Chapter 2.05

STORMWATER DRAINAGE DESIGN STANDARDS

The Department of Public Works and Utilities is assigned responsibility for administration of these design standards

Section 1. DEFINITIONS

Conveyance structure: A pipe, open channel, or other facility that transports runoff from one location to another.

Drainage criteria: Specific guidance provided to the engineer/designer to carry out drainage policies. An example might be the specification of local design hydrology ("design storm").

Drainage plan: The plan that an engineer/designer formulates to manage urban stormwater runoff for a particular project or drainage area. It typically addresses such subjects as characterization of site development; grading plans; peak rates of runoff and volumes of various return frequencies; locations; criteria and sizes of detention ponds and conveyances; measures to enhance runoff quality; salient regulations and how the plan addresses them; and consistency with secondary objectives such as public recreation, aesthetics, protection of public safety, and groundwater recharge. It is usually submitted to regulatory officials for their review.

Existing Urban Area: Those areas inside the corporate limits of the City of Lincoln. as well as those areas outside the corporate limits having a zoning designation other than AG Agriculture and AGR Agricultural Residential, as defined by the Lincoln Municipal Code. *(Added 5-10-04; Resolution No. A-82748)*

Flood Design Criteria: Chapter 10 of the City of Lincoln Drainage Criteria Manual, adopted on February 22, 2000 by Resolution No. A-80038, as amended. *(Added 5-10-04; Resolution No. A-82748)*

Floodplain planning/floodplain management: Technical and nontechnical studies, policies, management strategies, statutes and ordinances that collectively manage floodplains along rivers, streams, major drainageways, outfalls, or other conveyances. The federal government normally plays a major role in floodplain planning and management, whereas in urban stormwater management and design, local governments dominate the decision-making process.

Major drainageway: A readily recognizable natural or improved channel that conveys runoff that exceeds the capacity of the minor drainage system, including emergency overflow facilities.

Major system: The portion of the total drainage system that collects, stores, and conveys runoff that exceeds the capacity of the minor system. The major system is usually less controlled than the minor system, and will function regardless of whether or not it has been deliberately designed and/or protected against encroachment, including when the minor system is blocked or otherwise inoperable. It may be collinear with, or separate from, the minor system. It should be noted that there are those who object to the use of the terms "major" and "minor" to describe portions of the drainage system, perhaps because these terms imply that the minor system is less important. Other terms (primary system, convenience or basic system, overflow system, major/primary drainage ways, subordinate system, etc.), have been suggested. Major/minor are used in this Standard because they seem to be the most widely used terms.

Minimum Corridor: Minimum flood corridor shall mean the existing channel bottom width plus 60 feet plus six times the channel depth and the corridor will be centered on the channel, as shown in Figure 1 below, or aligned such that the corridor follows the natural flow of flood waters. *(Added 5-10-04; Resolution No. A-82748)*

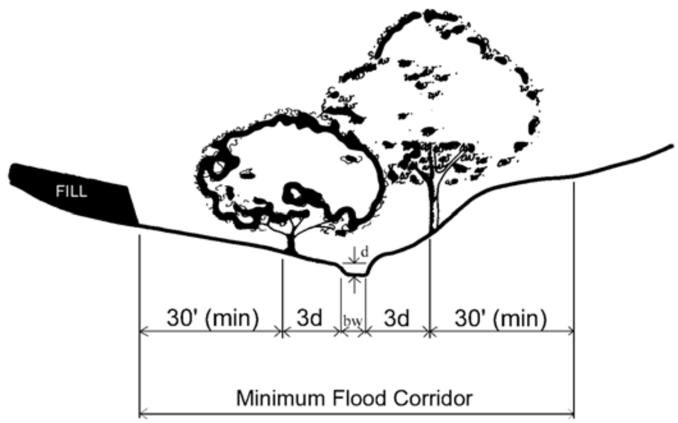

Figure 1 - Minimum Flood Corridor

Minor system: The portion of the total drainage system that collects, stores and conveys frequently-occurring runoff, and provides relief from nuisance and inconvenience. This system has traditionally been carefully planned and constructed, and normally represents the principal portion of the urban drainage infrastructure investment. The degree of inconvenience the public is willing to accept, balanced against the price it is willing to pay, typically establishes the discharge capacity or design recurrence frequency of a minor system. Minor systems include roof gutters and on-site drainage swales, curbed or side-swaled streets, stormwater inlets, underground system sewers, open channels and street culverts.

Multiple-purpose facility: An urban stormwater facility that fulfills multiple functions such as enhancement of runoff quality, erosion control, wildlife habitat, or public recreation, in addition to its primary goal of conveying or controlling runoff.

New Growth Areas: Those areas outside the corporate limits of the City of Lincoln and zoned AG Agriculture and AGR Agricultural Residential as defined by the Lincoln Municipal Code. *(Added 5-10-04; Resolution No. A-82748)*

Outfall facility: Any channel, storm drain, or other conveyance receiving water into which a storm drain or storm drainage system discharges.

"Risk-based" design: Design of urban stormwater management facilities not only on the basis of local standards, but also on the basis of the risk (cost) of the flow exceeding a selected design. Virtually all stormwater management projects have some component of risk which is inherent in selection of a design return frequency. Risk may also account for special upstream or downstream hazards that would be posed by adherence to some recommended standard. For example, the designer of culverts in a subdivision might choose to upsize particular storm drains from a 10-year to a 50-year basis to protect properties, or to make other provisions to secure emergency discharge capacity.

