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Chapter 6 Storm Drains

6-1 Introduction

A storm drain (storm sewer) is a network of pipes that convey surface drainage from catch basins or other surface inlets, through manholes, to an outfall. Storm drains are defined as closed pipe networks connecting two or more inlets, see Figure 6-1.

All storm drain designs will be based on an engineering analysis which takes into consideration runoff rates, pipe flow capacity, hydraulic grade line, soil characteristics, pipe strength, potential construction problems, and potential runoff treatment issues. The majority of time spent on a storm drain design is calculating runoff from an area and designing a pipe to carry the flow. A storm drain design may be performed by hand calculations or by one of several available computer programs and spreadsheets.

Runoff is determined using the Rational Method, the Santa Barbara Urban Hydrograph (SBUH) method; see Chapter 2 for further discussion. Pipe capacity is calculated using Manning's Equation, which relates the pipe capacity to the pipe diameter, slope, and roughness. The Region's Hydraulics Engineer reviews the design and if required the Headquarters (HQ) Hydraulics Office provides final approval as part of the hydraulics report review, see Chapter 1 for further approval guidelines.

6-2 Design Features

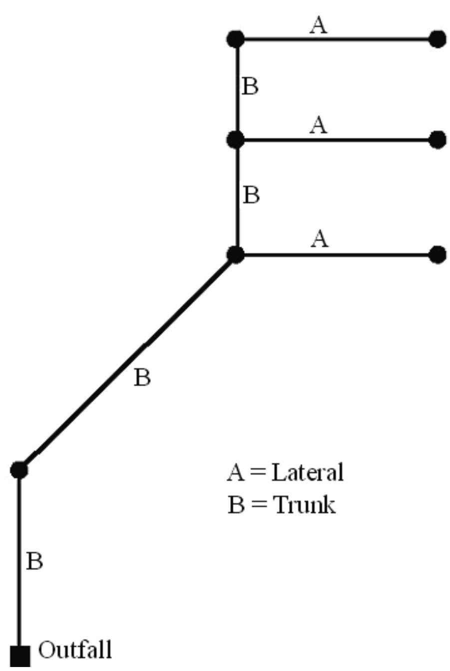
Along with determining the required pipe sizes for flow conveyance, storm drain system design incorporates the following features:

1. **Soil Conditions** — Soil with adequate bearing capacity must be present to interact with the pipes and support the load imparted by them. Surface and subsurface drainage must be provided to assure stable soil conditions. Soil resistivity and pH must also be known so the proper pipe material will be used.
2. **Inlet Spacing and Capacity** — Design guidelines are detailed in Chapter 5, Drainage of Highway Pavements. For minimum clearance between culverts and utilities, designers should consult the Region Utilities Office for guidance.
3. **Junction Spacing** — Junctions (catch basins, grate inlets and manholes) should be placed at all breaks in grade and horizontal alignment. Pipe runs between

junctions should not exceed 300 feet (100 meters) for pipes smaller than 48 inches (1,200 millimeters) in diameter and 500 feet (150 meters) for pipes 48 inch (1,200 millimeters) or larger in diameter. When grades are flat, pipes are small or there could be debris issues; designers should consider reducing the minimum spacing. Region Maintenance should be consulted for final approval on maximum spacing.

4. **Future Expansion** — If it is anticipated that a storm drain system may be expanded in the future, provision for the expansion shall be incorporated into the current design. Additionally, prior to expanding an existing system, the existing system should be inspected for structural integrity and hydraulic capacity.

5. **Velocity** — The velocity of flow should be 3 feet per second (1.0 meter per second) or greater to prevent the pipes from clogging due to siltation. Velocity of flow should not be excessively high since high flow velocities (approaching and above 10 feet per second) produce very large energy losses in the storm drain system and also cause abrasion of the pipes. The velocity should be calculated under full flow condition even if the pipe is only flowing partially full with the design storm.



A lateral(s) discharges into a trunk line. The trunk line then receives the discharge and conveys it to an outfall. Storm drains are classified as a network that has at least two inlets connected by pipes.

Storm Drain Structure

Figure 6-1

6. **Grades at Junctions** — Pipe crowns of branch or trunk lines entering and exiting junctions should be at the same elevation. If a lateral is placed so its flow is directed against the main flow through the manhole or catch basin, the lateral invert must be raised to match the crown of the inlet pipe. (A crown is defined as the highest point of the internal surface of the transverse cross section of a pipe.)

