Section 9

STORM DRAINAGE (SD)

9-1 GENERAL - This section is formulated to clearly define acceptable drainage analysis and design criteria for development in the City of Grass Valley.

9-2 CITY POLICIES AND REQUIREMENTS - All residential lots shall have minimum pad elevations of 1-foot above the 100-year water surface elevation and all commercial sites shall have minimum finished floor elevations of 1-foot above the 100-year water surface elevation assuming failure of the drainage system. This requires the Design Engineer to provide an overland release for all projects or provide storage for the 100-year storm frequency.

The overland release path shall be constructed in a manner to transport the peak rate of runoff from the 100-year storm frequency through the site assuming all storm drains are inoperative, all upstream areas are fully developed, and that antecedent rainfall has saturated the tributary watershed. Streets, parking lots, playgrounds, pedestrian areas, pedestrian walkways, utility easements, and other open space areas may be considered compatible uses within the overland release path.

Except for single family or duplex residential lots, site drainage shall be collected on-site and conveyed via an underground storm drain system to an approved existing storm drainage system without flowing into existing street gutters or existing roadside ditches.

Unless regional storm water mitigation devices are available, specific mitigation shall be required for the project, shall be located on-site, and shall be maintained by the landowner.

9-3 DEVELOPMENT IN A FLOODPLAIN - Residential lots developed in a floodplain shall have pad elevations a minimum of 2-feet above the 100-year flood elevation. A Letter of Map Amendment (LOMA) or a Letter of Map Revision (LOMR) is required for any residential lot in or adjacent to the flood hazard area as shown on a Flood Insurance Rate Map. Non-residential projects shall have finished floor elevations a minimum of 2-feet above the City's 100-year flood elevation. Elevation Certificates are required for all such structures.

In the case of no-grade or contour grade lots located adjacent to the floodplain, and where a portion of the lot may become inundated with the 100-year storm event, a standard Guarantee letter shall be submitted to the Engineering Division prior to plan approval, or issuance of a building permit. The Guarantee letter shall be submitted by a Registered Civil Engineer or Land Surveyor and confirm that the lowest ground elevation adjacent to the building foundation meets the minimum requirements for pad elevations as described above.

If a tentative project is submitted which shows fill or other significant improvements within the floodplain, a hydraulic study shall be required to determine the effect of the encroachment. Encroachments shall not result in any off-site increase in water surface elevation. The Design Engineer should contact FEMA to ascertain what existing studies, if available should be used as a base model for the proposed development. The Design Engineer is responsible for assembling the necessary data and presenting the study to the City and FEMA for review. The study should reflect ultimate build out conditions of the watershed. When submitting plans that show improvements in the floodplain, the Design Engineer must submit a "Compliance Statement," stating that the proposed improvements shown in the plans are accurately reflected in the approved hydraulic study. A sample of the hydraulic study submittal requirements and sample Hydraulic Study Worksheets are provide in the attachments at the end of this section.

Parking lots and storage areas shall be no more than 1.5-feet below the 100-year water surface elevation.

When developing property inundated by a floodplain, the portion of the property that extends into the floodplain shall be dedicated to the City in fee or as a Flood Water Conservation Easement as determined by the Engineering Division. In areas where the floodplain has been dedicated as part of a Specific Plan but the 100-year flood levels are shown to extend slightly outside this dedicated floodplain area, the development shall fill the property located outside the dedicated floodplain to an elevation that is a minimum of 2-feet higher than the 100-year flood elevation, or incorporate that area into the floodplain.

NOTE: Design requirements for bike paths within floodplains are provided in the section entitled "Bikeways" of these Improvement Standards.

9-4 FEDERAL FLOOD PROGRAM - The City of Grass Valley is a participant in the National Flood Insurance Program (NFIP) and all development in the City shall comply with the regulations of the Federal Emergency Management Agency (FEMA) and the City's Flood Damage Prevention Ordinance.

Amendments of the FEMA flood maps will be required of all new developments located in a FEMA flood zone. Petitions for a Letter of Map Amendment, including any fee required by FEMA, shall be submitted to the Public Works Department prior to approval of improvement or site plans.

