SECTION 9

STORM DRAINAGE DESIGN

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SECTION 9

STORM DRAINAGE DESIGN

9-1   CITY POLICY AND REQUIREMENTS

A. The planning, design and construction of drainage facilities and other related appurtenances to be owned, operated and maintained by the City of Elk Grove shall comply with these standards herein referred to as the "Standards".

B. These design and construction standards are intended to provide <u>minimum</u> standards for design, construction and repair of all drainage facilities/infrastructure within the City of Elk Grove.

C. Designs shall be consistent with City plans including the General Plan, specific plans, master plans, and capital improvement plans/programs. Specific requirements for the improvement and construction of drainage facilities are set forth, in order of precedence, in the following documents:

> City of Elk Grove Municipal Codes
> City of Elk Grove Floodplain Management Policies
> City of Elk Grove Improvement Standards (this document)
> City of Elk Grove Standard Construction Specifications

D. The storm drainage system design shall be based on a drainage study that describes the improvements necessary to mitigate any adverse impacts of changed runoff caused by the project including changes to quantity, quality, volume and duration. The design of a new storm drain system shall include consideration of the downstream creek or storm drain. The consulting engineer shall show that the existing storm water system can convey the proposed drainage without adverse flooding, erosion or other water quality impacts to upstream, downstream or adjacent facilities or areas; or that such facilities or areas are being improved or protected to the point where the drainage can be conveyed without adverse impacts.

E. Improvements shall not cause a net loss of storage, nor an increase in velocity, of drainage water within the 100-year floodplain.

F. All submitted studies, plans, and calculations shall be signed and stamped by a Registered Civil Engineer prior to approval and all work shall be in accordance with these design standards and good engineering practice.

G. The Director shall decide all questions of interpretation of "good engineering practice," guided by the standards and manuals of the discipline in question.

H. All drainage facilities shall be located within the City's right-of-way unless otherwise approved by the Director. Adequate access for maintenance (including repair and replacement) of the system shall be provided. The minimum width of any area designated for access, maintenance, or a facility site is 25 feet.   Any area designated for public drainage facilities, including overland flow conveyance routes, not confined to existing public right-of-ways shall be dedicated as a fee title parcel to the City. In exceptional cases, the Director may approve alternate forms of dedication. The City will not accept any conservation or other conditional easement on drainage courses to be conveyed to the City.

I. The Design Guidelines for the City of Elk Grove are summarized in Tables 9-1, and 9-1A.

J. All new structures shall be protected from the 100-year (1 %) flood event. Certified pad elevations must be submitted with the application for building permit. All finished floor elevations shall be set at least one foot (1.0) above all sources of 100-yr flooding. If the elevation of the 100-year (1%) flood event is not available, it must be calculated by a Registered Civil Engineer, to the satisfaction of the Director.

K. Private storm drain systems shall be clearly noted on the plans and maintenance responsibilities recorded in the covenants, conditions, and restrictions for each parcel.

L. Storm water quality treatment facilities shall be provided for new and redevelopment projects in accordance with Chapter 11 of these Standards.

M. Exceptions to any requirement in Chapter 9 must be approved by the Director and will only be granted if under extraordinary circumstances when in the best interests of the City of Elk Grove.

9-2   STORMWATER UTILITY

The City maintains public drainage facilities within the City of Elk Grove Storm Water Utility service area. Prior to issuance of building permit, each building and parcel within the City will become part of the Stormwater Utility.

9-3   DEFINITIONS

The following terms, abbreviations or definitions shall apply and the intent and meaning shall be interpreted as stated herein wherever they are encountered in these Standards or in any documents or instruments referenced by these standards unless otherwise approved by the Director.

ASTM	American Society for Testing and Materials.
Base Flood	100-year (1%) flood event pursuant to the City of Elk Grove Floodplain Management ordinance or any source of 100-year flooding as determined by Public Works.

Certified Pad Elevation	As defined in the Grading Section of these Standards
Director	Director of Public Works of the City of Elk Grove or his/her designee.
CLOMA/LOMA	Conditional Letter Of Map Amendment/ Letter Of Map Amendment.
CLOMR/LOMR	Conditional Letter Of Map Revision/ Letter Of Map Revision.
County	The County of Sacramento
Design Storm	The design runoff
Drainage Easement	A strip of land dedicated, condemned or reserved for drainage use.
Drainage Manual	The Sacramento City/County Drainage Manual consisting of five volumes dated December 1996 with as revised or updated. Volume 2 contains the Hydrology Standards with graphs and charts cited in these standards.
FEMA	Federal Emergency Management Agency.
Interim	A temporary facility- constructed and maintained by the developer.
NFIP	National Flood Insurance Program.
One Hundred- Year Storm	A hydrograph created using the Sacramento Method indicating runoff over time for a storm with a one-percent statistical probability of annual recurrence.
Overland Release Path	An alignment that allows the passage of floodwater through a development without damaging structures.
Reimbursement Agreement	An agreement between the Sacramento County Water Agency or City of Elk Grove and developer identifying eligible reimbursement costs.
Right-of-Way	A strip of land dedicated, condemned or reserved for public use.
SACCALC	The Sacramento calculator for determining design flows and HEC-1 hydrographs using the City of Elk Grove Hydrology Standards. This is a Windows based software available for free download.
SACPRE	Sacramento preprocessor software for developing runoff flows.
SCDWR	Sacramento County Department of Water Resources.
SCWA	Sacramento County Water Agency, a political subdivision of the State of California

Specifications	City of Elk Grove Standard Construction Specifications, latest version.
Standards	These storm drain design standards.
Ten-Year Storm	A hydrograph created using the Sacramento Method indicating runoff over time for a storm with a ten-percent statistical probability of annual recurrence.
Trunk Drainage	Mainline drainage from an area over 30 acres.
Volume 2	Volume 2, *Hydrology Standards*, of the Sacramento City/County Drainage Manual.

9-4 FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA) FLOOD PROGRAM

A. The City of Elk Grove is a participant in the National Flood Insurance Program and all development in the City shall comply with the regulations of the Federal Emergency Management Agency (FEMA) and the City's Floodplain Management ordinance. Amendments or revisions of FEMA flood maps will be required for all development located in a federal flood zone. Petitions for a Conditional Letter of Map Amendment (CLOMA) or Conditional Letter of Map Revision (CLOMR) shall be submitted to Public Works and FEMA and approved by both entities before improvement plan approval. Any required fees shall be paid directly to FEMA by the applicant.

B. Petitions for a Letter of Map Amendment (LOMA) or Letter of Map Revision (LOMR), including any fee required by FEMA, shall be submitted and approved by Public Works and FEMA before building permit issuance.

C. Fill for the removal of land from the FEMA 100-year floodplain of a watercourse, where building pads will be created, must comply with the FEMA standards and must be compacted to 95 percent (95%) of the maximum density obtainable with the standard proctor test method (ASTM Standard D-698) or an equivalent test method acceptable to FEMA.

D. These regulations do not preclude the City from requiring additional standards to protect the public from projected flood runoff.

9-5 DRAINAGE FEES AND CREDITS

All developments in The City and all future sub-zones of the City are subject to payment of a drainage impact fee based on the Drainage Capital Improvement Plan. Reimbursement agreements with the City/County shall be signed by the developer, and notarized, before approval of improvement plans.

9-6   IMPACTS TO EXISTING DRAINAGE

All drainage must enter and leave the project area at its existing line and grade, unless otherwise approved by the Director. No net increase of peak flows is allowed. And no net adverse impact for volume, quality or duration is allowed. All impacts must be mitigated in the project area or lands acquired for mitigation by the project.

9-7   LOCATION OF FACILITIES AND LAND DEDICATIONS

A. All storm drain facilities must be in the road right-of-way or parcel owned by the City in fee. Such parcels must be a minimum of 25 feet wide, sufficiently wide to accommodate normal construction equipment, and shall be easily accessible to such equipment as necessary to construct, operate, maintain and reconstruct the facility. These parcels shall be dedicated to the City of Elk Grove, and such parcels shall not split along property lines.

B. Where improvements outfall onto an adjacent property (such as day-lighting ditch profiles) dedication in fee to the City is required.

C. In the event necessary permanent offsite parcels or easements cannot be acquired through negotiation, the developer may request that the City consider condemning necessary rights-of-way. The person, firm, or corporation requesting such condemnation will be required to enter into a written agreement to pay all costs and expenses of the condemnation.

D. Acquisition and maintenance of temporary construction easements outside of the limits of the subdivision shall be the sub-divider's responsibility.

E. Drainage parcels, right-of-ways, or easements (if authorized) for drainage facilities, shall meet the following criteria:

   1. Minimum width of the parcel/right-of-way shall be twenty-five feet (25').

   For closed conduits, dedications shall have a minimum width equal to the greater of twenty-five feet (25') or the required trench width according to the standard detail for pipe bedding and initial backfill (Drawing SD-6, Specifications) plus two feet (2') of additional width for every foot of depth as measured from the bottom of the pipe to finished grade with accommodation of a minimum set back distance from the conduit to the edge of the parcel/right-of-way of ten feet (10').

