson 4.3) is a typical example of this type of intake constructed upstream of a barrage.

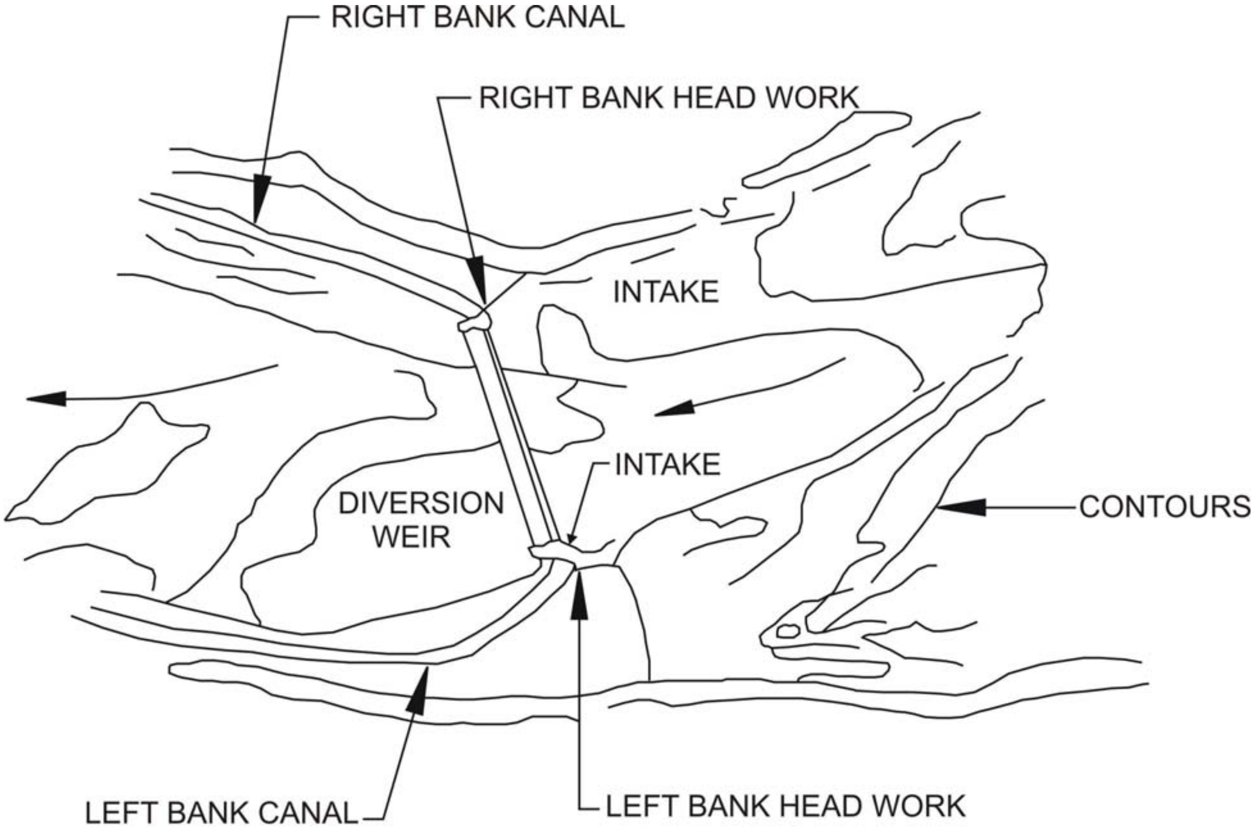

FIG10 a . RUN-OFF RIVER TYPE INTAKE (GENERAL LAYOUT)