7. **Minimum Pipe Diameter** — The minimum pipe diameter shall be 12 inch (300 millimeters), except that single laterals less than 50 feet (15 meters) long may be 8 inches (200 millimeters) in diameter (some manufacturers are unable to add protective treatment for 8 inches storm drain pipe).

8. **Maximum Pipe Diameter** – Designers should verify the maximum allowable pipe diameter into a drainage structure prior to design. Some standard plans for drainage structures have pipe allowances clearly stated in tables for various pipe materials.

9. **Energy Losses** — Energy losses are calculated to determine the hydraulic grade line. Energy losses only need to be calculated when the losses occurring might be significant; see section 6-6 for a discussion on calculating energy losses. Possible situations of concern include the following:

   - High flow velocities through the system.
   - Pipes are on flat slopes.
   - Inlet and outlet pipes forming a sharp angle at junctions.
   - Multiple flows entering a junction.
   - Pipes entering and leaving the junction are very shallow.

10. **Increase in Profile Grade** — In cases where the roadway or ground profile grades increase downstream along a storm drain, a smaller diameter pipe may be sufficient to carry the flow at the steeper grade. However, due to maintenance concerns, the Washington State Department of Transportation (WSDOT) design practices do not allow pipe diameters to decrease in downstream runs.

    Consideration could be given in such cases to running the entire length of pipe at a grade steep enough to allow use of the smaller diameter pipe. Although this will necessitate deeper trenches, the trenches will be narrower for the smaller pipe and therefore the excavation may not substantially increase. A cost analysis is required to determine whether the savings in pipe costs will offset the cost of any extra structure excavation.

11. **Outfalls** — An outfall can be any structure (man-made or natural) where stormwater from WSDOT highways is conveyed off of the ROW. Outfalls must conform to the requirements of all federal, state, and local regulations and documented as described in Appendix 1-3 of this manual.

    Additional considerations for outfalls include energy dissapators and tidal gates. Energy dissipators prevent erosion at the storm drain outfall, for design guidance see section 3-4.7 of this manual. Installation of tide gates may be necessary when the outfall is in a tidal area, consult the Region Hydraulics Engineer for further guidance.

12. **Location** — Medians usually offer the most desirable storm drain location. In the absence of medians, a location beyond the edge of pavement on state right of way or on easements is preferable. It is generally recommended when a storm drain is placed beyond the edge of the pavement that a one-trunk system, with connecting laterals, be used instead of running 2 separate trunk lines down each side of the road.

13. **Confined Space and Structures -** Per WAC 296, any structure (catch basin, manhole, grate inlet, or underground detention vault) more than 4 feet in depth is considered a confined space. As such, any structure exceeding 4 feet in depth that could be accessed by personnel must be equipped with a ladder. To determine if personnel will access the structure or if a Vactor Hose will be used for maintenance, consult the local maintenance office. Structures over 15 feet in depth should be avoided due to the limitations of WSDOT Vactor Trucks. Any design requiring a structure deeper than 15 feet must consult the Region Hydraulics Office for design approval. Underground detention vaults should only be considered as a last resort due to the overall expense of maintenance. Designers should consult the Region Maintenance Office and Region Hydraulic Engineer before including a vault in any design.

6-3 Data for Hydraulics Report

The design of a storm drain system requires that data be collected and documented in an organized fashion. A Hydraulics Report should be submitted which contains the related calculations (whether performed by hand or computer). See Appendix 1-3 of this manual for guidelines on what information should be submitted and recommendations on how it should be organized.

6-4 Storm Drain Design — Handheld Calculator Method

6-4.1 General

Storm drain design can be accomplished with a handheld calculator using the Rational Method and Figure 6-4.1 to show calculations. Figure 6-4.1 has five divisions: Location, Discharge, Drain Design, Drain Profile, and Remarks. These divisions are further expanded in the subsections below.

6-4.2 Location

The "Location" section gives all the layout information of the drain.

Column 1 gives a general location reference for the individual drain lines, normally by the name of a street or a survey line.

Columns 2 and 3 show the stationing and offset of the inlets, catch basins, or manholes either along a roadway survey line or along a drain line.

6-4.3 Discharge

The "Discharge" section presents the runoff information and total flow into the drain.

Column 4 is used to designate the drainage areas that contribute to particular point in the drain system. The drainage areas should be numbered or lettered according to some reference system on the drainage area maps. The type of ground cover (pavement, median, etc.) may be indicated. Since drainage areas must be subdivided according to soil and ground cover types, a drainage area may have several different parts.

Column 5 shows the area of the individual drainage areas listed in Column 4 in acres (hectares).

Column 6 shows the rational method runoff coefficient (see Chapter 2). Each individual drainage area must have a corresponding runoff coefficient.

