1. *Water Table, Bedrock, and Groundwater Conditions*

Concerns related to the development of a groundwater mound below the wet pond or infiltration facility, as well as the potential for polluting down-gradient groundwater supplies, often arise when infiltration facilities are considered. Based on a limited data base for stormwater impoundments and infiltration facilities, groundwater pollution does not appear to be a problem with most residential and commercial land uses. Under many conditions, the addition of groundwater by means of detention basins is highly desirable.

2. *Runoff Filtering*

Grease, oil, floatable organic materials, and settleable solids should be removed from runoff water before it enters the infiltration basin. These materials take up storage capacity and reduce infiltration rates. Runoff filtering devices such as vegetative filters, sediment traps, and grease traps can be used to remove objectionable materials. A modified basin design such as that illustrated in Figure 11.11 can be used to enhance and prolong the infiltration capacity of the basin. When a runoff filtering system or structure is included, its design must allow adequate maintenance.

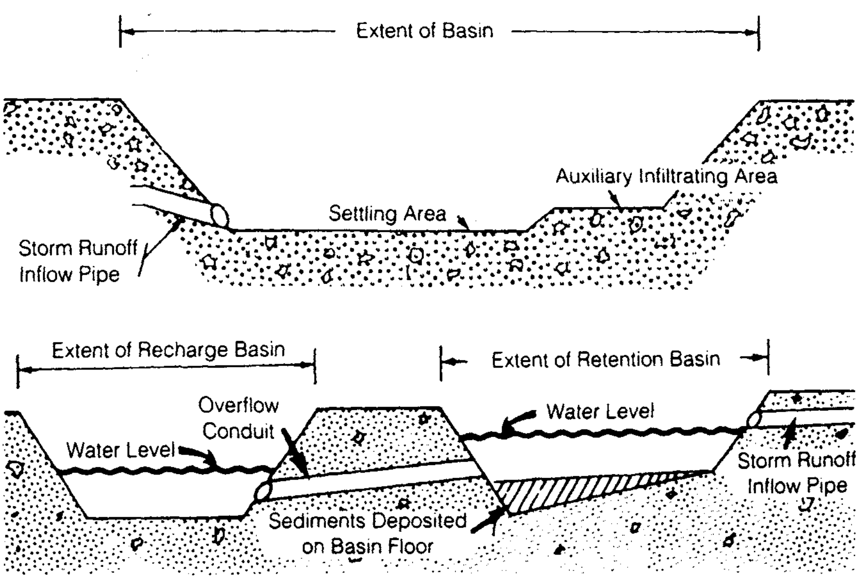


Figure 11.11—Basins to enhance infiltration.

3. *Excavation*

Initial basin excavation should be carried to within 1′ of the final elevation of the basin floor. Final excavation to the finished grade should be deferred until disturbed areas in the watershed have been stabilized or protected. The final excavation should remove all accumulated sediment. Relatively light tracked equipment is recommended for this operation to avoid compaction of the basin floor. After the final grading is completed, the basin floor should be deep-tilled using rotary tillers or disc harrows to provide a well-aerated, highly porous surface texture.

4. *Sediment Control—Vegetated Basins*

The cleanout frequency of infiltration basins will depend on whether they are vegetated or non-vegetated, and will be a function of their storage capacity, recharge characteristics, volume of inflow, and sediment load. Infiltration basins should be inspected at least once a year. Sedimentation basins and traps may require more frequent inspection and cleanout.

Grass bottoms on infiltration basins serve as a good filter material, although they may need occasional replacement. Use grass species that are most likely to work for the region of the country in which the facility is located that can withstand several days of submergence. Well-established turf on a basin floor will grow up through sediment deposits, forming a porous turf and retarding the formation of an impermeable layer. Grass filtration would work well with long, narrow, shoulder-type depressions (swales, ditches, etc.) where highway runoff flows down a grassy slope between the roadway and the basin. Grass planted on basin side slopes will help to prevent erosion.