9-5 DRAINAGE DIVERSIONS - The diversion of natural drainage is allowable only within the limits of the proposed improvement. All drainage must enter and leave the improved area at its original horizontal and vertical alignment unless an agreement, approved by the City Engineer, has been executed with the affected property owners. Temporary drainage diversions during construction shall be approved by the City Engineer and shall be located and constructed in such a fashion as to permit their removal when necessary for the prevention of damage to adjoining properties.

9-6 DRAINAGE EASEMENTS - Publicly owned drainage conduits and channels will not be allowed on private property unless they lie within a dedicated public drainage easement. Where minor improvement of an existing channel falls on adjacent property (such as day lighting a ditch profile) a notarized right-of-entry from the property owner(s) for such construction shall be required. A copy of the document, which grants such approval, shall be submitted to the City Engineer prior to the approval of the improvement plans.

A. Easements for closed conduits shall meet the following width criteria:

1. All easements for closed conduits shall have a minimum width in feet equal to the required trench width according to the standard detail for unshored trenches and excavation backfill plus two (2) additional feet of width for every foot of depth as measured from the bottom of the pipe to finished grade. All conduits shall be centered within their easements.

2. Minimum width of any easement for closed conduit shall be 15-feet.

3. Easements adjacent to property lines shall be located entirely on one parcel.

B. Drainage easements for open channels shall have significant width to accommodate the following criteria:

1. Contain the channel and channel slopes.

2. Provide for fencing, where required.

3. Provide for a 10-foot wide service road and maintenance access ramps, where required by the City Engineer. A service road may not be required where the channel bottom is lined and a

suitable access ramp is provided. Dedication of easements shall be completed and submitted to the City Engineer with copies of deeds or title reports for the affected properties before improvement plans will be approved.

4. Open channels (natural or man-made) with a drainage area that exceeds 300 acres shall have the 100-year water surface elevation limits dedicated to the City in-fee or as a Flood Water Conservation Easement.

9-7 DRAINAGE CAPACITY/DESIGN - All drainage systems shall be designed to accommodate the ultimate development of the entire upstream watershed. The 10-year peak storm discharge shall be used in the design of local drainage systems. In addition, other facilities such as streets, bridges, open channels, and buildings have requirements that relate to the 25- and 100-year peak storm discharge. The Design Engineer shall calculate the 10-, 25-, & 100-year peak discharge and submit these calculations along with the plans for all proposed drainage systems.

9-8 DESIGN PEAK DISCHARGE METHODS - The acceptable methods for the determination of runoff quantities for the 10-, 25-, & 100-year peak discharge are specified in the most recent edition of the State Highway Design Manual and the City of Grass Valley Storm Drainage Master Plan.

9-9 HYDRAULIC STANDARDS FOR DRAINAGE SYSTEMS- All storm drain pipelines and open channels shall be designed to convey the design peak runoff calculated per Section 10-8 and shall conform to the following requirements:

A. Hydraulic Grade Line - The hydraulic grade line for the 25-year discharge shall be a minimum of 1-foot below all inlet grates, manhole covers, and all other drainage structures in the system.

B. Manning's Formula - The "n" value used in Manning's formula shall conform to the following:

1. Manning's formula shall be used to compute capacities of all open and closed conduits other than culverts.

2. Minimum velocity in closed conduits shall be 2-feet per second. Maximum velocity shall be 15-feet per second, unless otherwise approved by the City Engineer. Velocities shall be based on full flow conditions.

9-10 STREET INUNDATION REQUIREMENTS - City streets are allowed to convey runoff for storm events larger than the 10-year. The standards for street inundation are specified in Table 9-6. The Design Engineer shall provide calculations showing that these standards are met.

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ALLOWABLE STREET INUNDATION: Table 9-6