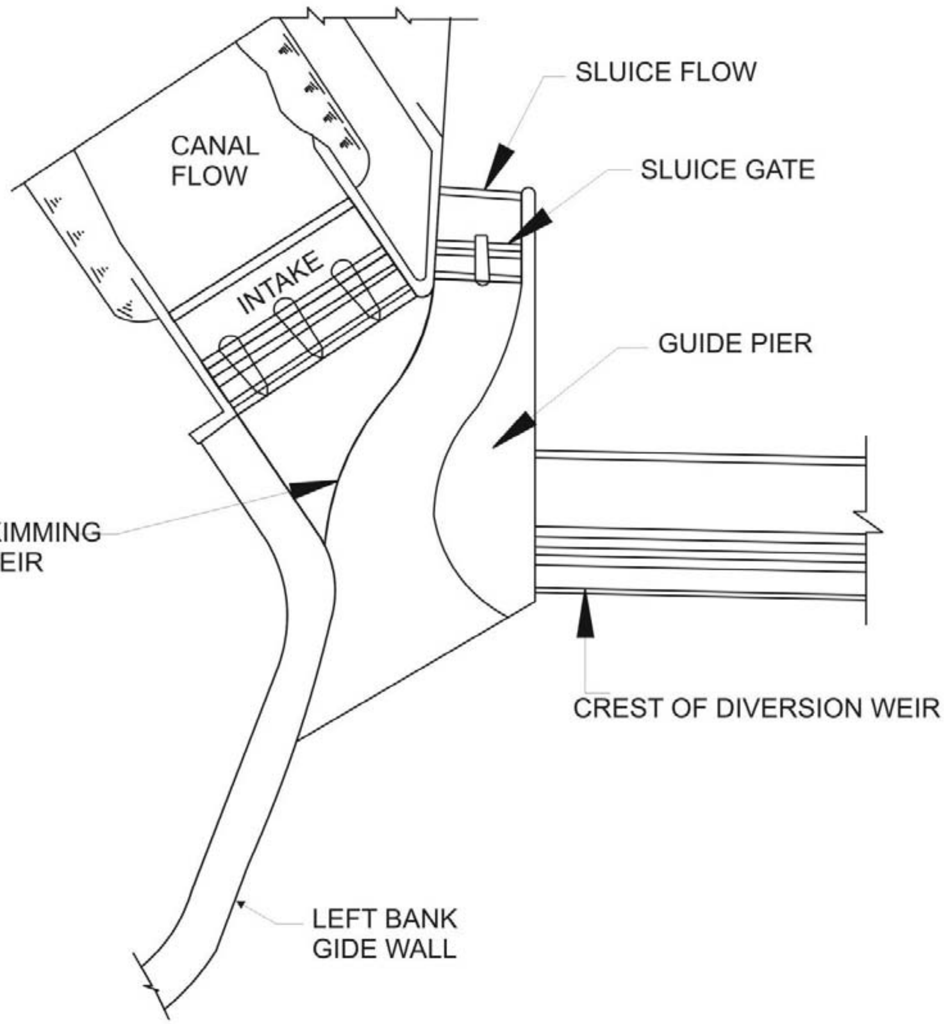

FIGURE 10(b) DETAILS OF INTAKE AND SEDIMENT EXCLUSION DEVICE THROUGH SLUICE

Reservoir type intake is provided where discharges for irrigation are drawn from storage built up for this purpose. Depending on the head, this is further categorized as under:

1. Low head (up to 15 m),
2. Medium head (15 to 30 m), and
3. High head (above 30 m).

Intake in concrete or masonry dams: In the case of concrete dams, irrigation intake structure can be located either at the toe when operating head is low or in the body of the dam itself when operating head is medium or high. Typical section of such an intake is shown in Figure 11.