5. *Sediment Removal From Non-vegetated Basin*

Sediment should be removed only when the basin floor is completely dry, after the silt layer has mud-cracked and separated from the basin floor. Equipment maneuverability and precise blade control are essential, and can greatly reduce the quantity of material to be removed. All sediment must be removed prior to tilling, which should be done at least once annually.

6. *Side Slope Maintenance*

Side slopes should have a dense turf with extensive root growth, which enhances infiltration through the slope surface and prevents weeds from gradually taking over. Grasses of the fescue family are recommended, primarily due to their adaptability to dry sandy soils, drought resistance, hardiness, and ability to withstand brief inundation. The use of fescues will also permit long intervals between mowings. This is important due to the relatively steep slopes which make mowing difficult. Mowing two to three times a year is generally satisfactory.

D. On-stream Impoundments

On-stream impoundments involve the use of the natural valley as the storage basin and the stream channel as the inflow-outflow conduit. Generally, an earth embankment is built to store the flood volume, although overflow structures are also used. Multiple-outlet spillways may be used to meet requirements for control of flows with different return frequencies. Open channels may also be enlarged to serve as stormwater impoundments when enough land is available and the channel has a relatively flat gradient.

On-stream impoundments are usually built as regional detention basins, but may also be on-site facilities built for a single development. In some respects, their design is similar to that of other impoundments. There are, however, some significant points of difference, which include:

(a) The on-stream impoundment must always provide for passing low stream flows. To avoid clogging and to enhance safety, the lowest outlet should be at the level of the stream bed.
(b) As a result of the need to pass low flows, it will usually be impractical to retain small storm flows in the interest of water quality.
(c) Unless the entire watershed above the impoundment is to be controlled, the emergency spillway capacity will be greater, sometimes many times greater, than would be required for an impoundment of similar storage capacity elsewhere. In such cases, an overflow dam may be used to avoid excessive spillway costs.
(d) In areas of erodible soils, sedimentation may be excessive.
(e) Backwater effects may require acquisition of rights-of-way higher than the structure itself.
(f) For on-stream impoundments, vertical drop outlets (such as those used in detention basins) must be designed with caution, because of the need to pass low flows, and because of potential sedimentation.

It should be obvious that on-stream impoundments must be designed with care and put in a proper regional context. **It is very important to note that simplified approaches, such as are often applied for small on-site detention basins, *cannot* be used to design on-stream impoundments.**

E. Oversizing Storm Sewers to serve as Stormwater Impoundments

The oversizing of storm sewers for stormwater impoundments has a narrow area of application (though it is often used in combined sewer systems to provide in-system storage). Such facilities are normally provided when land costs are extraordinarily high. For example, oversized storm sewers serving as stormwater impoundments have been used in connection with commercial developments where parking lot and roof storage availability were inadequate or considered undesirable. Oversizing storm sewers has also been used as a means of mitigating flooding problems in urbanized areas where land was not economically available.

Other limitations may include the oversized sewers' reduced ability to transport sediments, or the lack of a definitive site plan which provides for future stormwater access to the oversized sewer.

1. *Sewer and Intake Sizing*

The required storage volume can be determined by the methods discussed previously and in Chapter 5. The ultimate sewer size will be determined after considering upstream bypass flows, available head, physical constraints, and the overall hydraulics of the stormwater system.

Particular attention must be given to the location and types of intakes (i.e. inlets, catch basins, open grate manholes, and special structures), if the sewer's storage volume is to be fully utilized. In addition to evaluating the hydraulic characteristics of the intake structures, the designer should recognize that the effectiveness of intakes during major storm events can be significantly reduced by debris.

2. *Bypass Considerations*

Upstream bypass flows can rarely be economically conveyed through an oversized sewer impoundment facility, and overland conveyance should be considered.