Special structures: Those components of urban drainage systems that can be thought of as "features" or "appurtenances" such as manholes, inlets, energy dissipators, transitions, channel slope protection, storage facilities, and outlet works.

"Standard-based" design: Design of urban stormwater management facilities based on some specified set of regulatory standards. An example is the stipulation in local drainage policies that culverts for a given subdivision are designed to pass the 50-year flood before road overtopping.

Storm drain: Often buried pipe or conduit, also referred to as storm sewer that conveys storm drainage, also includes, curb & gutter, grate & curb inlets, swales, open channels, and culverts.

Stormwater detention: The temporary storage of stormwater runoff in ponds, parking lots, depressed grassy areas, rooftops, buried underground tanks, etc., for future release. Used to delay and attenuate flow, normally drained between storms.

Stormwater retention: Similar to detention except the facility may have a permanent pool of water or wetland that does not drain between storms.

Watershed Master Plan: A plan generated by the City or by the City in cooperation with other agencies, which includes hydrologic and hydraulic modeling for the base flood event, including floodplain elevation and limits. *(Added 5-10-04; Resolution No. A-82748)*

(Resolution No. A-82748, adopted 5-10-04, put existing definitions in alphabetical order and added those as indicated)

Section 2. GENERAL

The following design standards have been prepared to provide guidance to the engineers and developers interested in stormwater runoff related design and construction and in the management of stormwater runoff. The following design standards are based on national engineering state-of-the-practice for stormwater management, modified to suit the needs of Lincoln. The City of Lincoln and the Lower Platte South Natural Resources District (LPSNRD) have also developed an extensive and detailed document entitled "City of Lincoln Drainage Criteria Manual" (Manual) The Manual includes; various charts, tables, and a compilation of a large amount of technical information with illustrative examples to help users to design stormwater runoff related structures in a safe, practical and effective manner. The Drainage Criteria Manual, as amended, is hereby adopted by reference to and made part of the Stormwater Drainage Design Standards, and users shall refer to the Manual in concurrence with the following standards. The Manual can be obtained by contacting City's clerk or Department of Public Works and Utilities. Details of construction shall conform to the *City of Lincoln Standard Specifications for Municipal Construction and the Lincoln Standard Plans.* (*Amended 5-10-04; Resolution No. A-82748)*

Section 3. POLICY

3.1 Major and Minor System

Every urban area has two separate and distinct drainage systems, whether or not they are actually planned for and designed. One is the *minor* system and the other is the *major* system. The minor drainage system is typically thought of as storm drains and related appurtenances, such as inlets, curbs and gutters. The minor system is normally designed for floods with return frequencies of 2-years to 10-years, depending upon the kind of land use. For residential areas in Lincoln, the drainage system shall be designed for the 5-year storm. For the downtown areas, industrial/commercial areas, and arterial roadways the drainage system shall be designed for the 10-year storm. ***During design, the hydraulic grade line for all enclosed systems shall be determined to ensure that inlets act as inlets, not outlets***.

The major drainage system is normally a flow path designed to convey runoff from large and infrequently occurring events. The 100-year return frequency storm shall be the major drainage system design storm for all new developments. Runoff from major storms should pass through a development without flooding buildings or homes. Overland flow routes can be provided using streets, swales, and open space.

Open channels for conveyance of major storm runoff are desirable in urban areas and use of such channels is encouraged. Optimum benefits from open channels can best be obtained by incorporating parks and greenbelts with the channel layout. To the extent practicable, open channels should follow the natural channels and should not be filled or straightened significantly. Effort must be made to reduce flood peaks and control erosion so that the natural channel regime is maintained. Channel improvement or stabilization projects are encouraged which minimize use of visible concrete, riprap, or other hard stabilization materials.

3.2 Stormwater Runoff Computation

The calculation of the storm runoff peaks and volumes is important to the proper planning and design of drainage facilities. The calculation of runoff magnitude shall be by either the rational method, the Soil Conservation Service (SCS, now known as the Natural Resource Conservation Service) TR-55 method, or SCS method in the U.S. Army Corps of Engineers (USACE) HEC-HMS software. Refer to Chapter 2 of the Manual for limits of applicability.

3.3 Detention Facilities

Detention facilities shall have release rates that do not exceed the predevelopment peak discharge rates for the 2-year, 10-year, and 100-year storms. Hydrologic conditions as of 1 August 1999 shall be used to determine peak release rates for predevelopment conditions. Submittal of hydraulic design calculations is required to document that major and minor design storm peak flows are attenuated. On-site and regional detention facilities shall be designed with adequate access and sediment storage right-of-way (including sediment forebays) to facilitate maintenance.

3.4 Streets

The primary drainage functions of streets are to convey nuisance flows quickly and efficiently to the storm drain or open channel drainage with minimal interference to traffic movement and to provide an emergency passageway for the major flood flows with minimal damage to adjoining properties, while allowing for safe movement of emergency vehicles.