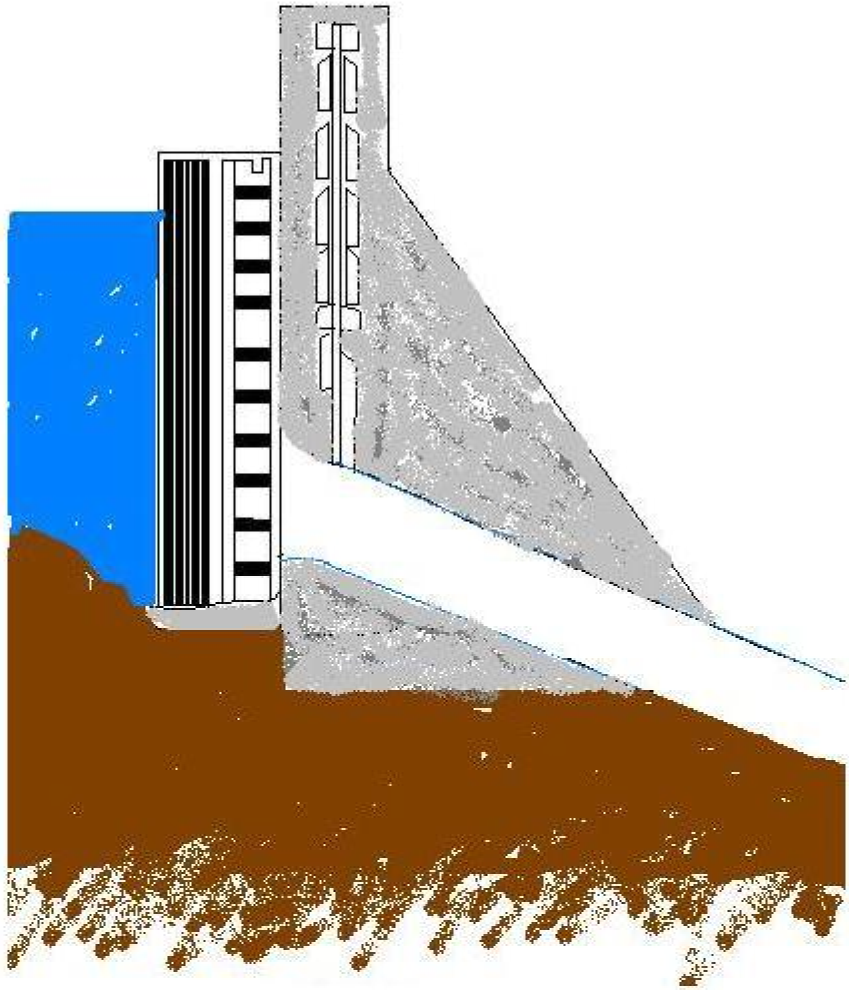

FIGURE 11. Typical intake through a concrete dam

Intake in earthen dams: When the reservoir is formed by an earthen dam, the irrigation tunnel is laid below it or in the abutment. The intake structure for such situations will be a sloping intake or tower type of intake. Typical layouts for sloping and tower type intakes are shown in Figure 12 and 13 respectively. As far as possible, reinforced cement concrete pressurized system should be avoided in the body of the earth dam. Measures like provision of steel liners and suitable drainage downstream of core, provisions of joints for differential settlements when not founded on rock should be considered in case pressure conduits are provided under earth dams.