STREET	10-YEAR STORM	25-YEAR STORM	100-YEAR STORM
RESIDENTIAL			
At continuous grade, uphill and downhill	Traveled lanes remain clear and do not carry storm water.	Maximum depth at gutter flow line shall not exceed top-back-of-S/W (if no S/W, or S/W is offset) or a max. of 6". Centerline of street shall remain dry.	Maximum depth at gutter flow line shall not exceed 4" above the top-back-of-curb or a max. of 10". Max. depth at centerline is 4”
At Sag Points	Storm water elevation does not exceed top back of curb or sidewalk. Maximum depth in traveled way - 6”. Centerline shall be dry.	Storm water elevation does not exceed 4” above the top back of curb. Maximum depth in traveled way - 6”.	Storm water is a minimum of one-foot below building pads. Ponding does not exceed more than 120' from inlet along any street segment.
COLLECTOR			
At continuous grade, uphill and downhill	Traveled way remains clear and does not carry storm water.	Maximum depth at gutter flow line shall not exceed top-back-of-curb or a max. of 6".	Storm water flow is contained within the right of way. The center 12 feet of roadway shall remain clear of storm water.
At Sag Points	Storm water elevation does not exceed top back of curb or sidewalk. Maximum depth in traveled way - 6”. Centerline shall be dry	Storm water elevation does not exceed 4” above the top back of curb. Maximum depth in traveled way - 6”.	Storm water flow is contained within the right-of-way. The center 12 feet of roadway shall remain clear of storm water.
ARTERIAL			
At continuous grade, uphill and downhill Or At Sag Points			All travel lanes are clear of storm water flow. Bike lanes are allowed to be inundated. Storm flow contained within the right-of-way.

9-11 CLOSED CONDUITS - The specific type of pipe or alternate pipe to be used in any development shall be shown on the approved plans. If the Design Engineer proposes to use any type of pipe not shown on the approved plans, the plans shall be resubmitted to the City Engineer for approval.

A. Size and Material - Drainage systems to be maintained by the City shall have a minimum pipe diameter of 12-inches. The types of pipe materials that are allowed are stated in the City of Grass Valley Construction Standards.

B. Cover Requirements - See the City of Grass Valley Construction Standards, latest edition, for pipe cover requirements.

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 Design Engineer shall design the pipe structural requirements in

accordance with good engineering practice. If trench conditions are uncertain, a note shall be placed on the plans making it the Contractor's responsibility to work with the Design Engineer to determine and place the proper strength pipe if poor trench conditions are encountered.

C. Alignment - Pipelines for storm drainage shall have a constant slope between manholes, junction boxes, and/or catch basins. Minimum radius of horizontal curvature shall be 200-feet. In no case shall the radius of curvature be less than the manufacturer's recommendations for the particular pipe size under consideration.

Drainage pipelines shall be located in the street whenever possible. The location of storm drainage pipelines in new streets shall be 5-feet north or west of, and parallel with, the street centerline. A minimum angle of 90 degrees shall be accommodated for downstream flow around bends, tees, and connection points.

When storm drainage lines are to be placed in existing streets, factors such as curbs, gutters, sidewalks, traffic conditions, pavement conditions, future street improvement plans, and existing utilities shall be considered. Where street width is not adequate, or the required separation between utilities limits placement of drainage lines in the street, pipelines may be placed directly under the curb and gutter with the approval of the City Engineer.

Open ditches, lined channels, swales, and floodplain areas shall be maintained as nearly as possible in their existing alignment. When an open ditch is to be constructed parallel to an existing roadway, the ditch shall be constructed outside the proposed right of way of the ultimate street development.

9-12 MANHOLES - Standard precast concrete manholes shall be constructed as required. Where special manholes or junction boxes are required, the City Engineer must approve the design. In no case will junction boxes or manholes be allowed which are smaller than 48-inches inside diameter. Manholes shall be located at junction points, angle points, changes in gradient, changes in pipe size, end of curves and beginning of curves. Manholes or junction boxes will not be required for a reach of pipe less than 80-feet in length that is to be connected to a 36-inch or larger diameter pipe, subject to approval of the City Engineer. For straight alignment, the spacing of manholes shall not exceed 500-feet. The spacing of manholes shall be nearly equal whenever possible. On curved pipe, spacing of manholes shall be as specified in Table 9-7:

MANHOLE SPACING: Table 9-7

RADIUS	PIPE DIAMETER	SPACING
400' OR LESS	ALL	300'
GREATER THAN 400'	24" OR LESS	400'
GREATER THAN 400'	GREATER THAN 24"	500'

A. Saddle Manholes - Saddle manholes may be constructed on storm drain conduit 36-inches or greater in diameter provided that no junction exists with any other storm drain conduit as determined by the City Engineer.

B. Covers - All manholes and junction boxes, other than inlets, shall have standard manhole covers per the Standard Drawings. No pipe will be allowed to enter a manhole into the transition portion of the manhole cone. Manholes will not be allowed in gutter flow line except where approved by the City Engineer. Slotted manhole covers may be used to pick up minor drainage in non-traffic areas.