3.5 Flood Corridor Management

In the Existing Urban Area, the preservation of a Minimum Flood Corridor is required along all channels outside the FEMA-mapped floodplain which drain greater than 150 acres or have a defined bed and bank. In New Growth Areas, the preservation of a Minimum Flood Corridor is required along all channels which drain greater than 150 acres or have a defined bed and bank, regardless of whether a floodplain or a floodprone area has been mapped along the corridor. For application of this standard to floodplains and floodprone areas in New Growth Areas see Section 10.3 of the Flood Design Criteria.

The width of minimum flood corridors shall be equal to the channel bottom width, plus 60 feet, plus six times the channel depth, and the corridor shall be centered on the channel or aligned such that the corridor follows the natural flow of flood waters.

Riparian vegetation and the existing grade within the identified flood corridors shall be preserved or enhanced to the maximum extent practicable, or mitigated during the development planning and construction processes when impacted by allowable encroachments. Individual areas of encroachments into the riparian vegetation and encroachments of fill into the existing grade will be permitted for operation, maintenance and repair, channel improvements, stormwater storage facilities, and utility crossings. Individual areas of encroachments may also be permitted for parks, pedestrian/bike trails, recreational uses, and public purposes, provided the encroachments are minimal and the uses are generally consistent with the purpose of the corridor. Prior to allowing vegetative encroachments or fill for permitted purposes into the minimum flood corridor, a sequencing process will be required which first seeks to avoid, then to minimize, then mitigate for impacts to the minimum flood corridor.

Documentation must be submitted to the City for review showing the steps taken using the sequencing approach, and the selected alternative. The sequencing process shall include an evaluation of alternative approaches in the order listed below:

1. Avoidance. Encroachment of riparian vegetation and the existing grade should be avoided if there is a practicable alternative that does not cause encroachment.

2. Minimization. If it is determined that avoidance is not practicable then steps must be taken to minimize impacts to the riparian vegetation and/or the existing grade.

3. Mitigation. Impacts to the riparian vegetation or to the existing grade must be mitigated after an appropriate and feasible alternative has been chosen through minimization.

Mitigation for loss of riparian vegetation in impacted areas shall occur at a 1.5 to 1 ratio. Where land uses prior to development have an impact on the buffer, the area should be replanted with vegetation compatible with the minimum flood corridor and water quality benefits.

Mitigation for fill in impacted areas shall occur at a 1.5 to 1 ratio and shall follow the standards that are applicable to compensatory storage requirements described in this Manual.

Through the watershed master planning process, develop approximate 100-year projected future condition flood profiles for mainstem and tributary channel corridors that are between the limits of detailed study by FIS and the boundary of the uppermost 150-acre sub-basin(s). Once the master plan flood profiles have been accepted by the City, regulate new development along the channel areas so the lowest opening in new buildings is protected from the flood profile.

In watersheds where FIS floodplains have not been delineated and where flood prone areas have not yet been determined through the watershed master planning process, regulate new development so the lowest opening of adjacent new buildings is protected to one foot above the calculated 100-year flood profile. Flood corridors delineated during development of land shall be legally described and recorded. *(Amended 5-10-04; Resolution No. A-82748)*

3.6 Erosion and Sediment Control from Construction Site Activities

An NPDES "notice of intent" and a Stormwater Pollution Prevention Plan (SWPPP) shall be required before land disturbance or vegetation removal activities occur on any site equal to or greater than one acre in size. Contractors and developers shall contact the City on the business day prior to performing land disturbance or vegetation removal on any site equal to or greater than one acre in size. Construction sites will be inspected periodically for compliance with submitted SWPPPs. The structural and non-structural best management practices (BMPs) are recommended to address stormwater quality enhancement. *(Amended 6-2-2003; Resolution No. A-82127)*.

Section 4. HYDROLOGY

The Rational Method shall be used for estimating peak flows and the design of small subdivision-type storm drain systems for developments with watershed areas from 0 to 150 acres. The Rational Method shall not be used for design of storage facilities. The SCS Method may be used for the design of all drainage structures and shall be used for design of any storage facility or any other facility with a drainage basin greater than 150 acres. Other methods may be used if they received prior approval from the Director of Public Works and Utility and if they are calibrated to local conditions and tested for accuracy and reliability. In addition, complete source documentation must be submitted for approval.

4.1 Design Frequency

Cross drainage facilities transport storm runoff under roadways. The cross drainage facilities shall be designed to convey (at a minimum) the 50-year runoff event without overtopping the roadway. The flow rate shall be based on upstream ultimate buildout land-use conditions. In addition, the 100-year frequency storm shall be routed through all culverts to be sure structures are not flooded or increased damage does not occur to the roadway or adjacent property for this design event.

Storm drains and inlets (Minor Systems) shall be designed to accommodate a 5-year storm in residential areas and a 10-year storm in commercial developments, downtown areas and in industrial developments, and arterial streets.

Overland flow routes (Major Systems) shall be designed to accommodate a 100-year storm without flooding buildings in all developments.

All storage facilities shall be designed to provide sufficient storage and release rates to accommodate the 2-, 10-, and 100-year design storm events such that the post development peak discharges do not exceed the predevelopment rates.

4.2 Rational Method

The rational formula is expressed as **Q = CIA** where; Q = peak rate of runoff (cfs), C = runoff coefficient representing a ratio of runoff to rainfall, I = average rainfall intensity (in/hr) for a duration equal to the time of concentration for a selected return period, and A = drainage area tributary to the design location, acres.