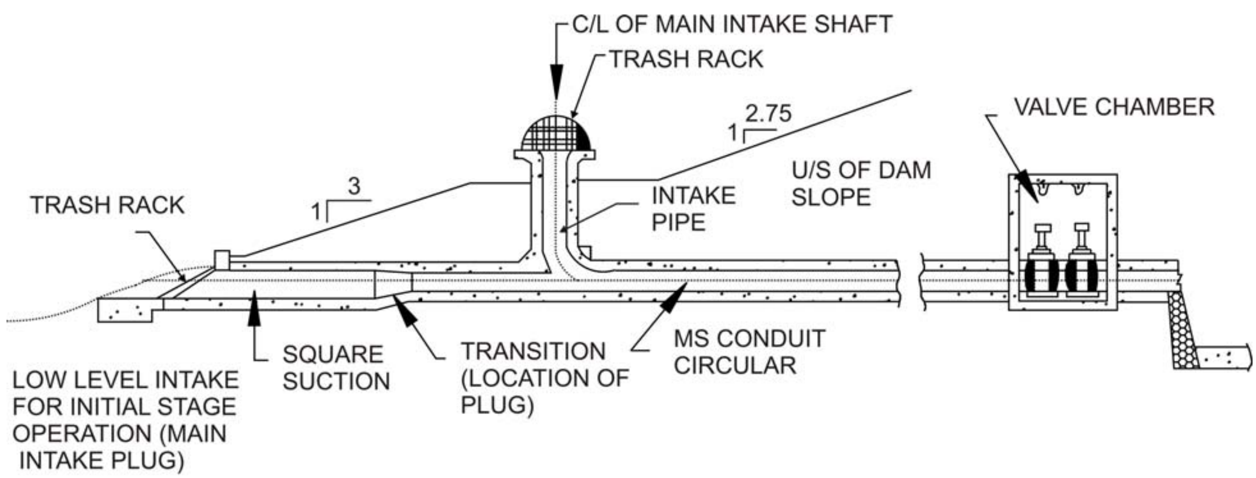

FIGURE12. TYPICAL INSTALLATION IN AN EARTH DAM-SLOPING INTAKE

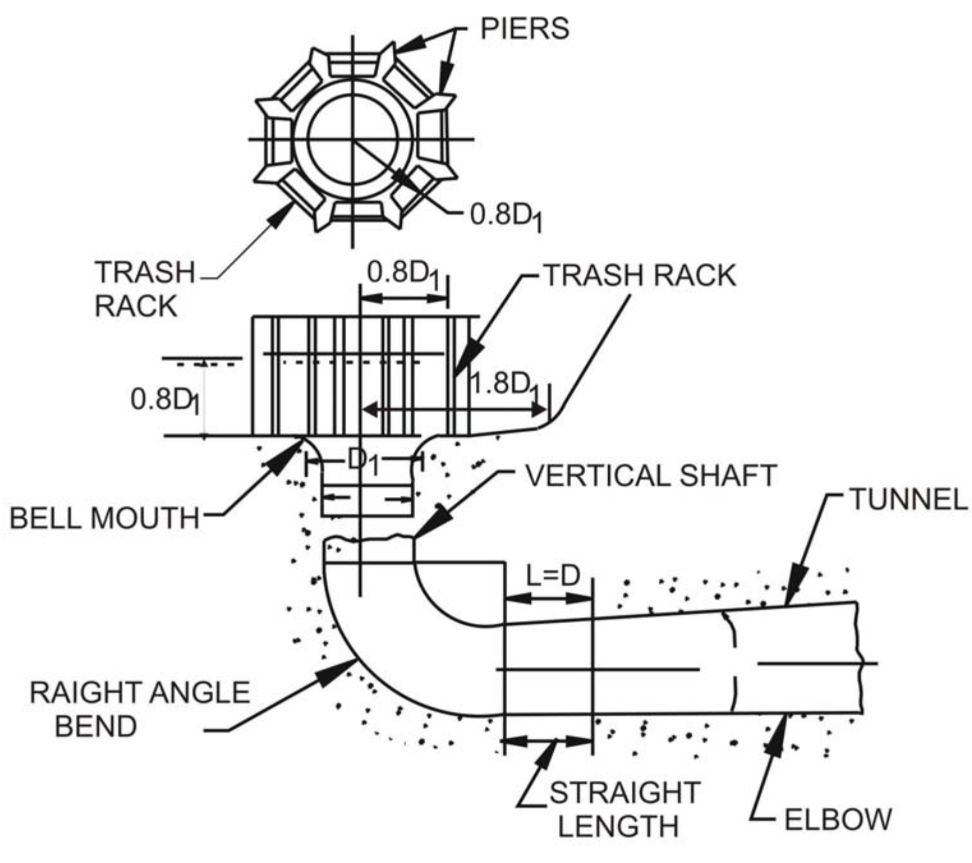

FIGURE 13 TYPICAL INSTALLATION IN AN EARTH DAM OF TOWER TYPE INTAKE

Intakes directly from the reservoir through abutments: In this case, the dam is separated from the intake structure. The dam may be of any material (concrete, earth, etc.) but the intake is constructed by grading the left or right abutments and leading the outlet pipes through the surrounding hills. Figures 14 (a) through (c) show the typical layout, section and plan of such an intake.

