CHAPTER 13

HYDRAULIC ANALYSIS AND DESIGN

SECTION 5

DETENTION BASINS
# TABLE OF CONTENTS

## 5.1 Introduction ................................................................. 502

## 5.2 Design Criteria ............................................................ 502

- 5.2.1 Design Storm Event Frequency ........................................ 502
- 5.2.2 Sizing Methodology for Volumes and Release Rates ............. 503
- 5.2.3 Roadway Embankments .................................................. 504
- 5.2.4 Site Considerations .................................................... 504
- 5.2.5 Maintenance .......................................................... 504

## 5.3 Detention Methods ........................................................ 504

- 5.3.1 On-Line Verses Off-Line ............................................... 505
- 5.3.2 Dry Verses Wet ......................................................... 505
- 5.3.3 On-Site Verses Regional ............................................... 505
- 5.3.4 Approaches to Detention ............................................... 506

## 5.4 Design Standards for Above-Ground Detention Basins .......... 506

- 5.4.1 State Engineer’s Office ................................................ 506
- 5.4.2 Grading Requirements .................................................. 506
- 5.4.3 Use of Retaining Walls ................................................ 507
- 5.4.4 Freeboard Requirements .............................................. 508
- 5.4.5 Inlet Configuration ..................................................... 508
- 5.4.6 Trickle Channel (Low Flow) .......................................... 508
- 5.4.7 Outlet Configuration ................................................... 508
- 5.4.8 Trash Racks .......................................................... 509
- 5.4.9 Embankment Protection/Spillway Requirements ................. 509
- 5.4.10 Landscaping Requirements .......................................... 510
- 5.4.11 Multiple Use Considerations ........................................ 511

## 5.5 Design Standards for Parking Lot Detention .................... 512

- 5.5.1 Depth Limitation ....................................................... 512
- 5.5.2 Outlet Configuration ................................................... 512
- 5.5.3 Performance .......................................................... 512
- 5.5.4 Flood Hazard Warning ................................................. 512

## 5.6 Design Standards for Underground Detention .................. 513

- 5.6.1 Materials ............................................................... 513
- 5.6.2 Configuration .......................................................... 514
- 5.6.3 Inlet and Outlet Design ............................................... 514
- 5.6.4 Maintenance Access ................................................... 514

## 5.7 Design Standards for Retention Ponds ............................ 514

- 5.7.1 Allowable Use .......................................................... 514
- 5.7.2 Calculation of Retention Volume ..................................... 515
- 5.7.3 Design Standards for Retention Ponds ............................ 515

## 5.8 Checklist and Design Aids .............................................. 516
5.1 INTRODUCTION

Detention of flood flows for all development and redevelopment projects is recommended in accordance with the policies presented in Chapter 3, Section 2 of these CRITERIA. The main purpose of a detention facility is to store the excess stormwater runoff associated with increased basin imperviousness and discharge this excess at a rate similar to the rate experienced from the basin without development. “Grandfathering” existing imperviousness is not acceptable, and comparison of runoff should be made against pre-developed conditions.

Rapid urban runoff can equate to higher downstream peak flows. Detention reduces the peak of the hydrograph and is considered a viable method to reduce urban drainage infrastructure costs. Detaining the peak of the storm runoff can significantly reduce downstream peak flow and flood hazards, as well as reduce pipe and channel sizes downstream. Storage also provides for sediment and debris collection, which helps to maintain water quality in downstream channels and streams.

This chapter provides the criteria for design and evaluation of all detention facilities. The CRITERIA strongly encourages integration of detention and water quality treatment requirements in accordance with the strategies presented in Chapter 15. All detention facilities must have adequate maintenance access and be maintained on a regular basis.

5.2 DESIGN CRITERIA

5.2.1 DESIGN STORM EVENT FREQUENCY

It is recommended that detention facilities be designed to control significant (minor event) runoff, with provisions to safely route flooding up to a 100-year storm (major event). Recommended design events are the 10- and 100-year recurrence interval floods, and may be combined with the water quality capture volume (WQCV), which controls up the first ½-inch of runoff. Designs which account for all three events include multi-stage outlets and are very effective at protecting downstream properties from flooding and protecting receiving drainageways from erosion and instability, commonly a result from development.