3. *Sediment Control*

The low velocities that normally characterize oversized sewers require a careful evaluation of sediment deposition and removal. Estimates of the types and quantities of sediment accumulation are required to ascertain future maintenance requirements, and access for periodic sediment removal must be provided.

F. Recreation and Aesthetic Uses

Impoundment areas are often designed to improve the aesthetic quality of developments. Home sites are more valuable if adjacent to a lake; and corporate headquarters and industrial facilities often feature a small lake, which can function as a detention basin or as a water source for firefighting. In favorable climates, ducks and geese or other birds will occupy even a small permanent impoundment, and fish can provide a focus of interest. While the aesthetic qualities associated with any body of water provide benefits to urban and suburban developments, they also involve certain design constraints and maintenance responsibilities. If the impoundment area is to be an aesthetic focal point, the designer should consider the water quality that can be achieved. Runoff from nearby impervious areas could be channeled around the pond to avoid having greases and oils enter the impoundment area. If upstream areas will undergo development, control measures must be installed to prevent large amounts of sediment from entering the impoundment area.

If a permanent pool is to be established it should be as large and deep as possible.

Maintenance of any impoundment area designed to enhance the aesthetic quality of a developed area is extremely important. The designer should provide for easy maintenance of any area adjacent to the pool, of the area within the normal pool elevation including the outlet structure, and of any areas that will contribute runoff to the impoundment area.

When they are not storing water, detention basins should accommodate other uses such as parking; recreation sites ranging from soccer and baseball fields to handball and volley ball courts; and other more passive recreation uses such as shaded picnic sites, trails, and park benches. Some communities allow the impoundment area to be included in the open space areas of a development when calculating the density for zoning purposes. Thus the developer does not lose the total value of this land, though he may have to reorient the site development to accommodate the impoundment area.

When using impoundment areas for other uses it should be remembered that the design must accommodate both uses. Parking areas that are used for impoundments should be designed so the water never reaches depths that would damage parked cars. If some impoundment areas are to be used for soccer and baseball fields, the soils must be such that they will quickly drain to produce a usable playing surface. Any vegetation that is planted in the impoundment area must be able to withstand the expected frequency and depth of inundation.

G. Underground Impoundments

Underground impoundments should generally be avoided, except where site conditions preclude any alternative. They are ordinarily used only for on-site facilities, though there have been some very large systems built (the Chicago TARP project, Milwaukee, San Francisco, etc.). They may consist of one or more parallel tunnels, or a deep basin decked over for some particular purpose. The primary problem is one of maintenance, including the removal of both trash and accumulated sediment. Underground impoundments should be built with adequate maintenance access, and sufficient headroom for the operation of small mechanized equipment. Stahre and Urbonas (1990) provide many practical recommendations concerning the design of underground impoundments, and the reader is encouraged to study this reference before proceeding with the selection or design of such facilities.

H. Pump-Evacuated Impoundments

The control of stormwater may require that runoff be conveyed to retention basins or temporary storage impoundments. If the required storage volume and available surface area are such that the bottom of the required impoundment is below the grade of the conveyance channel, pumping may be required (see also Chapter 9 for a discussion of pump stations). In some instances, it may be possible to drain the upper portion of the impoundment over a control structure near the invert of the conveyance channel. Pumping would then begin sometime after the flood has subsided and the conveyance channel has receded below flood levels. Factors to evaluate during the design of a pump-evacuated impoundment include:

(a) Flood damage reduction versus construction and O & M costs.
(b) Required storage volume versus available surface area.
(c) Depth limitations due to adverse soil conditions.
(d) Groundwater recharge and pollution control.

At least two pumps should be installed to provide redundancy and reduce the probability of failure. An additional small pump is sometimes necessary to handle groundwater seepage. These pumps should be of the submersible type, and of a non-clogging design to allow passage of mud and small debris (see Chapter 9). A substantial concrete structure or pump wet well is usually preferred for support of the pumps. All pumps should be designed to start or stop automatically according to the wet well level or the receiving capability of the downstream channel.