   2. Parcels or drainage easements for open channels shall have sufficient width to contain the ultimate channel; as well as, fencing and a twenty-foot (20') service road. Additional width shall be provided to allow equipment to safely negotiate the service road for the purposes of construction, operations and maintenance activities. Exceptions may be made on a case-by-case basis depending on the layout of adjoining roadways and recreational paths, with approval from the Director.

9-8   DRAINAGE DESIGN CAPACITY

A. All drainage systems shall be designed to accommodate the ultimate development of the entire upstream watershed.

B. Closed conduit systems shall be designed to accommodate at least the 10-year storm event flows as determined using the methods prescribed in Section 9-10. All new trunk systems for conveying the 10-year storm event flows shall be closed conduit.

C. Open channel drainage systems shall be designed to carry the 100-year frequency design storm, using the worst case duration and providing for at least 1 foot of freeboard. Minimum freeboard requirements and roughness coefficients may be set by the Director on a case-by-case basis. New open channels (including roadside ditches) shall not be constructed to convey the trunk line portion of the 10-year storm event.

D. Open channel drainage systems shall be designed to carry the 100-year frequency design storm, using the worst case duration and providing for at least 1 foot of freeboard. In unusual cases, more stringent freeboard requirements and roughness coefficients may be established by the Director.

9-9   DESIGN SUBMITTALS

A. A reconnaissance level or suitability level drainage study may have been required and prepared as part of a development application. As part of the design of a drainage system, a comprehensive drainage study must be prepared for review and acceptance by the Director.   The comprehensive drainage study shall include but is not limited to: definition with mapping of the existing watersheds; a detailed pre- and post-project hydrologic and hydraulic analysis of the project and project impacts; definition of the local controlling 100-year frequency water levels existing and with project; and the proposed method of flow conveyance with adequate supporting calculations. The study shall include any proposed improvements to mitigate the impacts of increased runoff from the project and any change in runoff including quality, quantity, volume, and duration. The study shall incorporate the City of Elk Grove Drainage Capital Improvement Plan; be consistent with the ultimate upstream development in the General Plan and any specific, area, or master plans; and shall conform to the City of Elk Grove Improvement Standards. It shall demonstrate that the proposed methods of flow conveyance mitigate the potential project impacts. The study shall further demonstrate that the lots on the proposed Final Map shall be outside the 100-year frequency floodplain after improvements are constructed in accordance with the policies in the City Floodplain Management Plan.   Study must be completed and stamped by a Professional Engineer, and determined by the City to be comprehensive, accurate, and adequate.

B. The drainage study submitted shall include, as a minimum, the following information and computations:

- Topographic map showing existing and proposed ground elevations.

- A shed map including on-site and off-site watershed boundaries draining onto the site. It shall also include land uses, total and sub-shed areas in acres.

- Quantity of flow (cfs) to each drainage inlet structure with corresponding area and land uses that generates the quantity.

- Quantity of flow (cfs) in each pipe.

- Flow line elevation of each manhole or junction structure.

- Top of structure rim elevation.

- Location of downstream outlet and hydraulic grade line at this location.

- Hydraulic grade line of the systems.

- Pipe size, material type, class, length and slope.

- Channel dimensions, flow and water surface profile computations.

- Overland Release hydraulic computations for street and non-street releases (including fence/wall openings and outlet).

- Analysis of permits required including type, processing time, and expected restrictions.

The applicant shall obtain applicable California Department of Fish and Game, U.S. Army Corps of Engineers, and other required state and federal permits. The conditions of such permits must be reviewed and conditions considered acceptable by the City, before the permit is issued.

C. Improvement Plans must contain the additional features

- Pipelines plans and profiles

- Open channel plans and profiles

- Phasing plans if all improvement are not constructed in the same time

- An overflow release map showing surface elevations and flow paths

- Notes concerning agreements and dedications

9-10 DESIGN RUNOFF

The required design methods, their appropriate applications, and design tools are summarized in Table 9-1. Use of design methods for runoff calculations in the City of Elk Grove is described in Volume 2 Hydrology Standards of the City/County Drainage Manual. SACCALC is a Windows based software, available for free download, for assistance with these calculations. Design criteria concerning the approach for new and infill projects are summarized in Table 9-1A.

Table 9-1

Minimum Design Runoff Flows

Application	Hydrology Calculation	Method	Design Tools
Design of: · street drainage · storm sewers · culverts (driveway)	Flow from Charts	Sacramento	Design Charts, HEC-1 and SACCALC
Special Design Case*: · street drainage · storm sewers · culverts	Peak Flow and/or 100-year Volume	Sacramento	Design Charts, HEC-1 and SACCALC
Design of overland release, culverts, and bridges**	Peak Flow and/or 100-year Volume	Sacramento	Design Charts, HEC-1 and SACCALC
Master Plans Design of: · open channels · bridges · detention facilities	Peak Flow and Volume	Sacramento	HEC-1and SACCALC
Water Quality Detention Basins	Volume	Sato	Design Chart

* Special design cases include: streets designated for emergency evacuation, high use public areas, areas with potential loss of life, areas with potential high property damages, areas with limited overland release, and areas lower than surrounding elevations.** Overland release flows may be determined from Figures 2-11 and 2-18 thru 2-23 of the Volume 2 Hydrology Standards for shed areas less than 160 acres.

Table 9-1A

Design Criteria by Project Type

Condition	Hydrologic Calculation	Design HGL	Constraints
Connecting or Infill Projects	Sacramento Method Zone 2 *Infill projects upstream of an existing closed conduit system originally designed using a different design method may use that alternate method if so authorized by the Director.	Use the 10/100 year water elevations of the drainage master plan or as calculated by the Engineer. If no drainage master plan, assume the 10-year water surface elevation at the connection point to be at the gutter flow line, or compute using summation of flow based on contributory areas working upstream starting at the downstream control.	Lowest building pad will be at least 1.0 foot above 100-year water level or 1.5 feet above the overland release peak flow level if the 100-year water level cannot be determined.
New Projects	Sacramento Method	For 10-year, 6 inches below DI.	Lowest building pad will be at least 1.0 foot above the 100-year water level.

Computation of runoff shall be performed in the appropriate manner prescribed below.

Use the Sacramento method as outlined on City of Elk Grove hydrologic design criteria is described in Volume 2, Hydrology Standards, of the City/County Drainage Manual.. Elk Grove is in the Zone 2 Rainfall Zone for the Sacramento Method. SACCALC is a Windows based software, available for free download, for assistance with these calculations.

The following shall be followed:

A. The runoff used in storm drain pipe design for drainage area 160 acres and smaller shall be computed from the Drainage Zone Chart and the accompanying design runoff graphs. The selection of the appropriate Zone 2 chart from the Hydrology Standards Volume 2 will be based on the City General Plan and the Sacramento Method. Copies of Zone 2 runoff graphs are included in these standards as drawings SD-1 to SD-4.

B. In drainage areas that contain multiple zoning, the runoff shall be computed from the following formula:

    i. $Q_{Design} = Q_r + (Q_m - Q_r) A_m/A_t + (Q_c - Q_r) A_c/A_t$

    ii.   Where: Q_r=Flow from residential curve using total area of watershed.
                         Q_m=Flow from multiple family formula using total area of watershed.
                         Q_c=Flow from commercial curve using total area of watershed.
                         A_m=Area of multiple family zoning.
                         A_c=Area of commercial zoning.
                         A_t=Area in total.

C. Use Table 9-2 to determine the appropriate runoff parameters to be used in selecting flow/discharge runoff curves from the Hydrology Manual. Single-family land use includes areas zoned AR-2 to RD-5.   Multi-family use includes areas zoned RD-7 to RD-30.

Table 9-2
10-Year Runoff Coefficients and Maximum Inlet Times

General Plan Land Use	10-year Runoff Coefficient	Inlet Time t_i (min.)
Impervious	0.95	5
Industrial	0.90	5
Office/Commercial	0.90	5
Multi-family	0.80	10
Single family	0.70	10
Schools - building & paved areas	0.90	5
Schools - landscape & grass areas	0.40	10
Parks - paved areas	0.90	5
Parks - landscape & grass areas	0.40	10
Other	area weighted average	5 to 10

D. At sag points where the total change in grade exceeds 4% within 200 feet of a drop inlet, the design Q at that inlet shall be increased to 0.7 cfs/acre. The runoff to be used in drainage channel and channel/bridge design for watersheds exceeding the capacity of a 72" pipe, typically over 160 acres, shall be determined using the Sacramento Method, Volume 2 Hydrology Standards.

9-11 HYDRAULICS

A. Hydraulic Grade Line

1. Hydraulic grade line calculations for pipe storm drain systems shall begin at the worst case existing ultimate 10-year channel or basin water surface elevation. For the design storm, the hydraulic grade line shall be a minimum one-half foot (0.5') below the elevation of all inlet grates and a minimum one foot (1') below the elevation of manhole cover. The hydraulic grade line must be checked for the 100-year channel or basin water surface elevation, in order to determine the extent of flooding and the 100-yr water surface elevation throughout the area served by the basin.