Designing detention facilities for less than a 100-year event in effect creates a “residual floodplain” in a major event. For example, if detention ponds and conveyance facilities are sized for a 25-year event, then there will be quantifiable surface flooding in a 100-year event. The Urban Drainage & Flood Control District completed a detailed evaluation of alternatives in the “Big Dry Creek Northern Tributaries Outfall Systems Plan Update” that considered potential cost savings by sizing conveyance structures for less than a 100-year event. However, by including the cost of land encumbrance from the residual floodplain, there may not be any savings.
5.2.2 SIZING METHODOLOGY FOR VOLUMES AND RELEASE RATES

Routing calculations are needed to design storage facilities. Some municipalities utilize empirical equations to size detention volumes and release rates for on-site storage facilities on small developments. All storage facilities for basins larger than 90 tributary acres must be analyzed with reservoir routing techniques. The Federal Aviation Administration (FAA) detention method is acceptable as long as a discharge rate, which varies with flood stage, is used. Table 5.1 summarizes acceptable methodologies for sizing detention facilities. Input and output listings used with software programs shall be provided in electronic and hard copy formats.

<table>
<thead>
<tr>
<th>Method</th>
<th>Site Conditions</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simplified Method Based on Empirical Equations</td>
<td>Small basins less than 90 acres. Do not use when off-site flows are present. Use with care when multi-stage controls are used.</td>
<td>This method has limited application subject to the site conditions.</td>
</tr>
<tr>
<td>Hydrograph Routing Procedures (HEC-1, HEC-HMS, Colorado Urban Hydrograph Procedure (CUHP)/Stormwater Management Model (SWMM), EPA-SWMM, UD-Pond Wizard or UD-Detention Spreadsheet are available for free download from <a href="http://www.udfcd.org">www.udfcd.org</a>)</td>
<td>Larger basins greater than 90 acres. Required when upstream detention facilities are present in watershed.</td>
<td>A historic imperviousness of 2% or less must be used in this procedure. The Natural Resources Conservation Service (NRCS) soil classification for the land area must also be used. Off-site tributary areas to the facility must be included in sizing volumes.</td>
</tr>
</tbody>
</table>

The maximum allowable unit release rates for the 10- and 100-year volumes shall be based on the predominant soil type at a site in accordance with Table 5.2. If NRCS soil surveys are not available for a site, then site-specific soils evaluation shall be completed.

<table>
<thead>
<tr>
<th>Design Return Period</th>
<th>NRCS Soil Group and Release Rate (cfs/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>10-year</td>
<td>0.13</td>
</tr>
<tr>
<td>100-year</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Above all, the release rate cannot exceed a non-hazardous discharge capacity of the downstream drainage system. Some regulatory jurisdictions require an analysis of pre-developed hydrology rather than using the simplified release rates based on soil type shown above.
5.2.3 ROADWAY EMBANKMENTS

Inadvertent detention often occurs upstream of roadway embankments if culverts are undersized. Large storm events will impound stormwater upstream of the culverts and the “spillway” is overtopping of the roadway. Unless these roadway impoundments are dedicated drainage facilities, their impact on reducing the downstream flow rate cannot be considered. The difficulty in quantifying the effects of inadvertent detention facilities is the virtual impossibility of assurance of their continued long-term performance or existence. There is generally no guarantee that the culverts will not be replaced in the future with larger structures. Only regional, publicly-owned and maintained detention facilities should be considered in hydrologic computations.

5.2.4 SITE CONSIDERATIONS

Impacts to upstream and downstream properties relative to proposed detention facilities shall be considered and minimized through appropriate facility design. If an adequate outfall does not exist or if some portions of the proposed development drain directly off-site, then it may be necessary for the new development to over-detain, thereby incorporating more restrictive release rates and larger detention volumes.