The required storage volume can be determined by developing hydrographs for selected recurrence intervals and simulating the operation of the impoundment. The difference between the inflow and the pumped and gravity outflows is the necessary storage. Several iterations may be required to determine the optimum inlet and outlet configurations. The following examples illustrate the design considerations for pumped evacuated reservoirs.

Example 11-2: Chicago, Illinois—Retention Basin to Eliminate Overbank Flooding This example is from a project constructed near Chicago, Illinois to reduce flooding from a small river in an urbanized region. The objective was to retain flood waters near their point of origin. The project, which was developed to eliminate overbank flooding caused by the 100-year storm was adopted for this comprehensive flood control plan to comply with the standards adopted by federal and local government agencies.

The recommended plan includes upstream channel improvements to increase the river's discharge capacity. A retention basin covering seven acres and with a storage volume of 110 acre feet was planned to intercept and retain a portion of the flood flows. The basin, shown in Figure 11.12, was located adjacent to the river and within the floodplain to minimize costs. By widening and deepening the channel, removing flow obstructions, and constructing a covered concrete conduit where space was restricted, the ability of the river to carry flood flows was increased. The basin invert is well below the conveyance channel, and pump-out facilities were required.

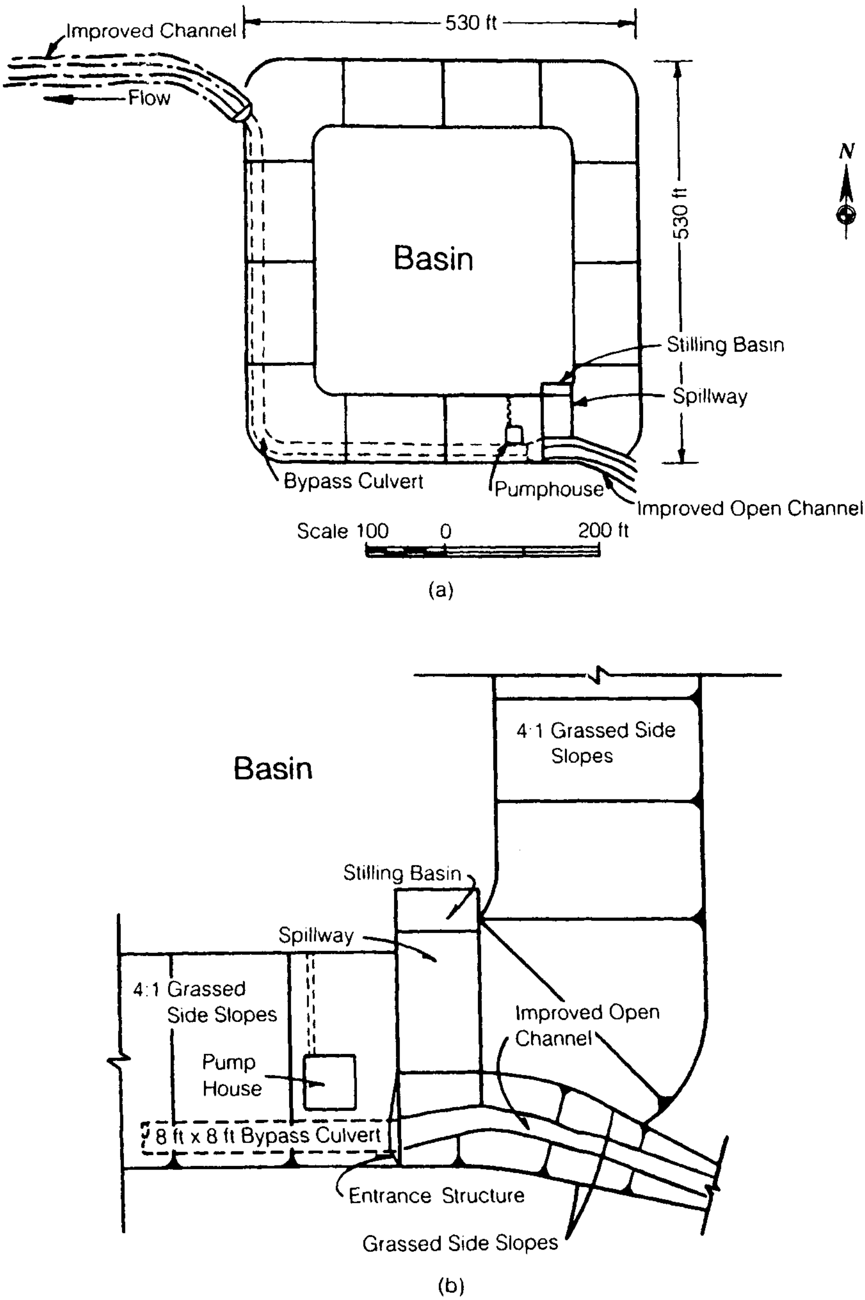


Figure 11.12—(a) Retention basin (Chicago) and (b) inlet detail (ft × 0.304 8 = m).

Flood water will flow into the basin over a concrete spillway and down a concrete lined channel to a stilling basin. For storms with less than a five-year return period, the river storage will not exceed the spillway crest elevation, and the entire flood will bypass the retention basin through an eight-foot square bypass culvert. As the river depth increases, flow in the bypass culvert will increase, up to a maximum of 390 cfs, and flows into the retention basin will be 450 cfs. During the 100-year storm 110 acre-feet of water will be stored in the basin with a maximum depth of 20′. The basin bank slopes are four horizontal to one vertical, which will allow easy access for grass cutting and other maintenance.