For inlet design the minimum t_c recommended shall not be less than 8 minutes. The value of rainfall intensity (I) can be obtained from IDF curve for the City of Lincoln are given in Figure 2-3 of the Manual. The value of C shall be representative of the subarea land use, for example, the average C=0.4 used for typical residential subdivisions is not appropriate for subareas bounded by the street centerline and the middle of the building pad where a more representative value is C=0.63.

The method for determining the runoff coefficient (C) is based on land use, soil groups and land slope. Table 2-4 in Manual gives the recommended coefficient C of runoff for pervious surfaces by selected hydrologic soil groupings and slope ranges. *The value of C shall be based on fully built-out land use conditions. The minimum runoff coefficient shall be 0.4, unless the developer can clearly demonstrate a value less than 0.4 is appropriate.*

4.3 SCS Unit Hydrograph Method

Techniques developed by the U. S. Soil Conservation Service for calculating rates of runoff require the same basic data as the rational method, drainage area, runoff factor, time of concentration, and rainfall. Two types of hydrographs are used in the SCS procedure, unit hydrographs and dimensionless hydrographs. The SCS 24-hr, Type II storm hydrographs shall be used for modeling rainfall in Lincoln. Refer to Chapter 2.6 of the Manual for the detailed information on SCS design procedures.

4.4 Hydrologic Computer Modeling

HEC-HMS (a nonproprietary model written by the U.S. Army Corps of Engineers) has been selected for use in Lincoln by the Public Works & Utility Department and the Lower Platte South NRD.

Section 5. STORM DRAINAGE

5.1 Pavement Drainage

The design storm for pavement period for pavement period shall be consistent with the frequency selected for other components of the drainage systems. Allowable maximum encroachment is provided in the following table:

Allowable Maximum Encroachment for Minor Storms	
Street Classification	**Maximum Encroachment**
Local	No curb overtopping.
Collector	No curb overtopping.
Arterial	No curb overtopping. Flow spread must leave at least one lane free of water in each direction.
Freeway	Refer to Nebraska Department of Roads design criteria.

When these encroachments are met, the storm drain system shall commence.

For the major storm runoff, the following street inundation is allowable:

Allowable Maximum Encroachment for Major Storms	
Street Classification	**Maximum Encroachment**
Local and Collector	The depth of water over the gutter flowline but shall not exceed the right-of-way width.
Arterial	The depth of water at the street crown shall not exceed 6 inches.
Freeway	Refer to Nebraska Department of Roads design criteria.

The following table provides recommendation for allowable cross street flow.

Allowable Cross Street Flow		
Street Classification	**Minor Storm Design Runoff**	**Major Storm Design Runoff**
Local	Flow equivalent to not greater than 5" allowable depth in upstream curb and gutter.	The depth of water over the gutter flowline but shall not exceed the right-of-way width.
Collector and Arterial	None	The depth of water over the gutter flowline but shall not exceed the right-of-way width.
Arterial	None	6 inches or less over crown.
Freeway	Refer to Nebraska Department of Roads design criteria.	Refer to Nebraska Department of Roads design criteria.

5.2 Storm Water Inlets Design

The following criteria shall be used for inlet design:

Land Use	Average Return Frequency (years)
Residential Areas	5
Commercial, Industrial, and Arterial Roads	10

Inlets

- 72-inch straight and canted curb inlets shall be used in the public street system
- Grate inlets may be used for parking lot drains, area drains, etc.
- Flow in the gutter should not exceed five (5) inches.
- Inlets should be placed at the low points in the street grade.

Design charts for standard City of Lincoln inlets are provided in the Chapter 3 of the Manual

The first inlet shall be placed at a point where the maximum depth of flow in the gutter is five inches. Subsequent inlets downstream from the initial inlets shall be located at or before points where the depth of flow in the gutter is five inches. Usually inlets shall be placed at the ends of radii and/or before crosswalks at intersections. Inlets that the study shows are needed at locations other than at intersections shall generally be centered between lot lines. Inlets shall be installed at the upper end of all storm drain lines and at low points in the street grades. It may be necessary at some locations to use more than one inlet to pick up the contributing flow. Canted inlets shall not be placed along intersection radii, unless approved by the Director of Public Works and Utilities.

Concrete valley gutters may be used across roadways at T-intersections of local roadways, if the calculated depth of flow for the minor system design flow in the curb and gutter section immediately upstream is less than 5 inches and if there is no existing or proposed storm drain conduit extended to the intersection. The pavement cross-slope on the “uphill” lane of the minor approach shall be reduced at a gradual rate from 3% to 1% to allow drainage of the “uphill” gutter flow line through the return. No valley gutters shall be used across collector or arterial roadways.

Curb and gutter grades that are equal to pavement slopes shall not exceed 8 percent or fall below 0.5 percent without approval from the Director of Public Works and Utilities.

The detailed procedures and necessary charts to design inlets are described in Chapter 3 of the Manual. Curb and gutter installation shall be designed in accordance with the most current City Standard Drawings and Specifications.