Designs shall take into account the location of structures near detention facilities and plan accordingly to prevent seepage into basements and structural damage.

5.2.5 MAINTENANCE

Maintenance is extremely important to long-term function of stormwater facilities. All detention facilities shall be designed with adequate maintenance access provisions and in a manner that facilitates ease of maintenance. Appropriate measures (typically an all-weather access road to the basin bottom) shall be included to allow for access by maintenance equipment. As a general rule of thumb, inspect all detention ponds and outlets one a year, preferably during wet weather, mow as required (at least twice a year), and remove accumulated sediment (after site construction in the tributary basin, and at least every 5 to 10 years once the basin is developed and stabilized).

Utilizing a forebay at all outfalls into the pond concentrates the largest pollutants and heavy sediments in one location for ease of maintenance. A forebay will reduce the frequency of dredging the detention pond. Otherwise; regular maintenance is required throughout the pond site.

5.3 DETENTION METHODS

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downstream flow rate cannot be considered. The difficulty in quantifying the effects of inadvertent detention facilities is the virtual impossibility of assurance of their continued long-term performance or existence. There is generally no guarantee that the culverts will not be replaced in the future with larger structures. Only regional, publicly-owned and maintained detention facilities can be considered in hydrologic computations.

5.3.1 **ON-LINE VERSES OFF-LINE**

In-line storage facilities are located within the flow path of the drainageway or conveyance system. Low and high flows pass through an on-line detention facility. Off-line systems are adjacent to the drainageway and only fill when a specific flow level is exceeded, and empties when sufficient conveyance becomes available in the downstream system.

5.3.2 **DRY VERSES WET**

A majority of detention ponds are designed to empty completely between storms. However, sometimes it is desirable to maintain a permanent pool in the stormwater facility during dry weather for habitat, recreation and/or aesthetic reasons. Wet ponds are usually more expensive than dry detention basins and usually serve a large watershed. Stormwater surcharges the permanent pool of the wet pond for controlled release after the storm. The key to a wet pond design is to maintain the permanent pool. Aeration can be an additional consideration to avoid the negative impacts of stagnation. A water budget, which compares inflows and outflows, is critical to a wet pond design and evaluates rainfall, runoff, infiltration, exfiltration, evaporation and outflow.

5.3.3 **ON-SITE VERSES REGIONAL**

There are two basic approaches to designing storage facilities: “on-site” and “regional”. When runoff storage facilities are planned on an individual site basis, they are referred to as “on-site.” Larger facilities that have been identified and sized as a part of some overall regional plan are categorized as “regional” facilities. In addition, the regional definition can also be applied to storage facilities that address moderately sized watersheds to encompass multiple land development projects. This chapter focuses primarily on on-site detention facilities. In order to consider regional facilities, the following criteria must be met:

1. The regional detention facility is designed to accommodate the fully developed flows from the upstream watershed.
2. The regional detention facility is constructed, or will be constructed in phases with the development; otherwise, temporary detention must be provided.
3. Legally-binding ownership and maintenance responsibilities by a public entity are clearly defined to ensure the proper function of the facility in perpetuity.
4. There is adequate conveyance of the fully developed flows from the site to the regional detention basin.
5. Design is completed in accordance these criteria:
   a. Multi-use (e.g., recreation) shall be considered in the design of detention basins.
   b. The creation of jurisdictional dams shall be strongly discouraged.
   c. Regional Detention Basins shall be located on publicly-owned lands whenever possible for long-term operations and maintenance.

5.3.4 APPROACHES TO DETENTION

Criteria for the following four approaches to on-site detention are presented in this chapter:
1. Surface ponds (preferred approach),
2. Inundation of Parking lots,
3. Underground storage, or
4. Retention as a temporary measure.

Underground detention is only allowed in ultra-urban settings where redevelopment is taking place and when no other on-surface methods are practicable. In these cases, underground detention must meet strict criteria.