Column 7 is the product of Columns 5 and 6. Column 7 is also the effective impervious area for the subsection.

Column 8, the summation of CA, is the accumulation of all the effective impervious area contributing runoff to the point in the system designated in Column 2. All the individual areas in Column 7 contributing to a point in Column 2 are summed.

Column 9 shows the time of concentration to the structure indicated in Column 2. Section 2-5.3 of this manual details how to calculate the time of concentration.

Generally the time chosen here would be the longest time required for water to travel from the most hydraulically remote part of the storm drain system to this point. This would include flow over the drainage basin and flow through the storm drain pipes. The time of concentration should be expressed to the nearest minute and as discussed in Chapter 2 is never less than 5 minutes.

Storm Drain Design Calculations

Figure 6-4.1

(WSDOT Form 235-013)

Storm Drain Design Calculations

Calculated By	Date	Checked By	Date	SR	Project	Sheet # Of Sheet

Location			Discharge										Drain Design				Drain Profile						
Drain Located On	From Station	To Station	Source of Drainage	Drainage Area (A)	Runoff Coeff. (C)	CA	Σ CA	Tc to Col.2 Station	Rainfall Intensity in/hr	Runoff cfs	Con. Inflow cfs	Total Flow cfs	Pipe Diameter ft	Pipe Slope ft/ft	Flow Velocity ft/s	Pipe Capacity cfs	Length ft	Elev. Change ft	Upstr. Ground Elev.	Downstr. Ground Elev.	Upstr. Invert Elev.	Downstr. Invert Elev.	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

When the runoff from a drainage area enters a storm drain and the time of concentration (Tc) of the new area is shorter than the accumulated Tc of the flow in the drain line, the added runoff should be calculated using both values for Tc. First the runoff from the new area is calculated for the shorter Tc. Next the combined flow is determined by calculating the runoff from the new area using the longer Tc and adding it to the flow already in the pipe. The Tc that produces the larger of the two flows is the one that should be used for downstream calculations for the storm drain line.

The easiest method for determining the Tc of the flow already in the system (upstream of the structure in Column 2) is to add the Tc from Column 9 of the previous run of pipe (this value should be on the row above the row that is currently being filled in) to the time it took the flow to travel through the previous run of pipe. To determine the time of flow (or more correctly, the travel time) in a pipe, the velocity of flow in the pipe and the length of the pipe must be calculated. Velocity is computed using Manning's Equation and is found in Column 16 of the previous run of pipe. The length used is the value entered in Column 18 for the previous run of pipe. Obviously, this calculation is not performed for the very first (most upstream) run of pipe in a storm drain system.

$$T_1 = \frac{L}{60V}$$

Where: T_1 = Time of concentration of flow in pipe in minutes

L = Length of pipe in feet (meters) Column 18

V = Velocity in ft/s (m/s) Column 16 of the previous run of pipe

The designer should note that this calculation assumes that the pipe is flowing full. It is accurate for pipes flowing slightly less than half full up to completely full. It will be slightly conservative for Tc calculations when the pipe is flowing significantly less than half full.

Column 10 shows the rainfall intensity corresponding to the time indicated in Column 9 and the location of the project.

The intensity is in inches per hour to the nearest hundredth for English units (millimeters per hour to the nearest tenth). The rainfall intensity used is a 25 year recurrence interval for storm drain laterals and trunks and the 10 year recurrence interval for laterals without trunks. See Chapter 2 for a complete description of how this intensity can be determined. Projects in eastern Washington should also consult Chapter 4 of the *Highway Runoff Manual* for further design guidance.

Column 11 shows the amount of runoff to the (nearest tenth of a cubic foot per second) (nearest hundredth of a cubic meter per second) up to the point indicated in Column 2. It is computed as the product of Columns 8 and 10. This is simply applying the rational method to compute runoff from all the drainage area upstream of the pipe being analyzed.

Column 12 shows any flow, other than the runoff calculated in Column 11, to the nearest tenth of a cubic foot per second (nearest hundredth of a cubic meter per second) that is entering the system up to the point indicated in Column 2. It is rare to have flow entering a system other than runoff from the drainage basin but this does occur. For instance, when an underdrain, which is draining ground water, is connected to the storm drain. The label for this column indicates that these flows are considered constant for the duration of the storm so they are independent of the time of concentration.

This column is also used when the junction is a drywell and a constant rate of flow is leaving the system through infiltration. When this occurs the value listed in Column 12 is negative. See Section 6-7 for a complete discussion of drywells.