Evacuation of water stored in the basin for the 100-year storm will be by gravity backflow over the spillway from elevation 793 to the spillway crest elevation 791. Two manually-started pumps will empty the basin from elevation 791 to the basin bottom elevation 773 in about three days. A smaller, automatically operated sump pump will handle seepage.

The benefits from this project included a 50% reduction in the 100-year flow rate, and increased conveyance.

Example 11-3: Los Angeles, California—Pump-Evacuated Storage Facility The second example illustrates the use of pump-evacuated storage by the Los Angeles County Flood Control District for the Walteria Lake Project. In the design of such facilities, the District employs a 50-year storm which has the maximum rainfall intensity occurring on day four.

The design hydrograph for the Walteria Lake Project is shown on Figure 11.13. It has a peak flow rate of 3,000 cfs and a required storage volume of 1,057 acre-ft. A pump station with four main pumps, each of 55 cfs capacity, is used to drain the basin. After a 50-year design storm, nearly sixty hours of continuous pumping is required to empty the basin.

Figure 11.14 shows the method used to optimize pumping and storage costs. It is usually desirable to thoroughly study the costs of storage, pumping equipment, pump station construction, and operation and maintenance, to balance costs with allowable discharge requirements.

Other inflow hydrographs for different conditions may be found to have different shapes, peaking sooner and with less pronounced maximum inflow than the Walteria Lake example. The pumping rate or outflow is plotted on the inflow hydrograph and the excess of the curve about the pumping rate represents the necessary storage (see Figure 11.14). In any such installation, consideration must be given to safety of the structure in the event of flows in excess of the design flow.