5.4 DESIGN STANDARDS FOR ABOVE-GROUND DETENTION BASINS

5.4.1 STATE ENGINEER’S OFFICE

Any dam constructed for the purpose of storing water, with a surface area, volume, or dam height as specified in Colorado Revised Statutes 37-87-105 as amended, shall require the approval of the plans by the State Engineer’s Office. Those facilities subject to state statutes shall be designed and constructed in accordance with the criteria of the state, in addition to these CRITERIA.

5.4.2 GRADING REQUIREMENTS

As a general rule, slopes should be as flat and the depths as shallow as site conditions and safety considerations allow. However, obtaining the required storage volume within a tight site often forces the pond design deep with steep side slopes. Safety must dictate, and if a person were to fall into the facility, slopes should be flat enough that they can easily climb out. Slope terracing with benches may be beneficial and improve the aesthetics.
Wherever possible, slope stabilization should be with vegetation and be traversable when wet.

Grading requirements for embankments shall be in accordance with Table 5.3. All earthen embankments shall be covered with topsoil and revegetated with grass. Mowing is difficult on 3:1 slopes, and 4:1 to 6:1 is the maximum slope that can be effectively mowed, depending on the equipment.

<table>
<thead>
<tr>
<th>Embankment Height</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 feet in height or less</td>
<td>No steeper than 4 (horizontal) to 1 (vertical).</td>
</tr>
<tr>
<td>Higher than 5 feet</td>
<td>Slopes shall not be steeper than 3 (horizontal) to 1 (vertical), but 4 (horizontal) to 1 (vertical) is preferred.</td>
</tr>
<tr>
<td>Riprapped embankments</td>
<td>No steeper than 2 (horizontal) to 1 (vertical).</td>
</tr>
<tr>
<td>Grassed detention facilities</td>
<td>Minimum bottom slope shall be 1.0 percent measured perpendicular to the trickle channel.</td>
</tr>
</tbody>
</table>

5.4.3 USE OF RETAINING WALLS

The use of retaining walls within detention basins is generally discouraged; however, if walls are unavoidable, low-height walls less than 30 inches that are constructed of natural rock or landscape block are preferred. Long-term maintenance access, safety and aesthetics are important design considerations. Maintenance equipment must be able to safely reach the bottom of the facility and have adequate space to operate and turn. If several retaining walls are used, a separation of at least 4 feet shall be provided. Any future outfalls to the basin shall be designed and constructed concurrently with the detention basin. This eliminates future disturbance of the retaining walls, which may jeopardize the wall’s structural integrity, in order to construct the future outfall. Foundation walls of buildings shall not be used as detention basin retaining walls.

Any retaining walls exceeding a height of 30 inches (as measured from the ground line to the top of the wall) may require handrails. All handrails/guardrails shall be designed to meet International Building Code (IBC) requirements.

Walled-in or steep-sided basins should be located away from major pedestrian routes and emergency egress routes should be provided. Site lighting may also be required to discourage illicit activity in walled-in basins.

A licensed professional engineer shall perform a structural analysis of the retaining wall for the various loading conditions the wall may encounter. The wall design and calculations shall be stamped by the professional engineer. The structural design details and requirements for the retaining wall(s) shall be included in the construction drawings.
5.4.4 FREEBOARD REQUIREMENTS

For sites greater than or equal to 5 acres, the elevation of the top of the embankment shall be a minimum of 1.0 foot above the water surface elevation when the emergency spillway is conveying the maximum design or emergency flow. For sites less than 5 acres, the minimum required freeboard is 1.0 foot above the computed 100-year water surface elevation in the detention facility.

5.4.5 INLET CONFIGURATION

Forebays shall be provided at all pipe inlets into the detention pond to concentrate trash and sediment deposition and reduce sediment loading to the facility. Forebays require frequent and regular maintenance.

5.4.6 TRICKLE CHANNEL (LOW FLOW)

A low flow or trickle channel constructed across the facility bottom from the inlet to the outlet is recommended to convey low flows, and prevent standing water conditions. Concrete valley gutters should be sloped a minimum of 0.5% toward the outlet works. Grassed bottom detention basins require a concrete trickle channel; otherwise, either the low flow area becomes marshy or scours a notch through the turf.