5.3 Manholes

Manholes shall be installed at the upper end of all storm drain lines and at all changes in grade, size, or alignment. The recommended maximum spacing is 600 feet for storm drain lines, 36 inches and less in diameter. Greater spacings than this will require approval by the Director of Public Works and Utilities. The crowns of all storm drain pipes entering and leaving a junction shall be at the same elevation. Laterals from a storm drain inlet to the main storm drain line may be tapped directly into the main storm drain line if the diameter of the lateral does not exceed one-half the diameter of the pipe being tapped. If the diameter of the lateral does exceed one-half the diameter of the pipe being tapped, a storm drain manhole or inlet will be required. The crown of the lateral pipe shall match the crown of the main storm drain pipe. Storm drain manholes shall be constructed in accordance with the most current City Standard Drawings and Specifications.

5.4 Storm Drains

For ordinary conditions, drain pipes should be sized on the assumption that they will flow full or practically full under the design discharge but will not be placed under pressure head. The Manning Formula is recommended for capacity calculations. The beginning point at which a storm drain shall be required in a street is where the depth of flow in one or both gutters requires inlets to be built. Easements for storm drain pipe and surface water flow shall be used where a drainage way must be maintained to carry stormwater flow in excess of the storm drain pipe capacity. The easement cross-section shall accommodate the depth and width of flow from the higher intensity storms. The minimum size of the storm drain pipe shall be 15" in diameter.

Street right-of-ways convey the portion of runoff in excess of pipe capacity, whether planned or not. Street right-of-way capacity is determined using Manning’s equation for open channel flow conditions. In order to determine if design flows can be accommodated by the storm drains system without causing flooding, or causing flows to exit the system at unacceptable locations, the designer shall determine *the hydraulic gradient.* The following design criteria shall be followed when determining the elevation at the HGL:

- The hydraulic grade line shall be 0.75 feet below the intake lip of any affected inlet, any manhole cover, or any entering nonpressurized system.
- The energy grade line shall not rise above the intake lip of any affected inlet, any manhole cover or any entering nonpressurized system.

Refer to Chapter 3 of the Manual for detail storm drain design procedures, necessary charts and tables.

5.5 Slope

The standard recommended maximum and minimum slopes for storm drains shall conform to the following criteria:

5.5.1. The maximum hydraulic gradient shall not produce a velocity that exceeds 20 feet per second.

5.5.2. The minimum desirable physical slope shall be 0.5 percent or the slope that will produce a velocity of 3.0 feet per second when the storm drain is flowing full, whichever is greater.

Systems should generally be designed for non pressure conditions. For very flat flow lines the general practice is to design components so that flow velocities will increase progressively throughout the length of the pipe system.

5.6 Location and Alignment

In new subdivisions the center of the street is reserved for storm drain system. When construction of a storm drain system is necessary in the older parts of the town, the location will be determined by the City. Permanent easements are required for public storm drains located on private property. No structures may be placed over a public storm drain system. All easements for storm drain pipe should be a minimum of 30 feet wide. In situations where it can clearly demonstrate that an easement less than 30 feet is adequate, the City may consider such a request. Easements for storm drain pipe and surface water flowage shall be used where a drainageway must be maintained to carry stormwater flow in excess of the storm drain pipe capacity. The easement cross-section shall accommodate the depth and width of flow from the 100-year storm. The width must also be designed to allow for access of maintenance equipment during the major storm. The developer shall obtain required permits prior to final approval of plans for proposed improvements located in railroad or highway right-of-ways.

5.7 Depth of Cover

The desired depth of cover above a storm drain pipe shall be 2 to 3 feet, with 1.5 feet being the absolute minimum at an inlet location. Depth of cover greater than 3 feet shall be avoided due to the possibility of the storm drain blocking access of sanitary sewer service lines to the main sanitary sewer lines.

5.8 Material and Joints

Only reinforced concrete storm drain pipe shall be used for public storm drain systems within the City limits, unless approved by the Director of Public Works and Utilities. Construction of pipe and joint shall conform to the City of Lincoln Standard Specification.

5.9 Bar Grates on End Sections

An open pipe inlet from an open channel (similar to a culvert inlet) into a closed pipe storm drain shall be designed and constructed with flared end sections with a bar grate. No bar grate is required on the end section of a pipe outlet into an open channel unless directed by the Director of Public Works and Utilities.

Section 6. DESIGN OF CULVERTS

Culverts shall be designed to convey (at a minimum) the 50-year runoff event without overtopping the roadway. The flow rate shall be based on upstream full-buildout land-use conditions from the City of Lincoln/Lancaster County Comprehensive Plan. Where roadside ditches convey the minor storm drainage in lieu of storm sewers, appurtenant culverts shall be designed to convey the 10-year storm event, but in no case shall be less than the minimum sizes specified in Section 4.5.16 of the Manual. In addition, the 100-year frequency storm shall be routed through all culverts to be sure structures are not flooded or increased damage does not occur to the roadway or adjacent property for this design event.

An economic analysis may justify a design to pass floods greater than those noted above where potential damage to adjacent property, to human life, or heavy financial loss due to flooding is significant.

Also, in compliance with the National Flood Insurance Program, it is necessary to consider the 100-year frequency flood at locations identified as being special flood hazard areas. This does not necessitate that the culvert be sized to pass the 100-year flood, provided the capacity of the culvert plus flow bypassing the culvert, is sufficient to accommodate the 100-year flood without raising the associated water surface elevation more than floodplain regulations or adjacent property elevations allow for that location. In addition, stormwater management facilities cannot be installed which would result in a major lowering of the associated water surface elevation without a downstream evaluation. The design engineer should review the City floodway regulations for more information related to floodplain regulations.