2. The hydraulic grade line shall be shown on the plans.

3. A note shall be made on the plans indicating stationing where the hydraulic grade line is below the soffit of the pipe.

4. For open channel systems, the hydraulic grade line shall be shown for the 10-year and 100-year storm events. Prior to acceptance of all channels, bridges or culverts the 10- and 100-year hydraulic gradeline elevations must be permanently marked on the structure.

5. In adjacent unimproved areas with no current development plans, the future gutter flow line is assumed one and one-half feet (1.5') lower than the natural ground elevation, for purposes of pipe hydraulics calculations. This also applies to in-fill development, where the elevation of the hydraulic grade line is not known.

B. Hydraulic Gradient

In order to analyze the drainage system to determine if design flows can be accommodated without causing flooding at some locations or causing flows to exit the system at locations where this is unacceptable, the consulting engineer shall analyze the hydraulic gradient. A water surface profile calculation must be performed by the design engineer for the entire system. The starting elevation for all hydraulic grade line calculations must be clearly noted on all plans and calculations. The source of this elevation must also be indicated (Master Plan, FEMA, etc.). If it is not readily available it must be calculated. If it is assumed, the basis of the assumption must be noted.

C. Friction Losses

Friction losses can be calculated two ways. These methods cannot be interchanged for design of the pipe system. One method shall be used throughout the analysis. The first method uses a conservative Manning's "n" value to account for minor losses.

1. Method 1

   A water surface profile calculation must be performed by the design engineer for all open channels, closed conduits and culverts.

   The minimum 'n' values to be used in the Manning's formula shall conform to the following:

Precast Concrete Pipe	0.015
High Density Polyethylene Pipe	0.015
Polyvinylchloride Pipe	0.015
Concrete Box Culvert (within a closed conduit system)	0.016
Ribbed Metal Pipe	0.015
Concrete Cast-In-Place Pipe	0.015
Pavement Surfaces	0.016
Open Channel Fully Lined	0.018
Corrugated Metal Pipe 2-2/3" x ½" Corrugations	0.024
Corrugated Metal Pipe 3" x 1" or 5" x 1" Corrugations	0.028
Open Channel with Lined Bottom, Clean Sides	0.035
Earth Channel with Clean and Uniform Sides	0.060
Earth Channel with natural bottom and sides	0.080 or higher

   Using Method 1 does not require the analysis of other minor losses. Pipes and culverts that are designed with inlet control shall account for losses associated with inlet control.

2. Method 2 – Minor Losses

   Calculation of minor losses more accurately models the system. Energy losses from pipe friction shall be determined by the following:

   $$S_f = [Qn/1.486\ AR^{2/3}]^2$$

   Where: S_f = friction slope, ft/ft
          Q = flow rate, ft^3/s
          n = Manning's coefficient
          A = area, ft^2
          R = hydraulic radius

   The head loss due to friction is determined by the formula:

   $$H_f = S_f L$$

   Where: H_f = friction head loss, ft
          L = length of outflow pipe, ft

The minimum "n" value used in Manning's formula shall conform to the following:

Precast Concrete Pipe	0.012
High Density Polyethylene Pipe	0.012
Polyvinylchloride Pipe	0.012
Concrete Box Culvert (within a closed conduit system)	0.013
Ribbed Metal Pipe	0.013
Concrete Cast-In-Place Pipe	0.014
Pavement Surfaces	0.016
Open Channel Fully Lined	0.018
Corrugated Metal Pipe 2-2/3" x ½" Corrugations	0.024
Corrugated Metal Pipe 3" x 1" or 5" x 1" Corrugations	0.028
Open Channel with Lined Bottom, Clean Sides	0.035
Earth Channel (Clean, Uniform Sides) or Natural Channel	0.060
Earth Channel with natural bottom and sides	0.080 or higher

D. Velocity Head Losses

Analysis methods must account for all minor losses.

Minor head loss is usually written as:

$$H_L = K_c\ (V^2/2g)$$

Where: H_L is the minor head loss
K_c is the sum of minor loss coefficients
$V^2/2g$ is the velocity head

The loss coefficient and the form of the equation are different depending on the type of loss, whether flow is open channel or pressure flow, and at times, whether flow is sub-critical or supercritical. Full discussion and values of coefficients are given in several references (Chow *Open Channel Hydraulics*; Brater and King *Handbook of Hydraulics*; Rouse *Fluid Mechanics for Hydraulic Engineers*; Hendrickson *Hydraulics of Culverts*). The following are minor head loss formulas for hydraulic structures commonly found in storm drain systems and open channels.

E. Entrance Losses

Entrance losses to box culverts and pipes of various materials can be estimated by using the entrance loss coefficients listed in Table 9-3 in conjunction with the minor head loss equation, once outlet control has been established.

F. Manhole and Junction Losses

Junctions are locations where two or more pipes join together to form another pipe or channel.

Multiple pipes or channels coming together at a junction should flow together smoothly to avoid high head losses. Items that promote turbulent flow and high losses include a large angle between the two (>60°), a large vertical difference between the two (greater than 6 inches (6") between the two inverts), and absence of a semicircular channel or benching at the bottom of the junction box in the case of pipes. Special problems arise when smaller pipes join a larger one at a junction.

1. Straight Through Manhole

   In a straight through manhole where there is no change in pipe size, the minor loss shall be calculated by:

   $$H_m = 0.05 \ (V^2/2g)$$

2. Incoming Opposing Flows

   Design of opposing flows or 90 degree angles must be avoided. The head loss at a junction, H_{j1}, for two almost equal and opposing flows meeting head-on with the outlet direction perpendicular to both incoming directions is considered as the total velocity head of outgoing flow.

   $$H_{j1} = V^2/2g$$

3. Changes in Direction of Flow

   When main storm drainpipes or lateral lines meet in a junction, velocity is reduced within the chamber and specific head increases to develop the velocity needed in the outlet pipe. As a bend becomes sharper (approaching 90°), the more severe the energy loss becomes. When the outlet conduit is sized, determine the velocity and compute head loss in the chamber by the minor head loss formula in conjunction with the following:

K	Degree of Turn (In Junction)
0.19	15
0.35	30
0.47	45
0.56	60
0.64	75
0.70	90 and greater

   Any degree of turn greater than 90 degrees requires the approval of the Director.

   For a graphic solution to other degree of turns, refer to drawing SD-5. For culverts the design engineer must determine if the culvert works with inlet or outlet control for the peak flow of the given design frequency.

Table 9-3

Entrance Loss Coefficients for Culverts (FHWA 1985) Outlet Control, Full or Partly Full Entrance Head Loss.
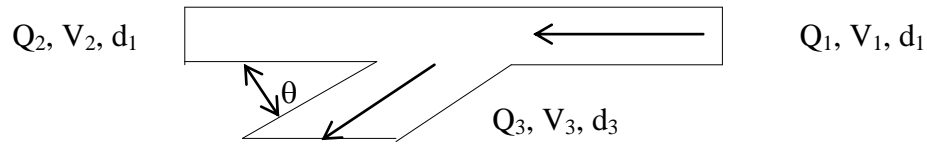
$H_e = k_e (V^2/2g)$

Type of *Structure and Design of Entrance*	*Coefficient k_e*
Pipe Concrete	
Projecting from fill, socket end (groove-end)	0.2
Projecting from fill, sq. cut end	0.5
Headwall or headwall and wing walls	
--Socket end of pipe (groove-end)	0.2
--Square Edge	0.5
--Rounded (radius = 1/12D)	0.2
--Mitered to conform to fill slope	0.7
--*End-section conforming to fill slope	0.5
--Beveled edges, 33.78 or 458	0.2
Bevels	
--Side- or slope-tapered inlet	0.2
Pipe, or Pipe-Arch, Corrugated Metal	0.9
Projecting from fill (no headwall)	0.5
Headwall or headwall and wing walls square-edge	0.7
Mitered to conform to fill slope, paved or unpaved slope	0.5
*End-section conforming to fill slope	0.2
Beveled edges, 33.78 or 458 bevels	0.2
Bevels	
--Side- or slope-tapered inlet	0.2
Box, Reinforced Concrete	
Headwall parallel to embankment (no wing walls)	
--Square-edged on 3 edges	0.5
--Rounded on 3 edges to radius of 1/12 barrel dimension, or beveled edges on 3 sides	0.2
Wing walls at 308 to 758 to barrel	
-- Square-edged at crown	0.4
--Crown edge rounded to radius of ½ barrel dimension, or beveled top edge.	0.2
Wing walls at 108 to 258 to barrel	
--Square-edged at crown	0.5
Wing walls parallel (extension of sides)	
--Square-edged at crown	0.7
--Side- or slope-tapered inlet	0.2

*Note: "End-section conforming to fill slope," made of either metal, concrete or HDPE are the sections commonly available from manufacturers. From limited hydraulic tests they are equivalent in operation to a headwall in both *inlet* and *outlet* control. Some end sections, incorporating a *closed* taper in their design, have a superior hydraulic performance.