5.4.7 OUTLET CONFIGURATION

To control the release rate, a multi-stage outlet is commonly used. For example, the WQCV may have a slow release rate, the 10-year event has a separate release, and the 100-year have a much larger outlet. A control orifice plate at the entrance of the pipe may be required to control the discharge of the design flow. The trash rack must be designed to prevent pinning a person during an extreme event. Clogging of the outlet with trash and debris is a particularly important concern, and a dedicated and stabilized emergency overflow is necessary to safely route flows in a big event. A simple plastic trash bag can completely block an outlet, and cause flooding.
5.4.8 TRASH RACKS

Trash racks (a grate in front of the perforated plate or outlet to capture large debris) may be needed for safety or to prevent small orifices from clogging. The trash rack opening should be at a minimum 4 times larger than the outlet pipe to reduce the velocity of water through the trash rack. Otherwise, fast moving water could pin a person against the outlet. For large openings with less potential for clogging, a trash rack may be more of a hazard due than a benefit. As a general rule of thumb, if the outlet can be seen by looking through the inlet, a person is safer being flushed through the pipe and a trash rack is discouraged. If the pipe is long with bends, by comparison the trash rack may be less of a hazard and is recommended.

5.4.9 EMBANKMENT PROTECTION/SPILLWAY REQUIREMENTS

Whenever a detention basin uses an embankment to contain water, the embankment shall be protected from catastrophic failure due to overtopping. Overtopping can occur when the basin outlets become obstructed or when a larger than 100-year storm occurs. The emergency spillway of a storage facility should be designed to pass flows in excess of the design flow of the outlet works. When the storage facility falls under the jurisdiction of the Colorado State Engineer’s Office (SEO), the spillway’s design storm is prescribed by the SEO (SEO 1988). If the storage facility is not a jurisdictional structure, the size of the spillway design storm should be based upon the risk and consequences of a facility failure. Generally, embankments should have spillways that, at a minimum, are capable of conveying the total peak 100-year storm discharge from a fully developed total tributary catchment, including all off-site areas, if any. Frequently, however, analysis of potential downstream hazards indicates that the spillway design storm should be larger than the 100-year event, especially if loss of life could occur as a result of floodwaters going around the spillway.

Failure protection for the embankment may be provided in the form of a buried heavy soil riprap layer on the entire downstream face of the embankment or a separate emergency spillway. Structures shall not be located in the path of the emergency spillway or overflow. The invert of the emergency spillway should be set equal to or above the 100-year water surface elevation. If a roadway becomes overtopped by emergency overflow, the cross street flow shall be limited to 6-inch depth maximum at the crown to minimize hazards to traffic.
5.4.10 LANDSCAPING REQUIREMENTS

Water diversion/detention areas and embankments should be designed and constructed to integrate with their surroundings, creating site amenities rather than eyesores. In open space or natural areas, techniques to be considered include creation of topographic changes that mimic natural conditions (including a variety of slope changes), using natural materials such as stone, blending with the textures and patterns of the surrounding landscape, and using materials that match the local environment.

Existing drainage patterns should be preserved whenever possible. Grading from the toe of the slope to the first foot should be gradual to provide a broad area identified as the littoral zone. This area is critical to support wetland functions and emergent vegetation for improved water quality. A diversity of vegetation is encouraged to support wildlife diversity that requires food and cover. For urban areas, a formal treatment in shape and vegetation can be appropriate. All above-ground detention basins shall be revegetated. Native grass species, either drill seeded or broadcast is more desirable than sod. Turf grass cannot survive in saturated conditions and requires the additional maintenance of mowing and fertilizing. Fertilizer has a negative impact on water quality and algae growth because of the additional loading of nitrogen and phosphorous.