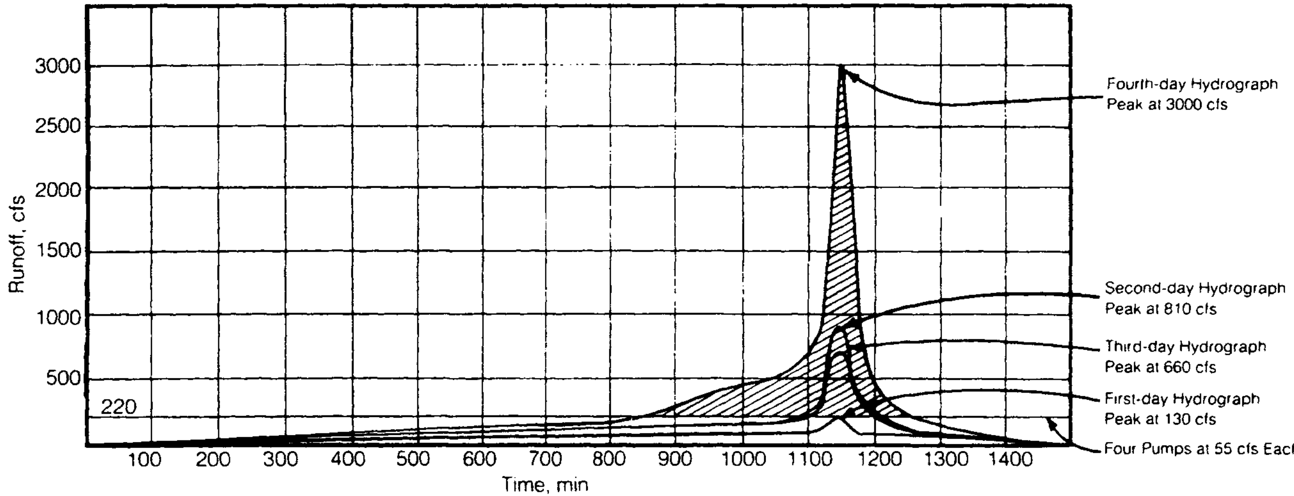
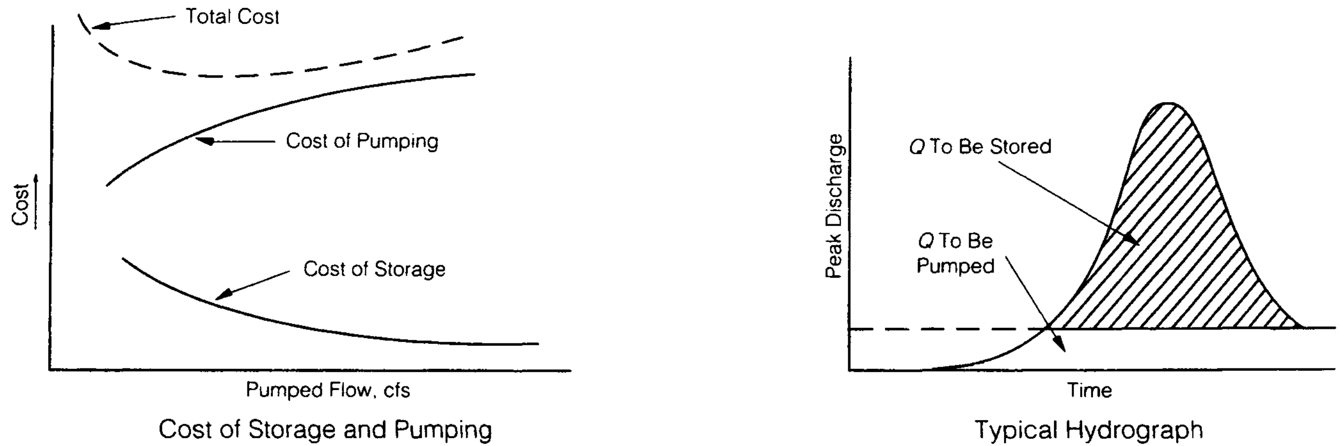


Figure 11.13—Design hydrograph, Walteria Lake project (cfs × 0.028 32 = m^3/s).



Storm Day	Rainfall, in.	Runoff, in.
First	0.65	0.19
Second	2.60	0.83
Third	2.28	0.71
Fourth	6.50	2.47

50-year Storm Rainfall and Runoff

Figure 11.14—Optimization of storage and pumping costs—Walteria Lake project (cfs × 0.028 32 = m^3/s and in. × 25.4 = mm).