Two procedures for designing culverts are described in the Manual: (1) manual use of inlet and outlet control nomographs and (2) use of a personal computer system HYDRAIN. It is recommended that the HYDRAIN computer model be used for culvert design since it will allow the engineer to easily develop performance curves to examine more than one design situation.

6.1 Loading Requirements

Reinforced concrete box culvert, reinforced concrete pipe culverts and corrugated metal pipe culverts shall be designed for an HS20 live load, with the appropriate impact factor, and dead load. Dead load (fill) shall be based on the depth of earth cover, plus the pavement, above the top of the culvert.

6.2 Headwalls

Culvert or storm drain headwalls constructed in or adjacent to public right-of-way shall be designed to protect pedestrians. This protection shall include a pipe railing fence on the headwall and any wingwalls, unless the grading and size of the pipe precludes the need for the fence, as approved by the Director of Public Works and Utilities.

6.3 Minimum Culvert Size

The minimum culvert size shall be 18 inches for roadways and 15 inches for driveways.

6.4 Debris Control

In general, bar grates shall not be used on flared end sections of culverts.

6.5 Driveway culverts

Driveway culverts are permissible along unpaved city streets. The Maintenance Division of the Public Works and Utilities Department shall determine culvert size and grade and install the culvert. The owner shall purchase the corrugated metal pipe culvert complete with flared end sections and have it delivered to the site.

Section 7. OPEN CHANNELS

For any open channel conveyance, channel stability must be evaluated to determine what measures are needed to avoid bottom scour and bank cutting. Channels shall be designed for long term stability, but be left in as near a natural condition as possible. The use of open, natural channels is especially encouraged in the major drainage system and can have advantages in terms of cost, capacity, multiple use (i.e., recreation, wildlife habitat, etc.) and flow routing storage. It shall be demonstrated that the natural condition or an alternative channel design will provide stable stream bed and bank conditions (Refer to Chapter 5 Open Channels in the Manual). Where this cannot be demonstrated, a concrete low flow liner with a nonerosive crossection may be required by the Director of Public Works and Utilities. Even where streams retain a relatively natural state, streambanks may need to be stabilized while vegetation recovers. To preserve riparian characteristics of channels, channel improvement or stabilization projects should minimize the use of visible concrete, riprap or other hard stabilization materials. The main classifications of open channel types are natural, bio-technical vegetated grass-lined, rock-lined, and concrete. Grass-lined channels include grass with mulch and/or sod, reinforced turf, and wetland bottom. Rock-lined channels include riprap, grouted riprap, and wire-enclosed rock. See Chapter 5 of the Manual for more discussion of channel types and design procedures.

7.1 Return Period Design Criteria

Open channels shall be sized to convey the 100-year storm.

7.2 Approximate Flood Limits Determination

Flood corridors delineated during development of land shall be legally described and recorded.

7.3 Velocity Limitations

Sediment transport must be considered for conditions of flow below the design frequency. Minimum channel flow velocity for the 2-year storm shall be 2.0 feet per second. A low flow channel component within a larger channel can reduce maintenance by improving sediment transport in the channel. Channel flow velocities shall be non erosive for the 2-, 10- and 100-year storms. Trickle channel design flow rates shall be 1% of the major storm flow rates and shall be non erosive. Grade control structures, streambank protection, and construction and maintenance considerations shall be determined during design.

Hydraulic analysis shall be performed during the planning and design phase to address the potential for erosion, and the need for stabilization measures. The following criteria and analysis techniques are recommended for natural channel evaluation and stabilization:

- The channel and overbank areas shall have adequate capacity for the 100-year post development storm runoff.
- The water surface profiles shall be defined and delineated so that the 100-year floodplain can be identified and managed. Plan and profile drawings shall be prepared of the floodplain, and allowances should be made for future bridges or culverts.
- Filling of the floodplain is subject to the restriction of FEMA floodplain regulations.
- Manning's n roughness factors representative of maintained channel conditions should be used.
- Erosion control structures such as drop structures and grade control checks should be provided as necessary to control flow velocities and channel erosion.

Natural channels should be left in as near a natural condition as feasible. However, with most natural channels, grade control structures will need to be constructed at regular intervals to limit channel degradation and to maintain what is expected to be the final stable longitudinal slope after full urbanization of the watershed. In addition, the owner is reminded that modification of the channel may require a US Army Corps of Engineers Section 404 permit

Grass-lined channels are encouraged when designing artificial channels. Advantages include: channel storage, lower velocities, provision of wildlife habitat, and aesthetic and recreational values. Design considerations include velocity, longitudinal slopes, roughness coefficients, depth, freeboard, curvature, cross-section shape, and channel lining material (vegetation and trickle channel considerations). Channel shape may be almost any type suitable to the site-specific conditions, and can be designed to meet multipurpose uses, such as recreational needs and wildlife habitat. However, limitations to the design include the following:

- Side slopes shall be 4 (horizontal) to 1 (vertical) or flatter. Slopes as steep as 3H:1V may be considered in areas where development already exists and there are right-of-way limitations.
- The bottom width shall be designed to accommodate the hydraulic capacity of the cross-section, recognizing the limitations on velocity and depth. Width shall be adequate to allow necessary maintenance.
- Maintenance/access routes shall be provided for along all major drainageways.
- Trickle channels or underdrain pipes should be provided on grass-lined channels to minimize erosion. As an alternative, low flow channels can be provided (low flow channels are particularly applicable for larger conveyances). Trickle channels should be designed to carry base flow originating from lawn watering, low intensity rainfall events, and snow melt.

