Chapter 6

STORAGE FACILITIES

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{Needs to be renumbered}

6.1 Introduction

6.1.1 Overview

The traditional design of storm drainage systems has been to collect and convey storm runoff as rapidly as possible to a suitable location where it can be discharged. As areas urbanize, this type of design may result in major drainage and flooding problems downstream. The engineering community is now more conscious of the quality of the environment and the impact that uncontrolled increases in runoff can have on land owners. The temporary storage of some of the storm runoff can decrease downstream flows and often the cost of the downstream conveyance system. Storage facilities can range from small facilities contained in parking lots or other on-site facilities to large lakes and reservoirs. This appendix provides general design criteria for detention/retention storage basins. On-site storage facilities are required unless the master planning process or regional analysis has shown that the detention requirements can be transferred to a regional facility, which is determined to be of regional benefit to the drainage system by the City and Lower Platte South Natural Resources District. On-site facilities may still be necessary to provide maintenance of receiving stream channel stability, maintenance and water quality.

Detention requirements may be waived by the Director if warranted. For example, for a development adjacent to a floodplain where detention would cause the localized drainage to coincide with stream flooding and thereby increase stream flooding. Documentation is required for such a waiver request.

6.1.2 Location Considerations

It should be noted that the location of storage facilities is very important as it relates to the effectiveness of these facilities to control downstream flooding. Small facilities will only have minimal flood control benefits and these benefits will quickly diminish as the flood wave travels downstream. Multiple storage facilities located in the same drainage basin will affect the timing of the runoff through the conveyance system, which could decrease or increase flood peaks in different downstream locations. Thus, it is important for the engineer to design storage facilities as drainage structures that both control runoff from a defined area and interact with other drainage structures within the drainage basin. Effective stormwater management must be coordinated on a regional, or basin-wide, planning basis.

6.1.3 Detention and Retention

Urban stormwater storage facilities are often referred to as either detention or retention facilities. For the purposes of this appendix, detention facilities are those that are designed to reduce the peak discharge and only detain runoff for some short period of time. These facilities are designed to completely drain after the design storm has passed. Retention facilities are designed to contain a permanent pool of water. Since most of the design procedures are the same for detention and retention facilities, the term, "storage facilities," will be used in this chapter to include detention and retention facilities. If special procedures are needed for detention or retention facilities, these will be specified.

6.1.4 Computer Programs

Routing calculations needed to design storage facilities, although not extremely complex, are time consuming and repetitive. To assist with these calculations there are many available reservoir routing computer programs. All storage facilities shall be designed and analyzed using reservoir routing calculations (e.g. HEC HMS).

6.1.5 Plan Review

- Detention or retention storage construction plans as applicable shall be submitted by the owner to the Nebraska Department of Water Resources for approval, or shall be certified by the owner that Nebraska Department of Water Re- sources approval is not required.
- Supporting calculations for hydrologic and hydraulic analysis and design shall be submitted by the owner to the Public Works and Utilities Department for review and approval. As a minimum, supporting calculations shall include; design storm inflow and outflow hydrographs, stage-storage-discharge curves, and cumulative inflow- outflow elevation curves for the design storms.

- Appropriate soil investigation (i.e., suitability for water storage, settlement potential, slope stability, and influence of groundwater) for the structure hazard classification.
- Construction plans for detention or retention storage, including the outlet structure, shall be submitted by the owner to the Public Works and Utilities Department for review and approval.
- The owner shall provide, at the end of construction, a separate written statement prepared by a licensed surveyor or engineer to the Director of Public Works that the grading and construction of storage facilities has been completed in conformance with the approved construction plans.

6.1.6 Ownership and Maintenance of Storage Facilities

Storage facilities proposed in a development, along with all inlet and outlet structures and/or channels, are to be owned and maintained by the developer or a property-owners' association unless a different ownership/maintenance arrangement has been approved by the Director of Public Works and Utilities. Because the downstream storm drainage system will be designed assuming detention storage upstream, a storage facility in the storm drainage system shall remain functional as a storage facility site permanently. Provisions shall be made in the approval of development by the Planning Commission and City Council for the permanence of the storage facilities and ongoing maintenance of the storage facilities. This historically and currently is done through sureties at the Final Plat stage.