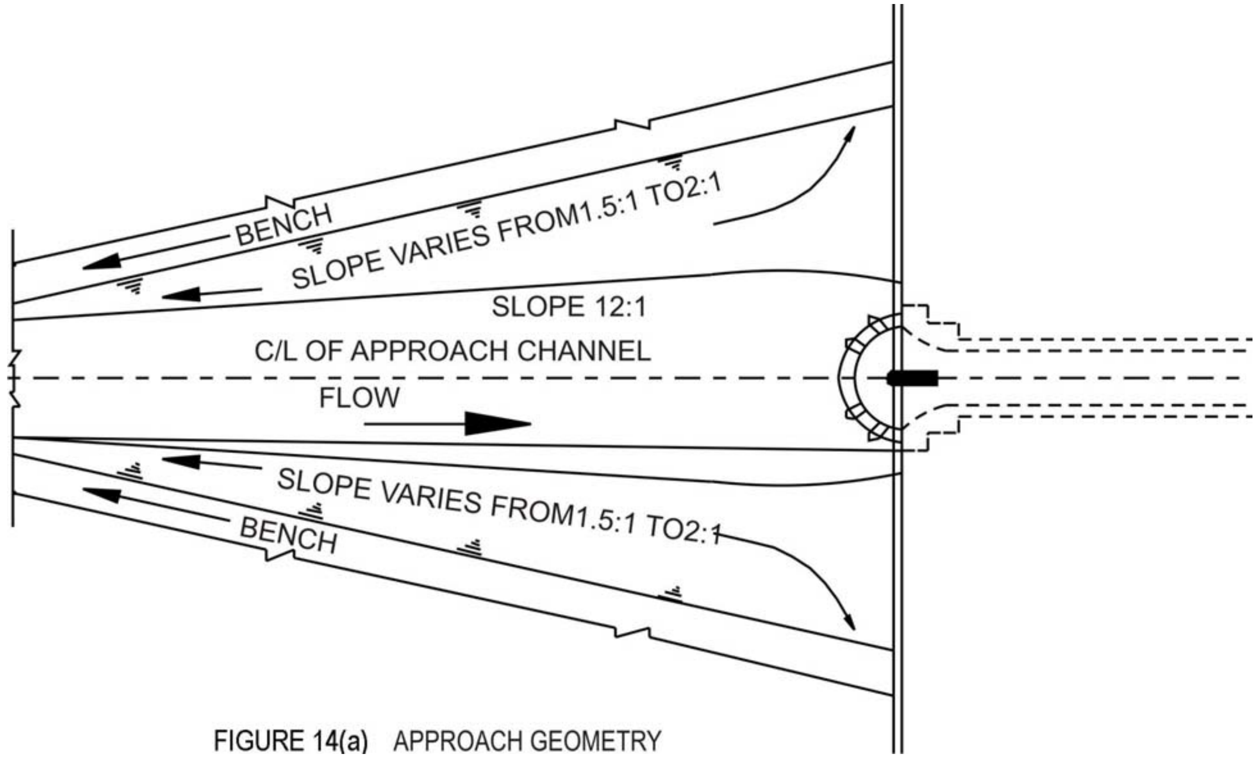

FIGURE 14(a) APPROACH GEOMETRY

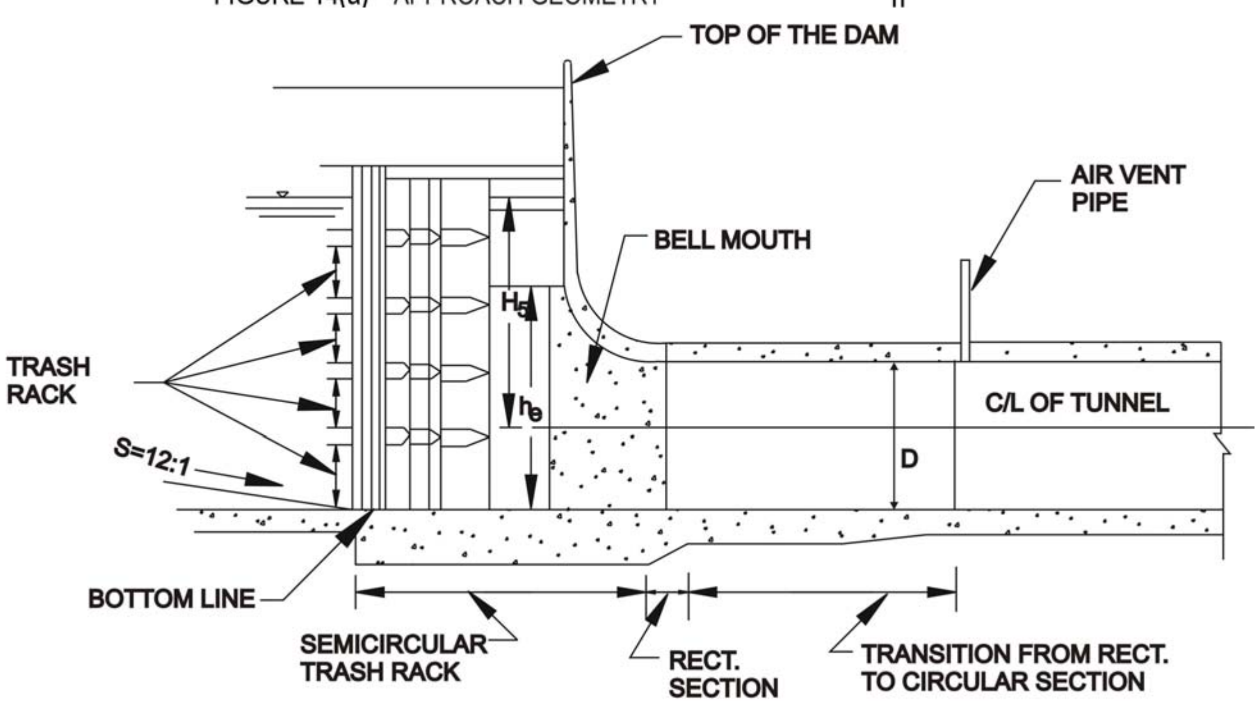

FIGURE 14 (b) SEMICIRCULER TYPE INTAKE STRUCTURE - ELEVATION

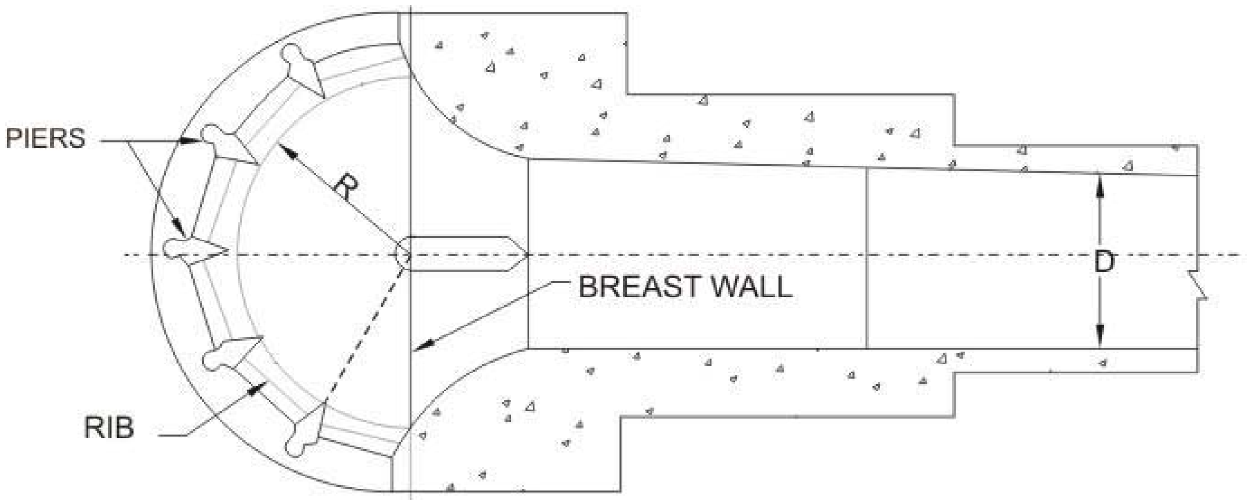

FIGURE 14(c) SEMICIRCULAR TYPE INTAKE STRUCTURE-PLAN

The hydraulic design of the various components of an intake, like the elevation of the centre-line, trash rack structure, bell mouth shape and transition details, etc. may be found from the Bureau of Indian Standards code IS: 11570-1985 “Criteria for hydraulic design of irrigation intake structures”.

Intakes for hydropower

Similar to the irrigation intakes, the hydropower intakes are also of two types:

1. Run-of-the-river type intakes, and
2. Reservoir type intakes.

Both these types of intakes have been discussed in detail in Lesson 5.2. However, it may be mentioned that on the whole, these intakes are quite similar to those constructed for serving irrigation requirements. The Bureau of Indian Standards code IS: 9761-1995 “Hydropower intakes – criteria for hydraulics design” may be referred to finalise details about the hydraulics design of hydropower intakes.