Landscaping improvements may be provided in the basin to enhance the aesthetics of the basin. When determining landscaping, long-term maintainability of the facility should be a high priority. The following is a list of guidelines for basin landscaping:

- Detention areas should have attractive natural-looking features, fit into the surrounding landscape and add to the overall character of an area. The shape of the detention basin should be as natural looking as practical, with terracing of the slopes and bottom. The tops and the toes of slopes should vary, and there should be an undulation in the shape and grading of the sides of the detention area.
- Slopes should vary and be well vegetated to prevent erosion. The use of appropriate groundcovers and grasses at the top of the slope help to soften the appearance of the detention area and can incorporate the detention area into the landscape design. Appropriate plant material, such as wetland species or drought tolerant species, should be planted in the detention area and on the slopes. Shrubs and trees should be planted back from the top of the slope. Native and perennial species should be used to the extent practical.
- Soil amendments should be considered since most facilities will be built in either urban soils or disturbed soils. This improvement aids the success of establishing vegetation since nutrients will be available and improved soil structure will ensure root stability.
• Vegetation zones in response to elevation and proximity to water is desirable. For instance the establishment of riparian plant communities adjacent to the water or inundated with each storm occurrence. Upland prairie species which are drought tolerant occur at higher elevations. Vegetation species selection should include consideration of evergreen attributes that provide cover all year long and fruit that provide food for multiple wildlife species. Since Colorado has a diversity of landscape habitat types, it is critical to select appropriate indigenous native vegetation species that thrive within proximity to the project area.

• Use of rock or wood mulch in and adjacent to detention facilities is discouraged because of its potential to be displaced and clog outlet structures. Mulch placed over filter fabric is particularly susceptible to displacement and should not be used on slopes greater than 6 (horizontal) to 1 (vertical) or below the 100-year water surface elevation.

• Rundowns, which convey runoff from streets and parking lots into channels or storage facilities, should be incorporated into the overall design and be attractively designed.

• Temporary irrigation should be considered for successful vegetation establishment.

5.4.11 MULTIPLE USE CONSIDERATIONS

Multiple uses of detention facilities are encouraged; however, it is critical that the uses of these areas be taken into account to ensure that usage conflicts are minimized. For example, areas used as soccer fields or golf courses need to drain within a reasonable timeframe to prevent soggy fields that are incompatible with recreational use. Other park and detention facility conflicts may relate to safety in areas used for child play, West Nile virus concerns, and/or protection and enhancement of wildlife. Specific factors that shall be considered for multiple use facilities include:

• Compatibility with design, historic designation or other protective constraints including wildlife habitat and protection.

• Compatibility with recreational uses. The level of organized and informal activity in a park must be considered.

• Technical constraints and opportunities including soil characteristics, turf management, or terrain.

• Potential for new natural areas and wildlife corridors.

• Size and configuration of the park.

• Maintenance and operations, funding resources, successful techniques for dealing with silt, debris, etc.

• The configuration and easements for underground utilities and their impact on the existing park land.

• Potential for total rehabilitation of existing sites to accommodate multi-purpose uses.
5.5 DESIGN STANDARDS FOR PARKING LOT DETENTION

5.5.1 DEPTH LIMITATION

The maximum allowable design depth of ponding in parking lots for the 100-year flood is 12 inches.

5.5.2 OUTLET CONFIGURATION

A drop inlet may be used to discharge to a storm sewer or drainageway. A weir and a small diameter outlet through a curb may also be used. The size and shape of the outlet are dependent on the discharge/storage requirements.

5.5.3 PERFORMANCE

To assure that the detention facility performs as designed, maintenance access shall be provided. The outlet shall be designed to minimize unauthorized modifications, which affect function. Any repaving of the parking lot shall be evaluated for impact on volume and release rates and is subject to approval.