6.2 Uses

6.2.1 Introduction

The use of storage facilities for stormwater management has increased dramatically in recent years. The benefits of storage facilities can be divided into two major control categories of quality and quantity.

6.2.2 Quality

Control of stormwater quality using storage facilities offers the following potential benefits (see Chapter 8):

- decreased downstream channel erosion (with proper design) through velocity control and flow reduction,
- reduced pollution loading through deposition, chemical reaction and biological uptake mechanisms,
- aesthetic and ecological habitat benefits at multi-objective sites,
- control of sediment deposition, and
- improved water quality.

6.2.3 Quantity

Controlling the quantity of stormwater using storage facilities can provide the following potential benefits:

- prevention or reduction of peak runoff rate increases caused by urban development,
- mitigation of downstream drainage capacity problems,
- reduction or elimination of the need for downstream outfall improvements, and
- maintenance of historic low flow rates by controlled discharge from storage.

{Deleted section 6.3}

6.4 Design Criteria

6.4.1 General Criteria

Storage may be concentrated in large basin-wide (or regional) facilities or distributed throughout an urban drainage system. Storage may be developed in depressed areas in parking lots, behind road embankments, freeway interchanges, parks and other recreation areas, and small lakes, ponds and depressions within urban developments. The utility of any storage facility depends on the amount of storage, its location within the system and its operational characteristics. An analysis of such storage facilities shall consist of comparing the design flow at a point or points downstream of the proposed storage site with and without storage. In addition to the design flow, other flows in excess of the design flow that might be expected to pass through the storage facility shall be included in the analysis. The design criteria for storage facilities shall include the following list. Compute inflow hydrograph for runoff from the 2-, 10- and 100-year design storms. Both predevelopment and post development hydrographs are required.

- release rate,
- storage volume,
- grading and depth requirements,
- safety considerations and landscaping,
- downstream property and structures
- outlet works and location, and
- efficiency of maintenance.

6.4.2 Release Rate

Control structure release rates shall be such that peak discharge rates for post development conditions do not exceed predevelopment peak runoff rates for the 2-year, 10-year and 100-year discharges at the project property line and in accordance with paragraph 6.4.6, unless waived by the Director of Public Works and Utilities. Parameters for predevelopment conditions shall be determined for actual site conditions existing on the site as of 1 August 1999. In addition, structures must provide detention for the water quality event (see Chapter 8) if the facility will be used for water quality purposes. Design calculations are required to demonstrate that runoff from the 2-, 10- and 100-year design storms is controlled. Runoff from intermediate storm return periods can be assumed to be adequately controlled. Multi stage control structures may be required to control runoff from all three storm events and if applicable the water quality event.

6.4.3 Storage

Storage volume shall be adequate to attenuate the post development peak discharge rates to predevelopment discharge rates for the 2-year, 10-year and 100-year storms. Routing calculations must be used to demonstrate that the storage volume is adequate. Storage volume shall allow for the sediment load anticipated from the contributing watershed. Proper implementation of site erosion and sediment measures will greatly reduce the sediment load. If sedimentation during construction causes loss of detention volume, design dimensions shall be restored before completion of the project. For storage facilities, all temporarily stored runoff shall be drained within 72-hours.

6.4.4 Grading and Depth

Following is a discussion of the general grading and depth criteria for storage facilities, followed by criteria related to detention and retention facilities.

6.4.4.1 General

The construction of storage facilities usually requires excavation or placement of earthen embankments to obtain sufficient storage volume. Dams that meet State Dam Hazard Classifications shall be designed as per the applicable Department of Natural Resources requirements. Specific City of Lincoln requirements are that vegetated embankments shall have side slopes no steeper than 4:1 (horizontal to vertical), that the top width of any embankment shall be no narrower than 14 feet, and traversable vehicular access for maintenance purposes shall be provided from public right-of-way. Traversable vehicular access is considered to be 14-foot level or nearly level ground across the width of the access with a maximum slope of 10:1 and access to a minimum of two sides along the storage facility.

Other considerations when setting depths include flood elevation requirements, public safety, land availability land value, present and future land use, water table fluctuations, soil characteristics, maintenance requirements, adjacency to nearby structures and required freeboard. New development shall be designed so the lowest opening of adjacent new buildings is a minimum of one foot above the calculated 100-year flood elevation or one foot above the overtopping elevation of the nearest downstream hydraulic structure, whichever is greater. Aesthetically pleasing features are also important in urbanizing areas. Fencing of basins is addressed in section 6.14.