The following equation may be used to determine the loss in head in cases where it may be necessary to split or branch the flow into another drain.

Figure 9-1

Q_2, V_2, d_1 [figure: branch drain splitting. Q_1, V_1, d_1 entering from the right, splitting at angle θ into Q_3, V_3, d_3] Q_1, V_1, d_1

$$H_{br} = cV_1^2/2g$$

Divergence Angle - θ	$Q_3/Q_1 = 0.3$	$Q_3/Q_1 = 0.5$	$Q_3/Q_1 = 0.7$
90°	c = 0.76	0.74	0.80
60°	c = 0.59	0.54	0.52
45°	c = 0.35	0.32	0.30

4. **Several Entering Flows**

The computation of losses in a junction with several entering flows utilizes the principle of conservation of energy, involving both position energy (elevation of water surface) and momentum energy (mass times velocity head). Thus, for a junction with several entering flows, the energy content of the inflows is equal to the energy content of the outflows plus additional energy required by the collision and turbulence of flows passing through the junction. In addition, when two nearly equal flows enter the junction from opposing directions, head loss is considered as the total velocity head of the outgoing flow.

For example, the total junction losses at the sketched intersection are as follows:

Figure 9-2
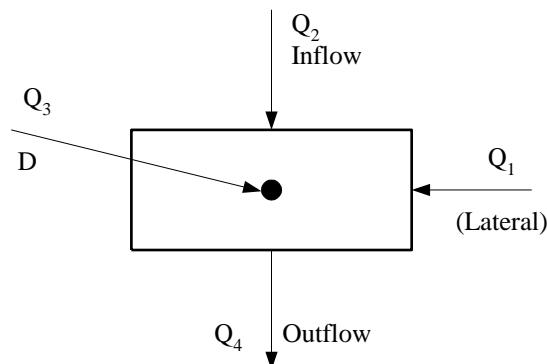
$$Hj_2 = [(Q_4V_4^2) - (Q_1V_1^2) - (Q_2V_2^2) + (KQ_1V_1^2)] / (2gQ_4)$$

Where: Hj_2 = junction losses, ft
Q = discharges, cfs
V = horizontal velocities ft/s
V_3 = is assumed to be zero
K = bend loss factor

Subscript nomenclature for the equation is as follows:

Q_1 = 90 ° lateral, cfs
Q_2 = straight through inflow, cfs
Q_3 = vertical dropped-in flow, from an inlet, cfs
Q_4 = main outfall = total computed discharge, cfs
V_1, V_2, V_3, V_4 are the horizontal velocities of foregoing flows, respectively in feet per second

Also assume:

$H_b = K (V_1^2)/2g$ for change in direction.

No velocity head of an incoming line is greater than the velocity head of the outgoing line.

Water surface of inflow and outflow pipes in junction to be level.

When losses are computed for any junction condition for the same or a lesser number of inflows, the above equation will be used with zero quantities for those conditions not present. If more directions or quantities are at the junction, additional terms will be inserted with consideration given to the relative magnitudes of flow and the coefficient of velocity head for directions other than straight through.

G. Bend Loss

Bend losses shall be calculated from the following equations:

$H_b = K_b (V^2/2g)$

In which: $K_b = 0.20 (\Delta/90°)^{0.5}$

Where: Δ = Central angle of bend in degrees.

Bend losses should be included for all closed conduits, those flowing partially full as well as those flowing full.

H. Trash-Rack Head Loss

The head loss through a stationary trash-rack is commonly determined from the following equation:

$H_{TR} = K_{TR} (V_n^2/2g)$

$K_{TR} = 1.45 - 0.45 A_n/A_g - (A_n/A_g)^2$

Where: K_{TR} = Trash-rack coefficient
A_n = Net area through bars, in ft^2
A_g = Gross area of trash-rack and supports (water area without trash-rack in place), in ft^2
V_n = Average velocity through the rack openings (Q/A_n), in ft/sec

For design, assume that the rack is clogged, thereby reducing the value of A_n by 50%.

9-12   CLOSED CONDUITS

The specific type of pipe or alternate pipe to be used in the development shall be shown on the profile sheets.   The minimum inside diameter for pipes used in the public right of way shall be no less than twelve inches (12") for laterals and twelve inches (12") for mains. No storm drain conduit shall have a diameter less than that of the conduit immediately upstream of it.

A. Material
Publicly maintained drainage systems shall be constructed of the following materials and installed consistent with the latest edition of City of Elk Grove's Standard Construction Specifications:

1. Reinforced Concrete Pipe

    Class of pipe shall be based upon depth as detailed in the Standard Drawings. Pipe shall conform to ASTM C76, latest revision. The consultant shall specify on the plans that the assembly of joints shall be in accordance with the pipe manufacturer's recommendations and the requirements of ASTM C443.

2. Concrete Cast-In-Place-Pipe

    a.) Where Concrete Cast-In-Place-Pipe is to be used, a soil report is required for the project that addresses placement of Concrete Cast-In-Place-Pipe.

    b.) The Consulting Engineer shall provide details on the plans for connection of the concrete cast-in-place-pipe to the different piping materials being used.

3. Polyvinyl Chloride Pipe

    Polyvinyl Chloride (PVC) Pipe may be used conforming to the Construction Specifications. Use of polyvinyl chloride downstream of the last manhole or junction structure to outfalls to channels or detention basins is not allowed.

4. High Density Polyethylene Pipe

    a) HDPE shall not be used in existing or future roadways or for driveway culverts. It may only be used for trunk lines outside roadways.

    b) Use of High Density Polyethylene Pipe downstream of the last manhole or junction structure to open channels, detention facilities or to a daylight condition is not allowed.

5. Metal Pipe

    a.) Metal pipe shall be corrugated steel, corrugated aluminum, corrugated aluminized steel Type II, ribbed steel, ribbed aluminized steel Type II or ribbed aluminum.

    b.) Metal pipe shall be designed for a minimum maintenance free service life of fifty (50) years in accordance with the methods specified in Section 854.3 and 854.4 of the California Department of Transportation Highway Design Manual (a copy of Figure 854.3B may be found in the back of in these Drainage Standards). To assure that the service life is achieved, alternative metal pipe may require added thickness and/or protective coatings. The Consulting Engineer shall provide certified copies of the laboratory report giving the results of pH and resistivity tests. The report shall also include a map showing the location of each site and depth where samples were taken.

    c.) Unless otherwise specified by the Director, a minimum of two soil samples shall be taken for the first 1,000 lineal feet of pipe or fraction thereof on a project with a minimum of one additional sample being required for each additional 1,000 lineal feet of pipe or fraction thereof. The samples shall be taken along the approximate alignment and at the approximate depth of the pipe to be installed. Priority in sampling shall be given to trunk facilities.

B. Cover Requirements

At locations where the minimum cover requirements cannot feasibly be obtained, the conduit shall be provided with a concrete cover or other methods of pipe protection as approved by the Director. Cover shall be measured from the top of a rigid Portland cement concrete pavement or the bottom of a flexible asphalt concrete pavement structural section.

1. <u>Minimum Cover</u> - The minimum cover requirements shall be per Table 9-4 and measured from the top of pipe to top of subgrade (bottom of A.B.).

Table 9-4

Minimum Pipe Cover Requirements

Pipe Material Type and Location	Minimum Cover Requirement
High Density Polyethylene (HDPE) – non traffic areas	Twenty-four (24") – top of pipe to top of grade
Corrugated Metal	Span/8 but not less than twelve inches (12")
Spiral Rib – Steel	Span/3 but not less than twelve inches (12")
Spiral Rib – Aluminum with spans less than or equal to 72"	Span/2 but not less than twelve inches (12")
Spiral Rib – Aluminum with spans greater than 72"	Span/3 but not less than thirty inches (30")
Reinforced Concrete in unpaved areas	1/8 the diameter or rise (the greater of) but not less than twelve inches (12")
Reinforced Concrete under flexible pavements (Class IV and V)	1/8 the diameter or rise (the greater of) but not less than twelve inches (12")
Reinforced Concrete under flexible pavements (Class I, II, and III)	1/8 the diameter or rise (the greater of) but not less than twenty-four inches (24")
Reinforced Concrete under rigid pavements	A nine-inch (9") space between top of pipe and bottom of slab consisting of compacted granular fill shall be maintained at a minimum.
Cast-in-Place-Concrete-Pipes in paved areas	The structural section (AC & AB) plus twenty-four inches (24")
Cast-in-Place-Concrete-Pipes in unpaved areas	Twenty-four inches (24")
Polyvinyl Chloride – C900 and C905	Twelve inches (12")
Polyvinyl Chloride – D2241 and D3034	Twenty-four inches (24")

Note: All depths shown are for a minimum trench width equal to the outside diameter of the pipe plus sixteen inches (16") measured at the top of the pipe.

2. <u>Maximum Cover</u> - Maximum height of cover shall be per Tables 9-4a and b.