5.5.4 FLOOD HAZARD WARNING

All parking lot detention areas shall have multiple signs posted identifying the detention basin area. The signs shall have a minimum area of 1.5 square feet and containing the following message:
5.6 DESIGN STANDARDS FOR UNDERGROUND DETENTION

Underground detention is strongly discouraged for the following reasons:

- Underground detention is not visible; therefore, it tends to be “out-of-sight, out-of-mind.” As a result, these devices do not typically receive regular maintenance, nor is their performance periodically monitored.
- Maintenance access is often poor, which can be a deterrent to maintenance.
- Anaerobic (absence of dissolved oxygen) conditions in bottom sediments are more likely to develop in underground devices. This condition can release pollutants that were bound to the sediment and cause bad odors.

Nevertheless, there are some cases where the use of such facilities is necessary due to extreme space constraints in smaller, ultra-urban redevelopment sites. The use of underground detention will be considered under these circumstances; however, the applicant must comply with the following restrictions prior to receiving authorization for its use:

- Clear evidence must be provided documenting why detention cannot be provided on the ground surface and why the use of an underground facility is the best choice for the site, considering factors such as initial installation, maintenance, and ability to assure long-term function.
- Any water quality treatment must still be provided above-ground, even if detention is provided below ground.

When no other alternative is practicable, the requirements for underground detention are provided below.

Dry wells, which are underground vaults with a porous open base to promote infiltration, typically do not have adequate storage volume for significant storm events. Although they may function for frequent smaller storm events, their reliability for infiltration and ability to manage large storm events are questionable.

5.6.1 MATERIALS

Underground detention shall be constructed using corrugated aluminum pipe (CAP), reinforced concrete pipe (RCP), concrete vaults or approved equivalents. Galvanized or aluminumized pipes are not acceptable. The pipe thickness, cover, bedding, and backfill shall be designed to withstand HS-20 loading.
5.6.2 CONFIGURATION

Pipe or vault segments shall be sufficient in number, height, and length to provide the required minimum storage volume. The minimum headroom height of the pipe or vault segments shall be 48 inches to permit maintenance. If parallel pipes are used, the pipe segments shall be placed side by side and connected at both ends by elbow and tee fittings. The pipe segments shall be continuously sloped at a minimum of 0.25% to the outlet. Manholes for maintenance access shall be placed in the tee fittings, bends and in the straight segments of the pipe, when required.

Permanent buildings or structures shall not be placed directly above the underground detention.

5.6.3 INLET AND OUTLET DESIGN

Inlets to detention facilities can be surface inlets, pipes and/or a local private storm sewer system.

Outlets from underground detention shall be designed with ease of maintenance to prevent clogging. A two-pipe outlet may be required to control both minor and major design return periods. The invert of the lowest outlet pipe shall be set at the lowest point in the detention vault. The outlet pipe(s) shall discharge into a standard manhole or standard inlet or into an open drainageway with erosion protection. If an orifice plate is required to control the release rates, the plate(s) shall have a hinge on one side to open into the detention pipes to facilitate back flushing of the outlet pipe(s) and be firmly bolted or secured to the wall to prevent leakage around the edges.

5.6.4 MAINTENANCE ACCESS

Access easements to the detention facility shall be provided. Maintenance access designs shall take into consideration Occupational Safety and Health Administration (OSHA) requirements for confined space entry.

5.7 DESIGN STANDARDS FOR RETENTION PONDS

5.7.1 ALLOWABLE USE

A retention facility (a pond with a zero release rate or a very slow release rate when a trickle outflow can be tolerated) is used when there is no formal drainageway available within a reasonable distance of the site or one that is grossly inadequate. When designing a retention facility, the hydrologic basis of design is difficult to describe because of the random nature of rainfall events. Thus, sizing for a given set of assumptions does not ensure that another scenario produced by nature (e.g., a series of small storms that add up to large volumes over a week or two) will not overwhelm the intended design. For this reason, retention ponds are strongly discouraged as a permanent solution for drainage problems since they may be full when needed. Retention ponds should be designed as temporary facilities, with an ultimate conversion to a detention system.
When a retention pond is proposed as a temporary solution to an evolving drainage problem, the pond shall be sized to capture, as a minimum, the runoff equal to 100-year, 24-hour storm plus 1-foot freeboard. The facility also shall be situated and designed so that when it overtops, no human-occupied or critical structures (e.g., electrical vaults) will be flooded, and no catastrophic failure at the facility (e.g., loss of dam embankment) will occur. Retention facilities shall be as shallow as feasible to encourage infiltration and other losses of the captured urban runoff. Retention ponds should be designed to drain between storms and release the water back to the stream system. The pond should preferably drain within 72 hours. If the storage volume cannot be infiltrated within this time frame, a secondary outlet should be designed to provide additional releases from the pond.