6.4.4.2 Detention

Areas above the normal high-water elevations of storage facilities shall slope at a minimum of 2% toward the facilities to allow drainage and to prevent standing water. Careful finish grading is required to avoid creation of upland surface depressions that may retain runoff. The bottom area of storage facilities shall be graded toward the outlet to prevent standing water conditions. A minimum 2% bottom slope is required on unpaved areas. A paved low flow or paved pilot channel constructed across the facility bottom from the inlet to the outlet is required for bottom slopes less than 2% to convey low flows, and prevent standing water conditions. A 2% or more bottom slope is preferred over a paved low flow or paved pilot channel.

6.4.4.3 Retention

Retention facilities are conducive to establishment of wetland and open water habitats. Site-specific criteria relating to such things as depth, habitat, and bottom and shoreline geometry shall be selected to encourage establishment of desired habitat. Where wetland habitat is desired, vegetative and geometric conditions shall be provided to minimize the propagation of undesired vegetation. Plant and wildlife experts should be contacted for site specific guidance. If the facility provides open water conditions, a depth sufficient to discourage growth of vegetation, except along the shore- line, (without creating undue potential for anaerobic bottom conditions) shall be provided. A depth of 5 to 10 feet is generally reasonable unless fishery requirements dictate otherwise. Aeration may be required in permanent pools to prevent anaerobic conditions. The maximum depth of permanent storage facilities will be determined by site conditions, design constraints, and environmental needs.

6.4.5 Outlet Works

Outlet works selected for storage facilities shall include a principal spillway and an emergency overflow, and must be able to accomplish the design functions of the facility unless adequate supporting documentation is provided to the satisfaction of the Public Works Department. Principal spillway discharge must be released in a nonerosive manner. Outlet works can be combinations of drop inlets, pipes, weirs, orifices, chutes, and channels. Slotted riser pipes are discouraged because of clogging problems, but curb openings may be used for parking lot storage facilities. Storage facilities shall pass the 2-year, 10-year and 100-year design storms for post development conditions without allowing flow to enter an emergency outlet through a combination of available storage and outlet works capacity. Outlet works must operate without requiring attendance or operation. The spillway crest elevation shall be set at a minimum of one foot above the maximum water surface elevation for the 100-year design storm. Minimum freeboard of three feet above the emergency spillway crest elevation will be necessary for embankment structures which are large enough to require review and permitting by NDWR. For large storage facilities, selecting a flood magnitude for sizing the emergency outlet shall be consistent with the potential threat to downstream life and property if the basin embankment were to fail. The sizing of a particular outlet works shall be based on results of hydrologic routing calculations.

Outlets such as V-notch weirs are preferred to pipes since they provide for multiple flood events, including events less than the 2-year storm, while pipes sized for the 2-year flood will not provide any control of smaller storm events.

6.4.6 Location and Downstream Analysis

Although storage facilities are designed to control the discharge at the outlet device, the discharge may need to be routed downstream to be sure that the downstream drainage system provides an adequate outlet for the discharge without causing drainage or flooding problems. This is particularly important where discharge from the storage facility may exceed the downstream drainage system capacity and overtop roadways, causing a hazard or property damage. Storage facilities will change the timing of the entire hydrograph. If several storage facilities are located within a particular basin, it is important to determine what effects a particular facility may have on combined hydrographs in downstream locations. If the storage facility being designed is located in a drainage basin that has a master plan, the discharge hydrographs from the outlet works shall be routed downstream to the bottom of the master plan subbasin. The resulting 2-, 10-, and 100-year peak flows with the proposed facility in place shall be compared to the master plan peak flows to verify the development drainage and storage facility plan is acceptable. If the resulting peak flows exceed the master plan flows, the designs shall be improved to be consistent with the master plan.

Detention sometimes can be located within floodplains and still effectively control flooding through the use of timing calculations. This is dependent upon the timing of the flood peak coming down the stream as compared to the time of the local on-site flooding. A methodology for this situation, assuming timing works out is to design and locate detention to "skim" the peak from the oncoming flood hydrograph through the use of a side-channel weir or a simple flow-through depression along the banks. Any detention proposed in the floodplain needs to have accompanying documentation to demonstrate that it will effectively control flooding.