- To preserve riparian characteristics of channels, design channel improvement or stabilization projects to minimize use of visible concrete, riprap, or other hard stabilization materials.

7.4 <u>Maintenance</u>

Open channels shall be maintained by the developer or a property-owners' association unless an alternative ownership/maintenance arrangement has been approved by the Director of Public Works and Utilities, Planning Commission and the City Council.

Section 8. STORAGE FACILITIES

On-site storage facilities are required unless the master planning process or regional analysis as 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 NRD. On-site facilities may still be necessary to provide maintenance of receiving stream channel stability, maintenance and water quality. All storage facilities shall be designed and analyzed using reservoir routing calculations. Watershed routing for storage facilities shall be performed manually using the procedures outlined in Chapter 6 of the Manual or using HEC-HMS.

8.1 <u>Plan Review</u>

8.1.1 Detention or retention storage construction plans 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 Resources approval is not required.

8.1.2 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 minium, supporting calculations shall include; design storm inflow and outflow hydrographs, stage-storage-discharge curves, and cumulative inflow-outflow elevation curves for the design storms.

8.1.3 Appropriate soil investigation (i.e., suitability for water storage, settlement potential, slope stability, and influence of groundwater) for the structure hazard classification.

8.1.4 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.

8.1.5 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 grading and construction of the storage facility have been completed in conformance with the approved construction plans.

8.2 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 sewer system will be designed assuming detention storage upstream, a storage facility in the storm sewer 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.

8.3 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. Compute inflow hydrograph for runoff from the 2-, 10- and 100-year design storms using the procedures outlined in Urban Hydrology for Small watersheds TR-55. Both predevelopment and post development hydrographs are required. The design criteria for storage facilities shall include the following list.

a. release rates,
b storage volume,
c. grading and depth requirements,
d. safety considerations and landscaping,
e. outlet works and location, and
f. efficiency of maintenance.

8.4 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 of the Manual, 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 of the initial ½-inch per impervious acre of storm runoff for 24-hours if the facility will be used for water quality purposes. 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, depending on the downstream system design capacity. Storage volume shall allow for the sediment load anticipated from the contributing watershed. 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.

Dams shall be designed as per the applicable Department of Water Resources requirements. Vegetated embankments shall have side slopes no steeper than 4:1 (horizontal to vertical), 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. 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.

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. 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 low flow or pilot channel constructed across the facility bottom from the inlet to the outlet is required to convey low flows, and prevent standing water conditions.

Where wetland habitat is desired, vegetative and geometric conditions shall be provided to minimized the propagation of undesired vegetation. If the facility provides open water conditions, a depth sufficient to discourage growth of vegetation, except along the shoreline, (without creating undue potential for anaerobic bottom conditions) shall be provided. Aeration may be required in permanent pools to prevent anaerobic conditions.

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. 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 budget shall consider all significant inflows and outflows including, but not limited to, rainfall, runoff, infiltration, exfiltration, evaporation and outflow.

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. 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 emergency spillway crest elevation shall be set at 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.

8.5 Location and Downstream Analysis

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 down stream 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.

8.6 Safe Dams Act

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 supporting why the embankment does not fall under NDWR jurisdiction.

8.7 Construction and Maintenance Considerations

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.

Sedimentation shall be controlled by constructing traps to contain sediment for easy removal or low-flow channels to reduce erosion and sediment transport. Bank deterioration shall be controlled with protective lining or by limiting bank slopes. Access easements shall be provided for heavy equipment when facilities do not abut public right-of-way. Access for vehicular maintenance shall be provided to the control structure, along side(s) of the storage pond as necessary (15-foot minimum width), and to the basin bottom for facilities with bottom widths greater than 15 feet. 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 condition. Retention storage, which proposes a permanent pool in addition to flood storage, 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.

Principal spillway openings shall be protected by trash racks. Trash racks at entrances to pipes and conduits should slope 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. The bar opening space for small pipes shall be less than the pipe diameter. The control for the outlet shall not shift to the grate, nor shall the grate cause the headwater to rise above planned levels.

Section 9. ENERGY DISSIPATORS

9.1 Design Criteria

9.1.1 Overview

Energy dissipators shall be employed whenever the velocity of flow leaving a stormwater management facility exceeds the velocity that will cause erosion of the downstream channel system. Several standard energy Dissipator designs have been documented by the U.S. Department of Transportation including hydraulic jump, forced hydraulic jump, impact basins, drop structures, stilling wells, and riprap. The detailed design procedures of the energy dissipators are given in Chapter 7 of the Manual.