Table 9-4a Maximum Pipe Cover Requirements - **Concrete and Plastic Pipe**
Measured to bottom of trench in feet

DIA.	RCP Class I	II	III	IV	V	Cast In Place	PVC	HDPE
12		8	12	30			14	49
15		10	15	35			14	45
18		11	16	38			14	43
21		12	17	39			14	
24	Not Permitted	12	18	39	No Limit	No Limit	14	43
27		13	19	39			14	
30		14	19	38				34
33		14	20	38				
36		13	17	27	69			45
42		14	18	29	62	38		46
48		15	19	30	60	30	Not Permitted	41
54		16	20	31	58	26		
60	14	16	21	31	57	24		48
66	15	17	22	32	56	21		
72	15	18	23	33	56	21		

Note: All depths shown are for a minimum trench width equal to the outside diameter of the pipe plus sixteen inches (16") measured at the top of the pipe.

Table 9-4b Maximum Pipe Cover Requirements - **Metal Pipes**
Measured to bottom of trench in feet

DIA.	CMP ** Thickness - inches 0.064	0.079	0.109	0.138	0.168	Ribbed Steel Pipe Thickness - inches 0.064	0.079	0.109	Ribbed Aluminum Pipe Thickness - inches 0.060	0.075	0.105	0.135
12	99											
15	99		No Limits									
18	99											
21	99	99										
24	93	99				36	50	67	21	29	49	64
30	74	93	99			30	40	56	17	24	40	51
36	62	78	99	99		26	35	48	14	21	34	44
42	53	66	93	99		21	31	41	13	18	30	37
48	46	58	81	99	99	20	28	38	12	17	26	34
54	47	52	72	93	99	19	26	34		15	25	31
60	43	53	65	84	99		25	32		14	23	28
66	39	48	68	76	93		22	30			21	26
72	35	42	62	70	85		22	28			20	25

Note: 1) All depths shown are for a minimum trench width equal to the outside diameter of the pipe plus sixteen inches (16") measured at the top of the pipe.
2) ** Normal pipe corrugation profile is 2 2/3" x ½". The corrugation of the pipes within the shaded box area shall have profile of 3" x 1" or 5" x 1".
3) When flow velocity exceeds five (5) feet per second, the next thicker gauge shall be used for CMP pipe.

C. Temporary Construction Vehicle Loading

1. A note shall be made on the plans stating the minimum cover requirements during construction for temporary heavy construction vehicle loading, such as scraper or truck haul routes.

2. For flexible pipes, place at least four feet (4') of cover over the top of the pipe.

3. For rigid pipes, place at least three feet (3') of cover over the top of the pipe.

D. Trench Requirements

1. Trenches shall be excavated with full depth and vertical sides whenever possible.

2. The minimum trench width shall not be less than the outside diameter of the pipe barrel plus sixteen inches (16"), measured at the top of the pipe. Where conditions require side sloping of trenches, the minimum vertical trench shall be from the bottom of the trench to one foot (1') over the top of the pipe

3. In fill areas, or in areas with poor soil conditions where it is anticipated that a good, firm, vertical-walled trench cannot be constructed, the consulting engineer shall design the pipe structural requirements in accordance with good engineering practice. A note shall be placed on the plans directing the contractor to place the proper strength pipe if trench conditions encountered differ from those stated in the design trench plans.

E. Spacing Requirements
When multiple adjacent pipe lines are used, they shall be spaced so that the sides of the pipes shall be no closer than two feet (2'), or for parallel pipes larger than forty-eight inch (48") the spacing shall be no closer than one half (1/2) the nominal diameter. This is to permit adequate compaction of backfill material. Special bedding and backfill considerations shall be taken when depths of parallel pipes vary.

F. Alignment Requirements
1. The location of storm drainage pipes in new streets shall be typically six feet (6') north or west of and parallel to the centerline of the street. In special situations, pipelines may be placed in alternative locations, including under curb and gutter, as approved by the Director.

2. All new storm drain mains shall be placed a minimum of one hundred feet (100') from existing and proposed water wells. Encroachments less than one hundred feet (100') require approval of City Planning and the water purveyor prior to plan approval.

3. Avoid unnecessary meandering and angular changes of pipelines. Angular changes, when necessary, shall not exceed 90 degrees unless approved by the Director. No angular changes in direction are allowed for concrete cast-in-place-pipe other than on a radius.

4. Pipeline Radius Criteria: All pipe placed on curves shall meet manufacturer's recommendations for curved alignment. All curves, radii, length of pipe joints, and types of pipe shall be shown on the plans. The minimum radius of curvature for concrete cast-in-place-pipe shall be determined by the formula $R = 30D$ where

R = radius of curvature, and D = nominal internal pipe diameter, with R and D expressed in the same units.

5. Pipelines shall be laid straight in both horizontal and vertical planes between manholes unless otherwise approved by the Director.

6. Where storm drain pipelines of different diameter join, the invert elevations shall be adjusted to maintain a uniform energy gradient.

G. Velocity

1. The minimum full flow velocity shall be no less than two (2) feet per second. The maximum velocity, at maximum pipe system capacity, shall be less than the critical velocity, where the value of the critical velocity must be calculated.

2. When full-flowing pipelines produce supercritical velocity or velocities larger than twelve (12) ft/second, , special provisions shall be taken to prevent pipe displacement, and manhole lid surcharge.

H. Pipe Inlets and Outlets

1. Headwalls, flared end section and other structures at inlets shall be designed to increase hydraulic efficiency, prevent erosion adjacent to the conduit and provide a counterweight to prevent flotation. Headwalls or flared end sections shall be used at both intake and discharge ends of culverts and pipes.

2. Standard headwalls shall be installed at pipe outlets per standard drawings of the latest edition of the Standard Construction Specifications.

3. The vertical face of the headwall shall be set back a sufficient distance from the channel side slope to accommodate flap-gates (when needed) in a fully opened position without encroachment of the flap past the channel side slope face.

4. All pipe and culvert entrance and outlet locations must be provided a concrete apron with a minimum length of five (5) pipe diameters for erosion control and maintenance purposes.

5. Pipe inlets greater than 24 inches will normally have a trash rack installed. Pipe Outlets greater than 36 inches, not in an area enclosed with a fence, will normally have a trash rack installed for access control.

6. Energy dissipators must be utilized at outlets at the end of the concrete apron. All energy dissipation shall be designed considering outlet velocities and hydraulic jumps. Rip-rap shall not be placed on the outlet apron.

I. Water and Soil Tight System

1. All storm drain pipe, manholes, and fitting connections, including drain inlet laterals shall be water and soil tight and tested in conformance with the City's Standard Construction Specifications.

2. A note shall be placed on the improvement plans stating these requirements and that the contractor is responsible for providing equipment and labor for performing tests and making measurements when directed to do so by the City's inspector.

J. Bored and Jacked Pipe
All casing pipes shall be sealed at both ends in such a manner as to provide water resistant seal.

K. Backfill Seepage
A concrete filled cutoff barrier shall be utilized at inlets and outlets where there is a high probability that water will periodically penetrate pipe backfill material.

9-13 MANHOLES & JUNCTION BOXES

Requirements for manholes are as follows:

A. Standard pre-cast concrete or saddle type manholes shall be used except where special manholes or junction boxes are required. The design of special manholes and junction boxes must be submitted to the Director for approval. Cast-in-place manholes shall conform to the Standard Drawings.

B. All manholes shall be a minimum 48 inches inside diameter unless approved on an exception basis by the Director. In no case will junction boxes or manholes be allowed which are smaller than twenty-four inches (24") inside dimension.

C. Manholes shall be sized to provide a minimum of nine inches (9") wall spacing between annular cutout edges of pipe openings.

D. Manholes shall be located at junction points, angle points greater than 15 degrees, and changes in pipe size or materials. On curved pipes with radii of 200-feet to 400-feet, manholes shall be placed at the beginning and end of curve and on 300-feet maximum intervals along the curve. On curves with radii exceeding 400-feet, manholes shall be placed at the beginning and end of curves and on 400 feet maximum intervals along the curve for pipes twenty-four inches (24") and less in diameter and 500-feet maximum intervals along the curve for pipes greater than twenty-four inches (24") in diameter. Manhole spacing on curves with radii less than 200-feet will be determined on an individual basis. Exceptions to these calculated manhole placement shall be allowed if the resulting manholes are within 100 feet of existing or proposed manhole.

E. Spacing of manhole, junction boxes (or inlets of such size as to be accessible for maintenance) shall not exceed 400-feet for drains fifteen inches (15") and smaller in diameter, 500-feet for drains between eighteen inches (18") and thirty-six inches (36") in diameter, and 600-feet for pipes greater than forty-two inches (42") in diameter.

F. All manholes and junction boxes other than inlets shall have standard manhole frames and covers as shown in the Specifications. Manhole and junction box covers shall be marked "STORM DRAIN" in raised lettering. Manholes will not be allowed in the gutter or sidewalk.

G. A reinforced flat top forty-eight inch (48") diameter (no cone) concrete lid as shown in the Construction Specifications shall be required when any pipe would enter the manhole above any portion of the base of a manhole cone. Maximum twenty-four inch (24") diameter riser (chimney) height shall be less than or equal to eighteen inches (18").