6.5 Safe Dams Act {sent to NDNR to review}

6.5.1 Background

National responsibility for the promotion and coordination of dam safety lies with the Federal Emergency Management Agency (FEMA). State responsibility for administration of the provisions of the Federal Dam Safety Act is governed by State of Nebraska Department of Natural Resources, Surface Water Chapter 46, Article 2. Rules and regulations relating to applicable dams are promulgated by State of Nebraska Department of Natural Resources.

Under the state regulations, a dam is an artificial barrier that does or may impound water that is 25 ft or greater in height or has a maximum storage volume of 50 ac-ft or more (including surcharge storage). A number of exemptions are allowed from the Safe Dams Act and the appropriate state office should be contacted to resolve questions. Detention or retention storage embankments which fall under the jurisdiction of the Department of Natural Resources must be designed and constructed in accordance with Safe Dam criteria with review and permitting by NDWR. An owner proposing a detention or retention embankment shall submit to Lincoln Department of Public Works, documentation of compliance with NDWR review and permitting requirements, or documentation why the embankment does not fall under NDWR jurisdiction.

6.5.2 Classification

Dams are classified as either new or existing, by hazard potential, and by size. The State of Nebraska Department of Natural Resources classifies dams under the Rules for Surface Water (August 1995), Title 457, Chapter 19 (entitled Dam Hazard Class). These classifications are presented below.

High Hazard Dam - A dam located where failure may cause loss of life, or serious damage to homes, normally occupied industrial and commercial buildings, important public utilities, main highways, or major railroads.

Significant Hazard Dam - A dam located in areas where failure may damage isolated homes, occasionally occupied buildings, main highways, minor railroads or interrupt public utility use or service.

Low Hazard Dam - A dam located in areas where failure may damage normally unoccupied buildings, undeveloped land, or township and county roads.

6.5.3 New Dams

Detailed engineering requirements are given in the regulations for new dams. Regulations that shall be consulted for further details and engineering requirements are State of Nebraska Department of Natural Resources, Surface Water Chapter 46, Article 2 and State of Nebraska Department of Natural Resources Rules for Surface Water (August 1995), Title 457.

6.6 General Hydraulic Design Procedure

6.6.1 Data Needs

The following data will be needed to complete storage design and routing calculations for submittal to the Public Works and Utilities Department.

- Inflow hydrograph for all selected design storms.
- Stage-storage curve for proposed storage facility. For large storage volumes (such as reservoirs), use acre-feet,

otherwise use cubic feet.

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- Stage-discharge curve for all outlet control structures.

Using these data, a design procedure is used to route the inflow hydrograph through the storage facility with different basin and outlet geometry until the desired outflow hydrograph is achieved.

{Deleted several sections}

6.11 Retention Storage Facilities

6.11.1 Introduction

Design of retention storage facilities must allow for performance of maintenance activities. The owner's capability for performing required maintenance shall be considered. Provisions for weed control and aeration for prevention of anaerobic conditions shall be considered.

6.11.2 Water Budget

Water budget calculations are required for all permanent pool facilities and shall consider performance for average annual conditions to demonstrate that adequate runoff is available for maintenance of a permanent pool. The water bud- get shall consider all significant inflows and outflows including, but not limited to, rainfall, runoff, infiltration, exfiltration, evaporation and outflow.

Average annual runoff may be computed using a weighted runoff coefficient for the tributary drainage area, multiplied by the average annual rainfall volume. Infiltration and exfiltration shall be based on site-specific soils testing data. Evaporation may be approximated using the mean monthly pan evaporation or free water surface evaporation data.

6.13 Construction and Maintenance Considerations

An important step in the design process is identifying whether special provisions are warranted to properly construct or maintain proposed storage facilities. To provide for acceptable performance and function, storage facilities that require extensive maintenance are discouraged. However, the following maintenance considerations should be viewed generally and should not limit efforts in the creation or enhancement of wetlands, open water habitats, plantings, or other natural/conservation design techniques that can contribute positively to the aesthetic or environmental elements of storage areas, particularly retention basins. In general, facilities shall be designed to minimize maintenance problems typical of urban detention facilities such as:

- weed growth
- grass and vegetation maintenance,
- sedimentation control,
- bank deterioration,
- standing water or soggy surfaces,
- mosquito control,
- blockage of outlet structures,
- litter accumulation and
- maintenance of fences and perimeter plantings.