C. Manhole Access - Manhole access shall be provided in accordance with the provisions of "Manhole Criteria" of the Sanitary Sewer section of these Design Standards.

9-13 INLETS - Drainage inlets in streets shall be located at property lines in residential subdivisions except at intersections, where they shall be placed at curb returns. Inlets shall be placed such that the length of flow in the gutter does not exceed 500-feet. The depth of flow in the gutter at the inlet shall not exceed 4.0-inches in a 10-year storm and shall not encroach into the traveled ways as specified in Table 9-6 for other design storms. The runoff volume shall include any flow that bypasses upstream inlets.

All inlets located within the City right-of-way or easements shall conform to the City of Grass Valley Construction Standards. Inlets may be modified for use without curb sections for on-site drainage. Where an inlet is proposed in public streets and sidewalk is not constructed adjacent to the back of curb, a concrete collar shall be placed behind the inlet.

Drainage inlets draining public streets may be connected directly to a trunk line, 36-inches in diameter or larger, by means of a lateral not exceeding 15-inches in diameter and 80-feet in length.

9-14 JUNCTION BOXES - Junction boxes shall be constructed of reinforced concrete or fabricated from reinforced concrete pipe section where size limitations permit. Structural calculations shall be provided for all junction boxes. Minimum wall thickness for reinforced concrete junction boxes shall be 6-inches.

The inside dimension of junction boxes shall be such as to provide a minimum of 3-inches clearance on the outside diameter of the largest pipe in each face. All junction boxes shall be rectangular in shape unless otherwise approved by the City Engineer. Junction boxes deeper than 4-feet shall have a minimum inside dimension of 48-inches.

9-15 INLET AND OUTLET STRUCTURES - The requirements for these facilities are as follows:

A. Headwalls, Wingwalls, and Endwalls - All headwalls, wingwalls, endwalls, preformed end sections, guard rails and bank protection shall be considered individually and shall be, in general, designed in accordance with the State Standard Specifications and Standard Plans and the City of Grass Valley Construction Standards.

Metal beam guardrails or chain link fencing may be required by the City Engineer at culverts, headwalls, box culverts, and on steep side-slopes.

B. Trash Racks and Access Control Racks - Trash racks will be provided where they are necessary to prevent clogging of culverts, storm drains, and to eliminate hazards. Access Control Racks shall be required on all pipes, 24-inches or larger in diameter.

C. Flared End Sections - Flared end sections shall conform to the provisions of the "Miscellaneous Facilities" section of the State Standard Specifications and the "Metal and Plastic Flared End Section" detail of the State Standard Plans.

D. Culvert Outlet - Culvert outlets shall be provided with a means of outlet protection or energy dissipation where outlet velocity cannot be reduced sufficiently to prevent downsteam scour or erosion. Outlet protection shall conform to the provisions of the "Cross Drainage" section of the State Highway Design Manual.

9-16 CROSS CULVERTS AND BRIDGES - This section specifies criteria for relatively short circular or box culverts and bridges for transverse crossings (typically road or railroad embankments). Cross culverts shall

be of the same material as allowed for closed conduits.

Cross culvert profiles will be determined on an examination of the channel for a minimum distance of 1000-feet on each side of the installation.

Driveway culverts will not be allowed unless the City has agreed to defer the construction of curb and gutter or the culvert is to allow for temporary construction access. Driveway culverts shall be approved by the City for size, grade, alignment and type.

A. Design Storm - Cross culvert size shall be determined on the basis of runoff as specified in the hydrology portion of this Section. Cross culverts, in general, shall be designed for a 25-year storm event with no head on the inlets. They shall also be sized such that no serious damage will be incurred due to ponding as a result of a 100-year event. A flood easement shall be provided for all areas impacted due to upstream ponding in the 100-year event. Culverts across arterials shall be sized for the 100-year storm with a minimum of one foot of freeboard below the lowest travel lane.

To account for debris collection, a clogging factor of 150 percent shall be applied to all storm frequencies in the design of bridges or culverts that cross a channel or stream with a drainage area that exceeds 300 acres.