H. Use grated manhole covers (Drawing SD-11) to pick up minor drainage in non-traffic areas only if debris clogging is not a concern.

I. Improvement plans shall include a special detail for all manholes at junction points where there is a change in pipe direction for pipe diameters exceeding forty-eight inches (48").

J. Resilient connectors, in conformance with Section 39-2.02 of the Specifications, are required between pre-cast manhole/box and pipe, and between pre-cast drop inlet and pipe. Water stops are required for pipe to cast-in-place manhole/drop inlet connections. Use non-shrinking/non-expansive grout for making connections of pipe and water stop to structure walls.

K. Stations of manholes/boxes shown on project drawings apply at center line of shaft.

L. Manhole/box lids shall be bolted to frame where lids are prone to surcharging when the storm drain system is at maximum capacity. A pressure manhole design may be required by the Director.

M. Storm drain manholes/boxes shall be tested in conformance with the Standard Construction Specifications.

N. There shall be no sumps in manholes outside of the public right-of-way. Manholes and junction boxes located outside of paved areas shall have rim set 0.5 feet above ground surface.

O. Drop inlets shall not be used as junction boxes, unless approved by the Director.

P. Junction boxes shall be constructed of pre-cast or cast in place reinforced concrete with minimum wall thickness of six inches (6"). The Consulting Engineer shall submit calculations indicating the junction box is designed to withstand H-20 loading

Q. The inside vertical dimension of junction boxes shall be such as to provide a minimum of three-inch (3") clearance on the outside diameter of the largest pipe in each face. Junction boxes shall have a minimum horizontal inside dimension of forty-eight inches (48"). All junction boxes shall be rectangular unless otherwise approved by the Director.

R. Pipes adjacent to junctions shall have tight, impermeable joints subject to testing requirements of Section 39-4.02 of the Specifications.

S. Junction boxes larger than ten feet (10') in any dimension shall have two manhole access points.

9-14 INLETS

A. All inlet design curves in these Standards assume clean inlets. The Consulting Engineer shall assume a 50% clogging factor when determining the number and location of inlets.

B. Additional inlets are required at sump locations per Section 9-11A of these Standards.

C. Type B inlets are typically used for streets with concrete curbs and gutters. See Figure 9-3, for flow capacity.

FIGURE 9-3

TYPE B INLET FLOWS
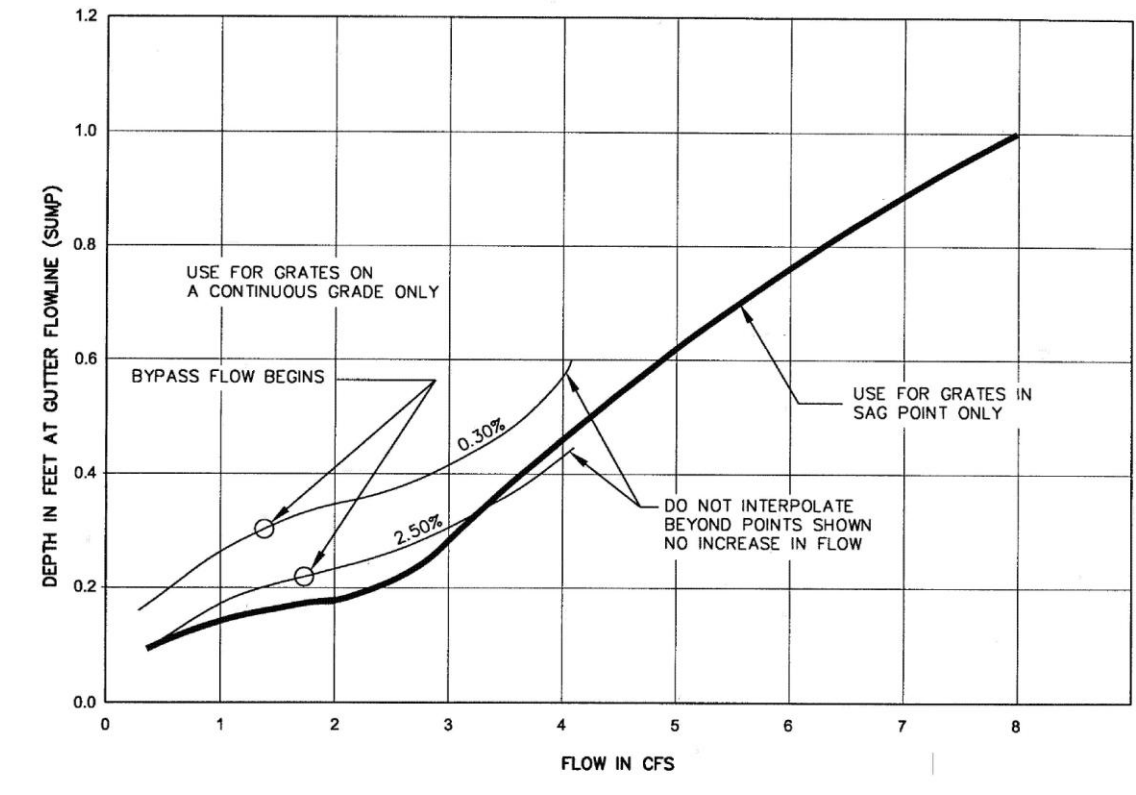
D. Always use grated inlets when the longitudinal slope of the street exceeds 4% where due to the high velocities it is difficult to direct the flows into the curb opening.

E. Type F inlets may be used in roadside ditches, swales, unimproved medians, and outside of the road right-of-way. Figure 9-1 provides design capacity for one two-foot wide window of a Type F inlet, clear of debris.

F. Curb opening catch basins with grating(s) and debris skimmers (Drawings 300,301,308,309 in the Specifications) may be used in locations where additional inlet capacity, beyond a single Type B inlet, is needed, or as where directed by the Director. The inlet width may vary from seven feet (7') to twenty-eight feet (28'). The H dimension is the gutter depression depth and shall be a standard two inches (2"). When more than one grate is required, use Drawing SD-16 for support assembly. Assure that the lateral is sized to serve the increased inlet capacity. Flow capacity for the 300 and 301 inlets is calculated using the methods found in the Federal Highway Administration (FHWA) Urban Drainage Design Manual Hydraulic Engineering Circular No. 22.

G. Inlets in Class "A" and "B" streets shall be placed at lot lines in residential subdivisions and at the curb return of intersections. Inlets shall be placed so that the length of flow does not exceed 500 feet, unless otherwise approved by the Director. Inlets at curb returns shall be constructed so that they are not in conflict with the Americans with Disabilities Act requirements for ramps. No face plates are allowed on inlets at the curb returns.

H. Type F inlets shall be designed based on the following chart and Figure 9-4. The chart assumes clean openings, so some clogging shall be accounted for by adding a grated lid or increasing the window opening(s).

FIGURE 9-4

TYPE F INLET FLOWS
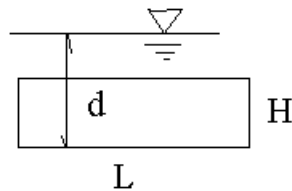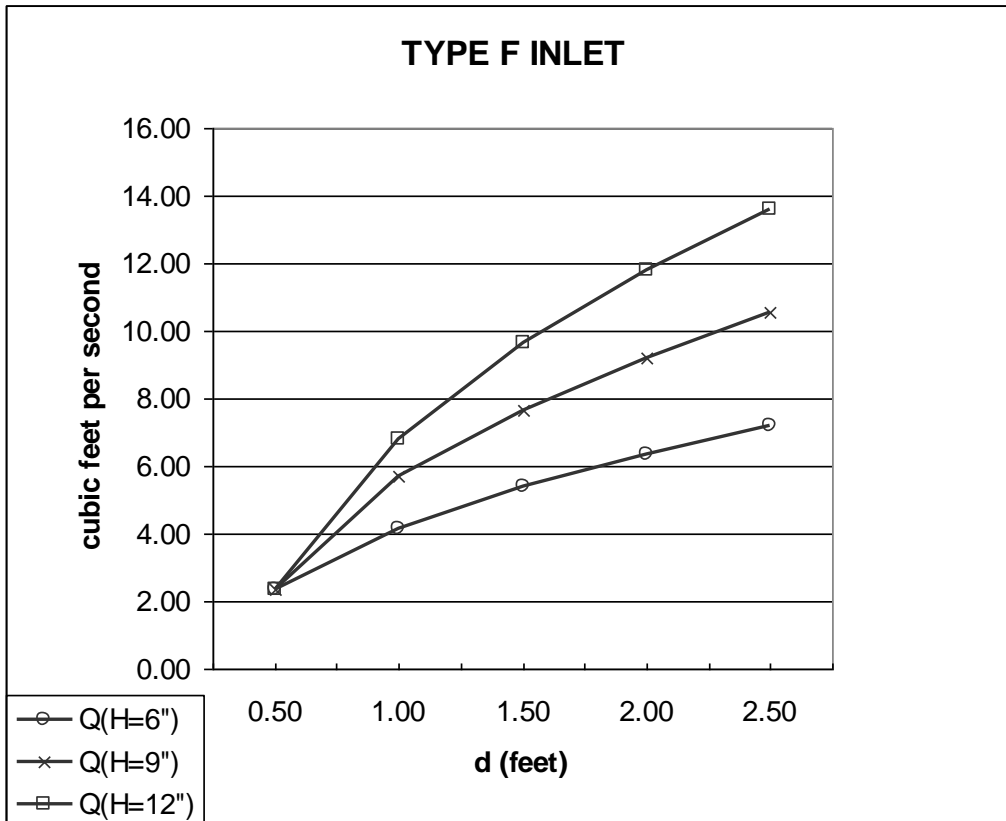
$$Q_{weir} = 3.33L\,d^{1.5} \qquad (d<H)$$