Column 13 is the sum of columns 11 and 12 and shows the total flow in cubic feet per second to the nearest tenth (cubic meters per second to the nearest hundredth) to which the pipe must be designed.

6-4.4 Drain Design Section

This section presents the hydraulic parameters and calculations required to design storm drain pipes.

Column 14 shows the pipe diameter in feet (millimeters). This should be a minimum of 8 inches or 0.67 feet (200 millimeters) for any pipe run with a length of 50 feet (15 meters) or less. Pipes runs longer than 50 feet (15 meters) must have a minimum diameter of 12 inches or 1 foot (300 millimeters). Pipe sizes should never decrease in the downstream direction.

The correct pipe size is determined through a trial and error process. The engineer selects a logical pipe size that meets the minimum diameter requirements and a slope that fits the general slope of the ground above the storm drain. The calculations in Column 17 are performed and checked against the value in Column 13. If Column 17 is greater than or equal to Column 13, the pipe size is adequate. If Column 17 is less than Column 13 the pipe does not have enough capacity and must have its diameter or slope increased after which Column 17 must be recalculated and checked against Column 13.

Column 15, the pipe slope, is expressed in feet per foot (meters per meter). This slope is normally determined by the general ground slope but does not have to match the surface ground slope. The designer should be aware of buried utilities and obstructions, which may conflict, with the placement of the storm drain.

Column 16 shows the full flow velocity. It is determined by Manning's Equation, which is shown below. The velocity is calculated for full flow conditions even though the pipe is typically flowing only partially full. Partial flows will be very close to the full flow velocity for depths of flow between 30 percent and 100 percent of the pipe diameter.

$$V = \frac{1.486}{n} R^{\frac{2}{3}} \sqrt{S} = \frac{1.486}{n} \left[\frac{D}{4}\right]^{\frac{2}{3}} \sqrt{S} \text{ (English Units)} \qquad (6\text{-}1)$$

$$V = \frac{1}{n} R^{\frac{2}{3}} \sqrt{S} = \frac{1}{n} \left[\frac{D}{4}\right]^{\frac{2}{3}} \sqrt{S} \text{ (Metric Units)}$$

Where:
- V = Velocity in ft/s (m/s)
- D = Pipe diameter in feet (meters)
- S = Pipe slope in feet/foot (meters/meter)
- n = Manning's roughness coefficient (see Appendix 4-1)

Extremely high velocities should be avoided because of excessive abrasion in the pipe and erosion at the outlet of the system. Drop manholes should be considered for pipe velocities over 10 fps (3.0 meters per second). The engineer should also keep in mind that energy losses at junctions become significant above 6 feet per second (2 meters per second).

The minimum velocity as determined by this equation is 3 feet per second (1 meter per second).

Column 17, the pipe capacity, shows the amount of flow in cubic feet per second (cubic meters per second), which can be taken by the pipe when flowing full. It is computed using the following formula:

$$Q = VA = V \frac{\pi D^2}{4} \qquad (6\text{-}2)$$

Where:
- Q = Full flow capacity in cfs (cms)
- V = Velocity as determined in Column 16 in ft/s (m/s)
- A = Cross sectional area of pipe in feet squared (meters sq)
- D = Diameter of pipe in feet (meters)

6-4.5 Drain Profile

Columns 18 through 23, The drain profile section includes a description of the profile information for each pipe in the storm drain system. It describes the pipe profile and the ground profile. The ground elevations should be finished elevations, to the hundredth of a foot. The items in this section are generally self-explanatory. The only exception is Column 18, the length shown is the horizontal projection of the pipe, in feet (meters), from the center to center of appurtenances. Generally, profiles should be set to provide a minimum of 2 feet (0.6 meters) of cover over the top of the pipe, see Chapter 8 for further design guidance.

6-4.6 Remarks

Column 24, Remarks is for any information, which might be helpful in reviewing the calculations. This space should note unique features such as drop manholes, long times of concentration, changes in the type of pipe, or changes in design frequency.

6-5 Storm Drain Design — Computer Analysis

With the addition of personal computers to most engineering workstations, storm drain design by handheld calculator has become less prevalent. Storm drain design by computer analysis offers some distinct advantages over calculations performed by hand. Chief among these advantages is the decreased amount of time required to perform the pipe sizing and hydraulic grade line calculations and the reduced chance for calculation errors.