B. Computation of Flow - Inlet or outlet conditions control flow in transverse culverts. In culverts operating under inlet control, the cross-sectional area of the culvert barrel, the inlet geometry, and the amount of headwater at the entrance, are of primary importance. Outlet control involves the additional consideration of the elevation of the tailwater in the outlet channel and the slope, roughness, and length of the culvert barrel.

Anticipated downstream flow depth and allowable headwater depth govern the available head on culverts. The type of flow under which a culvert will operate may be determined from a given set of conditions. This may be avoided by computing headwater depths from the charts in this section for both inlet and outlet control and then using the higher value to indicate the type of control and to determine the headwater depth. This method of determining the type of control is accurate except for a few cases where the headwater depth is approximately the same for both types of control. The monographs provided in this section shall be used for culvert design with uniform barrels. Where barrel sizes or entrance configurations differ between barrels, written calculations shall be provided to the satisfaction of the City Engineer.

The roughness coefficient, “n”, can be adjusted for the monographs by use of the following equation:

$$L_1 = L * [\frac{n_1}{n}]^2$$

STANDARD HYDRAULIC CALCULATION SHEET

TO	FROM	AREA	CUMU. AREA	Tr	q	Fi	Qp	STORM DRAIN PIPE						HYD GRADE LINE		
								DIA	SL	L	Qmax	VEL	Tc	SL	UMH	LMH

9-17 DETENTION AND RETENTION BASINS - If detention or retention basins are required for peak flow reduction, drainage plans, hydrologic and hydraulic calculations prepared by a Registered Civil Engineer, shall be submitted for approval by the City Engineer. Hydrology shall be in accordance with these Design Standards and the State Highway Design Manual.

A. Hydrologic Criteria - The effectiveness of the on site storage shall be evaluated using basic hydrologic concepts and criteria for storage basins. The drainage plans and calculations shall indicate the following conditions before and after development:

1. Quantities of water and water flow rates.

2. Major watercourses, flood hazard areas, drainage areas and patterns and drainage courses.

3. Diversions, collection systems and sumps.

B. Design - The design of detention and retention basins shall minimize the required maintenance time and cost. Access shall be provided to the basin, passable under all weather conditions.

1. Elevation - The 100-year design pool elevation should be at or below natural ground. No more than 50 percent of the basin's storage depth shall be above existing ground.

2. Capacity - All storage basins shall be designed with adequate capacity to manage the 100-year storm event.

3. Emergency Overflow/Spillway - An emergency overflow is required for all storage basins, capable of passing a design flood equal to 125 percent of the 100-year storm event.

4. Freeboard - The basin shall be designed such that there is a minimum 2-foot freeboard height above the 100-year storm event water level. In addition the basin shall provide a minimum 1-foot freeboard height above the emergency spillway water level.

5. Energy Dissipater - Inlets and outlets of storage basins shall be provided with energy dissipaters and/or erosion protection as required by the City Engineer.

6. Outlet Control - A metered outlet structure is required to provide the necessary flow attenuation to mimic the pre-development conditions for the 10-, 25- and 100-year storm events. Outlet structures include small gravity pipes, "V" shaped weirs, notched weirs and orifice plates, or as approved by the City Engineer.

9-18 STORMWATER TREATMENT DEVICES - All projects that create or replace impervious surfaces are required to consider site design strategies to maximize pervious surfaces within the development area and to incorporate stormwater treatment measures.

A. Treatment Device Requirements - The stormwater treatment device shall consist of a permanently installed system, capable of removing 80 percent of the average annual total suspended solids (TSS) load without scouring previously captured pollutants. The separator shall also be capable of removing 95 percent of the free floatable oil, while trapping fine sand, silt, clay and organic particles, in addition to larger sand, gravel particles, and small floatable.

In order to use and alternate treatment system in lieu of the standard facility, the engineer or manufacturer would have to provide data showing that the alternate treatment meets these performance requirements.

9-19 ACCESS FOR MAINTENANCE - Following the Engineering Division's initial review and conceptual approval of the grading and improvement plans, the plans shall be reviewed for maintenance access for drainage facilities. These facilities may include, but are not limited to bridges, culverts, headwalls, lined and unlined channels/ditches, sand/oil separators, manholes, retention basins and drain inlets. The access way shall be a minimum 12-foot wide and include 6-inches of ¾-inch aggregate base (95 percent relative compaction) over 6-inches of processed, native soil (95 percent RC). A cul-de-sac with a minimum diameter of 75-feet may also be required.