9.1.2 Design Limitations

If ice buildup is a factor, it shall be mitigated by sizing the structure to not obstruct the winter low flow and by using external dissipators. Debris control facilities shall be designed using Hydraulic Engineering Circular No. 9, "Debris-Control Structures" and shall be considered where clean-out access is limited and if the dissipator type selected cannot pass debris. The flood frequency used in the design of the energy dissipator device shall be the same flood frequency used for the culvert design. The use of a greater frequency is permitted, if justified by low risk of failure of the crossing, substantial cost savings, limited or no adverse effect on the downstream channel, and limited or no adverse effect on downstream development. The culvert exit velocity shall be consistent with the maximum velocity in the natural channel or shall be mitigated by using channel stabilization and energy dissipation. The hydraulic conditions downstream shall be evaluated to determine a tailwater depth and the maximum velocity for a range of discharges. Lake, pond, or large water body shall be evaluated using the high water elevation that has the same frequency as the design flood for the culvert. (See Lincoln Flood Insurance Study for the appurtenant stream information.)

9.1.3 Design Options

The material selected for the dissipator shall be based on a comparison of the total cost over the design life of alternate materials and shall not be made using first cost as the only criteria. This comparison shall consider replacement cost and the difficulty of construction as well as traffic delay. Traffic shall be protected from external energy dissipators by locating them outside the appropriate "clear zone" distance per the AASHTO Roadside Design Guide or shielding them with a traffic barrier. If weep holes are used to relieve uplift pressure, they shall be designed in a manner similar to underdrain systems.

Section 10. STORMWATER BEST MANAGEMENT PRACTICES

10.1 <u>Overview</u>

10.1.1 <u>Introduction</u>

To comply with federal law, the City of Lincoln is adopting a program to encourage the use of water quality Best Management Practices (BMPs) for new developments and redevelopment efforts. BMPs are defined as measures that function to keep either pollutants from entering stormwater or remove pollutants from stormwater. Various BMPs have been implemented throughout the United States. In general, they can be categorized as either structural or nonstructural. Structural BMPs can be thought of as constructed facilities designed to reduce runoff and/or passively treat urban stormwater runoff before it enters the receiving waters. Nonstructural BMPs consist of pollution prevention BMPs and source control BMPs. Both structural and nonstructural BMPs are used for erosion control during construction.

The selection of the most appropriate BMPs for a given site or basin is largely dependent on whether development is in place or has yet to occur. In areas with existing development, nonstructural BMPs are the most cost-effective because retrofitting structural controls in a developed area can be expensive. Structural controls are more appropriate for new development and significant redevelopment, where they have been integrated into the planning of the infrastructure.

Because non point source pollution is varied in nature and impact, no individual BMP may fit all situations. It must be tailored to fit the needs of particular sources and circumstances. An effective strategy for minimizing stormwater pollution loads is to use multiple BMPs (structural, nonstructural, and source controls). Multiple BMPs and combining BMPs in series can provide complementary water quality enhancement that minimizes pollutant loads being transported to the receiving waters. General planning and design guidelines are provided in chapter 8 of the Drainage Criteria Manual.

Section 11. EROSION AND SEDIMENT CONTROL

11.1 Purpose and Scope

The purpose of the design standards for erosion and sediment control is to set forth standards for construction site stormwater discharges to meet the requirements of the Federal Clean Water Act, the Nebraska Environmental Protection Act, and the City of Lincoln ordinances adopted to meet State and Federal requirements. Chapter 9 of the City's Drainage Criteria Manual (DCM), which is adopted by reference in the Stormwater Drainage Design Standards, provides more detailed criteria and should be used as a reference to meet the standards of this section.

11.2 Construction Activity

Construction Activity is defined in Lincoln Municipal Code Section 28.01.030 Regulations for Construction Site Discharges. Prior to any land disturbance associated with construction activity, a permit application must be submitted in the form of a Notice of Intent (NOI) to the Lower Platte South Natural Resources District (LPSNRD) on behalf of the City. The forms are to be submitted to the LSPNRD for authorization, and to the Nebraska Department of Environmental Quality for approval. The NOI must include a Construction Activity Stormwater Pollution Prevention Plan (SWPPP) with the information identified in Section 28.01.060 of the Lincoln Municipal Code and the Drainage Criteria Manual. The SWPPP must identify Best Management Practices (BMPs) to be implemented to control erosion, sedimentation, and pollutants. Chapter 9 of the City's DCM describes requirements for SWPPPs and provides specifications for a range of BMPs.

The Construction Activity SWPPP must be prepared and signed by a qualified individual such as a Professional Engineer, Landscape Architect, and/or Certified Professional in Erosion and Sediment Control (CPESC). If review comments are not received by the permittee within seven (7) business days after receipt of application by the LPSNRD, the application shall be deemed authorized. Prior to actual initiation of the construction activity, the applicant shall submit to the LPSNRD a Notice of Start of construction. Once the construction is complete in accordance with the design standards, the applicant shall submit to the LPSNRD a Notice of Termination.

The building phase of development for a common plan of development or sale may be covered under one SWPPP that is submitted by and under the control of the permittee. Any person engaging in construction activity under a Construction Activity SWPPP must meet the requirements of Section 28.01.070 of the Lincoln Municipal Code.

11.3 Criteria for Erosion and Sediment Control

More specific criteria for meeting the Design Standards for Erosion and Sediment Control can be found in Chapter 9 of the City's Drainage Criteria Manual which, as amended, is adopted by reference and made a part of the Design Standards for Erosion and Sediment Control.

(Amended 6-25-07; Resolution No. A-84431: prior Amendment 6-2-03; Resolution No. A-82127).