Proper design focuses on elimination or reduction of maintenance requirements by addressing the potential for problems to develop.

- Both weed growth and grass maintenance may be addressed by constructing side slopes that can be maintained using available power-driven equipment, such as tractor mowers.
- Sedimentation shall be controlled by constructing traps to contain sediment for easy removal.
- Bank deterioration can be controlled with protective lining or by limiting bank slopes.
- Standing water or soggy surfaces may be eliminated by sloping basin bottoms toward the outlet, or by constructing underdrain facilities to lower water tables.
- In general, when the above problems are addressed, mosquito control will not be a major problem.
- Outlet structures shall be selected to minimize the possibility of blockage (i.e., very small pipes tend to block quite easily and shall be avoided).
- One way to deal with the maintenance associated with litter and damage to fences and perimeter plantings is to locate the facility for easy access so this maintenance can be conducted on a regular basis.
- Access easements shall be provided for heavy equipment when facilities do not abut accessible public right-of-way

- Access for vehicular maintenance shall be provided to the control structure, along the sides of the storage pond as necessary (14-foot minimum width), and to the basin bottom for large facilities . When a facility abuts a City right-of-way such as a local or arterial street, maintenance access from the abutting City right-of-way is an option which may be acceptable if it will not result in an unsafe or otherwise unworkable conditions.
- Retention storage, which proposes a permanent pool in addition to detention, shall be constructed to facilitate silt removal and disposal.
- An outlet shall be provided that will allow the retention facilities to be completely drained when required for silt removal, maintenance, or inspection.
- Provisions shall be made for the deposit of silt removed from the stilling basin and/or the main pool.

6.14 Protective Treatment

Protective treatment may be required to prevent entry to facilities that present a hazard to children and, to a lesser extent, all persons. Fences and/or a safety bench may be required for detention areas where one or more of the following conditions exist:

- Rapid stage increases would make escape practically impossible where small children frequent the area.
- Water depths either exceed 2.5 ft for more than 24 hours or are permanently wet.
- Large and/or deep facilities
- A low-flow watercourse or ditch passing through the detention area has a depth greater than 5 ft or a flow velocity greater than 5 ft/s.

Guards or grates may be appropriate for other conditions, but in all circumstances heavy debris must be transported through the detention area. In some cases, it may be advisable to fence the watercourse or ditch rather than the detention area.

Fencing should be considered for normally dry storage facilities with design depths in excess of 2.5 ft for 24 hrs, unless the area is within a fenced, limited access facility.

6.15 Trash Racks and Safety Grates

Trash racks and safety grates serve several functions:

- they trap larger debris well away from the entrance to the outlet works where they will not clog the critical portions of the works;
- they trap debris in such a way that relatively easy removal is possible;
- they keep people and large animals out of confined conveyance and outlet areas; and
- they provide a safety system whereby persons caught in them will be stopped prior to the very high velocity flows immediately at the entrance to outlet works and persons will be carried up and onto the outlet works allowing for a possibility to climb to safety.

Well-designed trash racks serve these purposes without interfering significantly with the hydraulic capacity of the outlet (or inlet in the case of conveyance structures). The location and size of the trash rack depends on a number of factors including: head losses through the rack, structural convenience, safety, and size of outlet.

Trash racks at entrances to pipes and conduits should be sloped at about 3:1 to 5:1 to allow trash to slide up the rack with flow pressure and rising water level, the slower the approach flow, the flatter the angle. Rack opening rules-of- thumb abound in the literature. Figure 6-11 gives opening estimates based on outlet diameter. Judgment should be used in areas with larger debris (e.g. a wooded area) that may require more opening space.

The bar opening space for small pipes shall be less than the pipe diameter. Collapsible racks have been used in some places if clogging becomes excessive or a person becomes pinned to the rack. Alternately, debris for culvert openings can be caught upstream from the opening by using pipes placed in the ground or a chain safety net. Racks can be hinged on top to allow for easy opening and cleaning.

The control for the outlet shall not shift to the grate. Nor shall the grate cause the headwater to rise above planned levels. Therefore, headlosses through the grate shall be calculated. A number of empirical loss equations exist, though many have difficult-to-estimate variables.