$$Q_{weir} = 0.60(2gd)^{0.50} \qquad (d>H)$$

9-15 OVERLAND RELEASE

Piped storm drain systems are not designed to convey peak flow from infrequent high intensity storm events. When the pipes and inlets are clogged or overwhelmed, surface runoff will pond in low areas and flow overland along designed overland release routes. The improvement plans shall include overland release routing and the consulting engineer shall provide supporting calculations. Risk of flood damage shall be reduced by insuring that the 100-year storm runoff ponds and flows through the proposed development with appropriate freeboard protecting existing and proposed structures, pursuant to Section 9-1 of these Standards. Hydraulic and erosion control calculations for overland release flows must be provided with the design.   .

A. For the purposes of determining overland release flows, the 100-year runoff will be determined using the Sacramento Method. For purposes of overland flow design, the designer may assume the storm drain pipes are flowing full into 100-year downstream water surface condition, or may actually calculate the flow conditions using the 100-year storm event with a 10-year HGL as the starting water elevation for the downstream channel.

B.   Arterial streets and selected collector streets, as determined by the Director, will be designed with at least one traffic lane in each direction completely above the 100-year HGL elevation.

C. The 100-year HGL elevation of overland flows on streets shall not exceed the back of sidewalk elevation by more than six inches (6") on streets with vertical curbing and eight inches (8") on streets with rolled curbing.

D. Where the overland release path leaves the paved right-of-way, concrete improvements shall be constructed as a mow strip, gutter or other permanent flow line. Decorative use of stamped concrete is encouraged. The use of grouted paving stones or cobbles is acceptable as long as they are placed on top of a two (2) inch minimum concrete base, are solid grouted, and do not protrude into the invert elevation/flow line. The outlet of the overland release flows must be similarly armored with a concrete apron. Additionally, energy dissipation features must be placed at the end of the apron and/or formed within the apron concrete.

E. Streets, publicly-owned parking lots, pedestrian areas, pedestrian walkways, utility routes and other open space areas may be considered compatible uses for the overland release routing. Appropriate barricades for traffic safety and signage as required by the City shall be placed as needed for release paths exiting the right-of-way.

Figure 9-5

The US Department of Transportation recommends, in Hydraulic Engineering Circular Number 22, the use of the following equation when the depth at the gutter is less than one fortieth (1/40) the width of flow. It is a variation of the Manning's formula because the hydraulic radius does not adequately describe the gutter cross section. The compound gutter and rolled curb are considered negligible and are ignored.

$$Q = \frac{K_C}{n} S_X^{1.67} T^{2.67} S_L^{0.5}$$
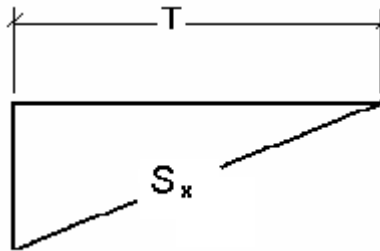
Where: Q = flow rate (ft^3/sec)

K_C = 0.56 (English units)

n = Manning's coefficient (use 0.016 for paved street)

T = width of flow or spread (ft)

S_X = cross slope, typically 0.020 (ft/ft)

S_L = longitudinal slope (ft/ft)

Depth at gutter = TS_X

9-16 PIPE STUBS

The criteria for pipe stubs shall be as follows:

A. A headwall or flared end and trash rack shall be required where the upstream pipe ends at a park or open field, and the site shall be graded toward the inlet.

B. Temporary pipe stubs shall be as deep as possible to provide for future extension, and raised to grade using a type F, type H, or type I inlet or other appropriate catchments. Type H Inlets shall be sized two (2) sizes larger than the connecting pipe or pipe stub.

9-17 HEADWALLS AND RACKS

The requirements for headwalls, wing-walls, end walls, trash racks, access control racks and railings are as follows:

A. All headwalls, wing-walls and end walls shall be considered individually and in general shall be designed in accordance with the Standards and Specifications of the California Department of Transportation.

B. Erosion control is of high importance where storm drain pipes discharge to natural channels. Energy dissipating structures shall be detailed on the improvement plans. P Pipe and culvert entrance and outlet locations shall be provided a concrete apron with minimum lengths as required in Sections 9-12 (H) and 9-23 for erosion control and maintenance purposes.

C. Trash racks will be provided on inlets to pipes entering an underground conduit system. Trash racks shall be designed such that the ratio of trash rack open area to drain opening is at a minimum four to one (4:1).

D. Racks shall be required on pipe outlets forty-two inches (42") or larger, unless access is restricted by fencing and omission is approved by the Director. The Director may require racks at smaller pipe outlets in locations that are deemed to warrant supplemental access control. Racks will not normally be installed on open-ended culverts.

E. Racks shall be designed such that the ratio of rack open area to drain opening is at a minimum four to one (4:1). They shall hinge at the top to allow them to open should debris and hydraulic forces provide pressure.
Racks on pipe outfalls 37 to 66-inch diameter shall be constructed as two separate hinged sections. For pipe outfalls greater than 66-inch diameter, the racks shall be split into three sections.

F. Public safety may require metal beam guardrail or chain link fencing at the top of culverts, headwalls, box culverts, and steep side slopes. Installation shall be in accordance with the Specifications.

G. Slopes around headwalls, wing walls, end walls, trash racks and other concrete structures shall be protected from erosion appropriately.

9-18 DRAINAGE PUMPS

Drainage pumping stations shall be designed in accordance with the latest edition of the Hydraulic Institute Standards and as specified by the Director. A pump station will include the following minimum features:

A. A standby backup pump.
B. An automated debris removal system at the inlet.

C. A diesel powered generator with automated start and stop and a 3 hour supply of fuel will be part of the station.

D. A low flow pump will be required to accompany any drainage pump station.

E. Automated control systems linked to a SCADA system.

F. Standardization of models and manufacturers of equipment in existing City-operated stations.

The City will provide a list of required features based on the size, locations and purpose of each station.

9-19 DETENTION SYSTEMS

Detention basins can be used for peak flow attenuation, detention, and retention and/or storm water treatment. Flood control detention system designs must be performed for all detention/retention basins, temporary or permanent.

A. Detention basin volume requirements shall be determined based on a 100-year, 24-hour storm. For the 100-year 24-hour volume, the basin must have 2 feet of freeboard. The total volume required for the basin shall be based on hydrologic routing computations detailed by the Hydrology Standards of the Sacramento City/County Drainage Manual. Basin routing curves shall be included in the design calculations submitted.

B. Detention basins shall have gravity inflow and outlet facilities providing terminal drainage capable of emptying a full basin within 72 hours. Detention basins with pump station outflow may also be considered with the approval of the Director. Downstream limitations must also be considered in sizing the pumping facility.

C. Side slopes of the basin and any berm shall be no more steep than 4:1. Shape should be irregular and slopes should vary around the basin to give it amore natural appearance, up to approximately 10:1 slopes. Bottom of the basin must slope towards outlet at a minimum 2% slope if vegetated or 0.5% if paved.

D. The bottom of the basin shall be a minimum of 2 feet above the highest ground water elevation and be based on the recommendation of a licensed engineering geologist or soils engineer.

E. The basin will have an 8 foot wide access road around the entire perimeter of the basin with a concrete access ramp into the basin. A concrete apron shall be constructed at the bottom of the basin for maintenance equipment staging.

F. If a water quality structure is included in the basin design, the volume of the water quality portion of the basin will be in addition to the volume required for detention. The water quality element of the basin must be designed according to the above referenced design standards and the *Storm Water Quality Design Manual* for the Sacramento and South Placer Region. See Chapter 11.

G. Approved detention basins shall require submittal of a "User Manual" for each detention basin. This manual shall include an 11"x17" sheet showing details of the detention basin

including: inlets, outlets, ramps, elevation, and a vicinity map showing the access route from the arterial and the 10- and 100-year elevations.

9-20   OPEN CHANNELS

All runoff for new development must normally be conveyed in closed conduits. Utilization of open channels may be authorized by the Director whenever one or more of the following applies:

1. The design flow rate exceeds the capacity of a seventy-two inch (72") pipe.

2. The outfall is at an elevation such that minimum cover cannot be obtained over the pipe.

3. County, State or Federal Government policies require that the channel remain natural. A parallel facility for runoff conveyance may be considered. If an agreement is needed between a State and Federal Agency, such agreement must be approved by the Director prior to its submittal to other agencies.