9-20 SUBMITTAL REQUIREMENTS FOR ALL HEC - 1 STUDIES - The following items listed under each category are required for each HEC-1 model run that is submitted.

A. HEC-1 Print Out - The following information shall be on the cover of the print out:

1. Name of engineering firm who preformed the study.

2. Name of project.

3. Version of HEC-1 program.

4. Date & time that the model was run.

5. A statement if the model is pre-project or post-project.

B. Computer Model CD -

1. The CD must be clearly labeled.

2. If more than one model file is on the CD, a listing and description of all files shall be included with the CD, in an envelope.

3. HEC-1, HEC-2 or HEC-RAS files shall be submitted on separate CD's

C. Watershed Map - showing the following:

1. Outline of all subsheds used in the HEC-1 study,

2. The label of each subshed as modeled in the HEC-1 study,

3. The area of each subshed as used in the HEC-1 study,

4. The location where each subshed merges with the next clearly marked.

D. Summary Sheets - The City of Grass Valley's "Model Summary Worksheet" pages 1-3 must be completed for each HEC-1 run submitted and attached to the print out. If the study compares pre-project to post-project HEC-1 models, the City's summary sheets shall include a listing of all of the types and the locations of the changes made.

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CITY OF GRASS VALLEY

HEC-1 MODEL SUMMARY WORKSHEET
PAGE 1 OF 3
GENERAL INFORMATION

Name of project: _____

Name of engineering firm performing the study: _____

Contact person _____ Phone # _____

If this replaces a previously submitted study, what is the name of that study? _____

This study reflects: ☐ Existing conditions ☐ Post-development conditions

If this HEC-1 study is used to compare pre-project to post-project runoff, what is the name of the study that you are comparing it with? _____ Run date _____

Has the pre-project study been approved by the City? ☐ **NO** ☐ **YES** Date _____

BASIN INFORMATION

Total area of the basin studied (sq. ml.)_____ Number of sub-sheds _____

Elevation of shed: High point _____ Low point _____ Ave. _____ Used_____

The method used to determine the design storm used in the model:

P.C. Flood Dist. Manual — HEC-1 synthetic storm
P.C. Flood Dist. PDP program — Rain gauge data

Duration of design storm: 1-hr 2-hrs 3-hrs 6-hrs 12-hrs 1-day other_____

Design storm frequency: 2-yr 5-yr 10-yr 25-yr 50-yr 100-yr other _____

Base flow (cfs/ sq mile): _____ Infiltration (in/ hour) _____

Response time of entire basin _____

Detention Basins Give location and size of all detention basins that were modeled:

Provide topo or grading plans used to calculate storage volume for each detention basin.

Location in model	Amount of storage resulting from each design storm	Storm frequency	Max. Stage Height (ft)	Freeboard to Spill Point (ft)
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

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HEC-1 MODEL SUMMARY WORKSHEET
PAGE 2 OF 3
SUBSHED INFORMATION

The total number of sub-sheds in the model _____

Provide assumed “n" factors used most often for the following surfaces:

Overland swales _____ Concrete gutters_____ Drainage Pipes _____

Earth-lined channels _____ Streams _____ Other _____

TITLE OF SUBSHED OR ROUTING LEG IN MODEL	PRIMARY LAND USES OF SUBSHED residential, open space, commercial, etc.	AREA OF SUBSHED (SQ ML)	METHOD USED IN ROUTING EXAMPLE: Kinematic wave, Muskingum	WAS DETENTION MODELED (YES OR NO)

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HEC-1 MODEL SUMMARY WORKSHEET
PAGE 3 OF 3
PRE-PROJECT TO POST-PROJECT CHANGES

This sheet shall be completed if this HEC-1 study is used to compare pre-project to post-project runoff .

Name of pre-project HEC-1 study : _____ Run date_____

Basin's peak flow rate: Existing conditions _____ Post-development conditions _____

Has the pre-project study been approved by the City? □ **NO** □ **YES** Date?_____

Locations in model	Types of changes made
Example - Shed-2S	*Changed earth-lined channels to drainage pipes and increased sub-shed area*