5.7.2 CALCULATION OF RETENTION VOLUME

Retention ponds shall be sized to completely contain the 100-year, 24-hour rainfall, which can be obtained from the NOAA Atlas (see maps Chapter 9, Section 4). No reduction in volume will be allowed for infiltration during the storm event. In other words, assume the tributary basin is 100% impervious. Minimum required pond volume is simply [Tributary Area] multiplied by [Rainfall Depth].

5.7.3 DESIGN STANDARDS FOR RETENTION PONDS

Side slopes of the pond shall be no steeper than 3 (horizontal):1 (vertical). A stabilized emergency overflow section capable of passing the full 100-year event at a minimum shall be provided that will safely route stormwater away from downstream development, which may be a significant design challenge if no formal downstream drainageway exists.

Design standards for retention ponds must comply with specific site development, flood-proofing, site investigation and physical design considerations, as described below.

1. Site Development: The total development site area must be accounted for when planning for the retention of stormwater runoff. Provide grading for the entire site development to drain to the retention pond. Any off-site basins that historically flow through the site must be provided flow routes around the site and returned to the natural drainageway. Colorado state law maintains that "a property within a natural drainageway is subservient to the historic drainage from upper lands." Off-site drainage cannot be excluded if there is no other discharge location to be used; therefore, in volume calculations, include all off-site drainage basin areas that cannot otherwise be rerouted around the development and returned to the natural drainage path.
2. **Floodproofing:** The construction of a retention pond is essentially creating an isolated floodplain on the property. Delineate the limits of the 100-year flood area on the design drawing. Provide 1 foot of freeboard from the 100-year maximum water surface elevation of retention pond volume. Provide a 100-year emergency release overflow route from the site, which returns the flow back to its natural drainage path. Ensure finished floor elevations are at least 1.0 feet above the water surface elevation when the emergency spillway is conveying the maximum design flow or emergency flow.

3. **Site Investigation:** Site selection for infiltration retention ponds is critical. Factors for evaluating site suitability include:
   - Location of groundwater table
   - Location of bedrock
   - Seasonal fluctuation of water table
   - Soil permeability and porosity
   - Soil profile
   - Environmental conditions (e.g., contaminated soils)
   - Proximity to structures (e.g., basements)

   The following factors would preclude the site’s use as a retention infiltration pond:
   - Groundwater of less than 4 feet below pond bottom
   - Bedrock within 4 feet of the pond bottom
   - Pond location over fill
   - Surface and underlying soils classified as NRCS Hydrologic Group D (having little or no infiltration capacity)
   - Saturated infiltration rate less than 0.3 inch per hour

   A thorough geotechnical and geohydrological investigation shall be performed to determine site suitability. The following shall be included in the investigation:
   - Soil borings to a depth of 10 feet or to bedrock
   - Percolation tests
   - Soil classification

### 5.8 CHECKLIST AND DESIGN AIDS

Several key considerations that the designer must take care to address include:
1. Grade earth slopes 4:1 or flatter.
2. Provide minimum freeboard of 1 foot.
3. Provide trickle channels in above-ground detention areas.
4. Protect embankment from overtopping conditions.
5. Provide proper trash racks at all outlet structures.
6. Provide signs as required.
7. Provide maintenance access.
8. Provide emergency spillway and check emergency overflow path.
9. Check finished floor elevation of any structure near the detention basin.
10. Ensure failure of underground detention is clearly evident from above ground.