Open channels are to be designed pursuant to the drainage study provided by the design engineer and to the satisfaction of the Director. Each project has unique hydraulic constraints and storm water quality requirements; therefore, the following should be deemed guidelines.

A. Open channels may consist of vegetated earth channels. Concrete lining may also be used.

B. Criteria for open channels shall be as follows:

1. Open channel design shall include a water surface profile analysis using the Army Corps of Engineers HEC-RAS computer program, UNET program or other steady or unsteady state hydraulic program, approved by the Director.

2. Open channels shall be designed to convey the 100-year flood event with a minimum one foot (1') of freeboard. Greater freeboard may be required depending on the sensitivity of the model, obstructions, and surrounding property.

3. The minimum velocity for open channels is 1.5 ft/s. The maximum velocity shall be as follows:

a.) Earth channels, six (6) ft/s

b.) Lined channels, ten (10) ft/s

c.) Bottom-lined channels, eight (8) ft/s

4. Super elevating the outside bank on bends may be required to maintain specified freeboard.

5. The centerline curve radius of an open channel shall be equal to the greater of twice the bottom width or thirty-five feet (35').

6. Earth channels and the side slopes of bottom lined channels shall be vegetated with native grasses or other permanent vegetative cover. All vegetation shall be approved by the Director. Hydro-seeding conducted during the wet season (October 1 – April 30) shall include additional appropriate soil stabilization materials to prevent erosion, in accordance with Section 11 of the Improvement Standards. A note shall be added to improvement plans stating "Vegetated open channels shall not be accepted by the City until 70% of the vegetation is established." No trees shall be planted below the 10-year hydraulic grade line.

7. Channels, deeper than two feet (2'), shall be constructed to a typical cross section with 3 horizontal to 1 vertical (3:1) or flatter side slopes. Exceptions require a soils report and the approval of the Director.

8. All channels deeper than 2 feet shall have a minimum bottom width of six feet (6').

9. Permanent erosion protection shall be placed at the top of the cut or bank to prevent erosion (see Standard Drawings). At locations where overland flows enter the channel, appropriate erosion control and energy dissipation methods shall be incorporated into the design.

12. For all channels, either improved or natural, the following items shall be shown on improvement plans in addition to information heretofore required:

   a.) Typical sections and cross-sections.

   b.) Profile of the existing channel and top of bank profile including enough of the existing channel each side of the development to establish an average profile grade through the development.

   c.) Ten and one-hundred year water surface elevations.

   d.) Road crossings with road profile indicating overland release.

9-21 OUTFALL PLANS

Requirements for outfall plans are as follows:

A. All permanent and temporary drainage outfalls shall be shown in both plan and profile on the improvement plans for a distance until a definite "daylight" condition is established.

B. The profiles shall include ditch flow-line and left and right top of bank elevations.

C. When improvements have more than one unit or phase, the drainage outfall shall be shown as extending to the property boundary and beyond, if required, although it may not be constructed with the current unit development.

9-22 SITE REQUIREMENTS

A. FENCING - Fencing shall normally be required around all City drainage facilities. The specific design and materials used are subject to the approval of the Director. The minimum requirements for fencing are as follows:.

1. Fencing shall be six foot (6') chain link or "decorative" style, located six inches (6") inside of right of way or easement.

2. Pedestrian gates shall be four feet (4') wide.

3. Vehicle gates shall be two eight foot (8') gates with a total opening of sixteen feet (16') wide. They shall be set a minimum of twenty feet (20') back from the edge of pavement to allow for a safe parking area off of the traveled way while opening and closing the gates. Gates must swing away from road right-of-way. A concrete driveway shall be provided at vertical curb locations. Asphalt concrete paving shall be provided between the traveled way and drive gate. Design the paving per Section 9-22 B2 of these Standards.

4. Signs may be required as considered appropriate by the Director. As a minimum, the vehicle gate access shall be marked "City of Elk Grove Drainage Facility – No Motorized Vehicles - No Parking". Signage statements, sizes, layout, and colors shall be approved by the Director.

5. Fencing and gates components shall composed of unpainted galvanized steel. Other materials such as aluminum, or other approved durable and corrosion-resistant materials may be used if decorative fencing is required for the area. Weld joints shall be cleaned and covered with a zinc-based coating.

B. ACCESS ROADS - Every drainage ditch, basin, channel, and underground pipeline outside the right-of-way will have an access road for maintenance, normally located at or above the 100-year flood elevation. An area with a minimum width of 25 feet shall be set aside for access.

1. A twenty foot (20') service road shall be provided having a sixteen foot (16') improved surface and two foot (2') shoulders on each side. Curve radii shall be a minimum of forty-two feet (42'). Turnouts shall be placed as dictated by horizontal sight distance and shall be no greater than one-thousand feet (1000'). Turn-around shall be placed at all dead ends.

2. For ditches less than 8 foot wide from bank to bank at the top of the ditch, a narrower 14 foot service road with a 10 foot improved surface and 2 foot shoulders with lesser turn radii and no turn-outs may be authorized.

3. For roads with no outlet, a turn-around shall be constructed with a minimum 40 foot outer radius at the end of the road.

4. Improved surfaces of the service road shall be a minimum six inches of AB. The center 10 feet of a 20 foot service road shall be paved, with a minimum of 2 inches of AC on 5 inches of AB. Existing sub grade shall be compacted to 85% and AB will be compacted to 90%.

C. RAMPS - Access ramps are required to the bottom of open channels and basins that are more than 4 feet below the service road to allow access for emergency and maintenance equipment. Each segment of a channel shall be accessible. Ramps shall be located in pairs where possible to allow entrance and exit of equipment.

1. The minimum width shall be twelve feet (12') at a maximum slope of ten percent (10%) See Drawing SD-25.

2. Ramps will be constructed of concrete; minimum 4 inches thick with appropriate base (may be colored to blend with the surroundings). Attention to both aesthetics and serviceability is required. Materials with characteristics similar to concrete may be substituted on an exception basis if authorized by the Director.

3. Details of the ramps shall be shown on the improvement plans.

9-23   CROSS CULVERT CRITERIA

The following standards apply when the 100-year water surface elevation is not freely spanned by a bridge:

A. Cross culverts for minor sheds shall be designed in accordance with procedures outlined in the U.S. Department of Transportation "Hydraulic Design of Highway Culverts," Hydraulic Design Series No. 5, September, 1985. For shed areas greater than 160 acres, use HEC-RAS or other software approved by the Director.

B. Cross culverts shall be checked against 100-year runoff to assure that no adverse effect will occur upstream or downstream.

C. Cross culvert profile will be determined by an examination of the overall profile of the channel for a minimum distance of 500-feet on each side of the installation, assuring that freeboard requirements are met, and inlet or outlet control shall be determined.

D. Where no overland release is possible, cross culverts shall be oversized by at least twenty five percent (25%).

E. Where roads are not to be overtopped, for public safety or physical constraints, the box culvert soffit shall have one-foot (1') of freeboard over the 100-year water surface elevation.

F. Culverts shall include a headwall or flared end section at both the upstream and downstream end. A concrete apron shall be provided at the inlet and outlet of a culvert, with the minimum length of the lesser of 20 (twenty) feet or five (5) pipe diameters.

9-24 DRAINAGE IN RURAL AREAS

Closed conduit pipelines, not open drainage ditches, shall be utilized for runoff collection and conveyance along public right-of-ways, except in rural residential areas zoned for agricultural/residential lots at least 2 acres in size. Non-roadside ditches shall use the criteria for open channels and may require private easements to be recorded for cross lot drainage.

When appropriate, open roadside ditches shall use the criteria for design of Class "C" streets and the following requirements:
A. Roadside ditches shall be sized to convey design runoff. Analysis of 100-year flows shall be considered per Section 9-1. Analysis shall include culverts. The 10-year and 100-year hydraulic grade lines shall be shown on the profile. A minimum grade of 0.3% or a minimum velocity of 1 ft/second shall be secured.

B. Roadside ditches shall use 4:1 or flatter side slopes. Roadside ditches, including slopes, shall be completely contained within the right-of way. See also Section 4 of these standards.

C. Driveway culverts shall be designed to pass the greater of the 10-year design runoff, the roadside ditch capacity, or a 12 inch minimum diameter. Culverts shall be constructed out of CMP or RCP pipe. Driveway slopes shall be 3:1 or flatter. Culverts shall be installed with either a six inch (6") thick concrete collar and headwall; or shall extend at least 1 foot beyond the driveway slope and include a flared end section at the upstream and downstream ends.

9-25 STORMDRAIN SYSTEMS IN PRIVATE STREETS

A. Private storm drain systems that connect to City maintained drainage facilities shall have a manhole immediately upstream of the connection within the public easement or right-of-way.

B. It shall be made clear on the plans which facilities are privately owned and appropriate signage shall be erected to inform the public.

C. Private storm drain pipes serving more than two parcels shall be built per these Improvement Standards.