Some computer programs will use the rational method for storm drain design while others will use a hydrograph method such as the SBUH method. Both of these methods are valid for WSDOT storm drain design; however, they will yield different peak runoff values. This is most distinct for drainage basins that have very short times of concentration. As a basin’s time of concentration extends beyond 15 minutes the two methods yield more similar answers. This difference in peak runoff values ends up having little effect on storm drain design since runoff from basins with short times of concentration tends to be small and the required pipe size is determined by the minimum allowable pipe size. As flows entering the system increase to the point that minimum pipe sizes are no longer the governing factor, the associated time of concentration becomes greater and the two methods produce similar peak flow rates.

There are several commercially available computer programs for storm drain design. Each of these programs has certain features that make them unique from other programs but the primary calculations are performed the same way. Because of this, nearly any commercially available computer programs that perform storm drain design are acceptable for designing WSDOT storm drains.

The Washington State Ferries Division and each WSDOT Region has access to the computer program Storm Shed for designers use. The HQ Hydraulics Office encourages the use of Storm Shed whenever designing storm drains and is available to lend technical assistance. To attain the latest version of Storm Shed software contact your Region IT or MIS support group. Prior to using Storm Shed, the storm drains should be located using a Microsoft® Excel Pavement Drainage Spreadsheet. A spreadsheet is available on the HQ Hydraulic web page at: http://www.wsdot.wa.gov/eesc/design/hydraulics. The spreadsheet lacks the advanced features found in commercially available computer programs but does offer a simple and effective way to locate storm drains.

6-6 Hydraulic Grade Line

The hydraulic grade line (HGL) represents the water surface elevation of the flow traveling through the storm drain system. If the HGL becomes higher at a manhole or catch basin than the rim elevation of that structure, flow will leave the storm drain. This can cause severe traffic safety problems and must always be avoided. Fortunately, if the storm drain pipes were designed as discussed in the previous sections, then the HGL will only become higher than the catch basin or manhole rims when energy losses become significant or if the storm drain is on a very flat gradient. However, the HGL should always be evaluated especially when energy losses become significant or when the pipes are installed at very flat gradients.

Typically when flow velocities in storm drains are moderate (less than 6.6 ft/s), energy losses are insignificant and can be ignored. However, when flow velocities become higher, energy losses need to be calculated. Once energy losses are calculated, the HGL can be calculated to determine if the storm drain will function properly.

The HGL can only be calculated after the storm drain system has been designed. The HGL is calculated beginning at the most downstream point of the storm drain and ending at the most upstream point, which is exactly the opposite direction that was used to design the pipe sizes.

The water surface elevation at the storm drain outfall must be known or calculated since it acts as the starting elevation of the HGL. Refer to Chapter 3 for an explanation on calculating water surface elevations at the downstream end of a pipe (the tailwater is calculated the same for storm drain outfalls and culverts). Once the tailwater elevation is known, the energy loss (usually called head loss) from friction is calculated for the most downstream run of pipe and the applicable minor losses are calculated for the first junction upstream of the outfall. All of these head losses are added to the water surface elevation at the outfall to obtain the water surface elevation at the first upstream junction (also the HGL at that junction). The head losses are then calculated for the next upstream run of pipe and junction and they are added to the water surface elevation of the first junction to obtain the water surface elevation of the second upstream junction. This process is repeated until the HGL has been computed for each junction. The flow in most storm drainpipes is subcritical; however, if any pipe is flowing supercritical (see Chapter 4 for an explanation of subcritical and supercritical flow) the HGL calculations are restarted at the junction on the upstream end of the pipe flowing supercritical. The HGL calculation process is represented in equation form below:

$$\mathrm{WSEL}_{J1} = \mathrm{WSEL}_{OUTFALL} + \mathrm{H}_{f1} + \mathrm{H}_{e1} + \mathrm{H}_{ex1} + \mathrm{H}_{b1} + \mathrm{H}_{m1} \quad (6\text{-}3)$$

$$WSEL_{J2} = WSEL_{J1} + H_{f2} + H_{e2} + H_{ex2} + H_{b2} + H_{m2}$$

$$WSEL_{Jn+1} = WSEL_{Jn} + H_{fn+1} + H_{en+1} + H_{exn+1} + H_{bn+1} + H_{mn+1}$$

Where: WSEL = Water surface elevation at junction noted

H_f = Friction loss in pipe noted (see Section 6-6.1)

H_e = Entrance head loss at junction noted (see Section 6-6.2)

H_{ex} = Exit head loss at junction noted (see Section 6-6.2)

H_b = Bend head loss at junction noted (see Section 6-6.3)

H_m = Multiple flow head loss at junction noted (see Section 6-6.4)

As long as the HGL is lower than the rim elevation of the manhole or catch basin, the design is acceptable. If the HGL is higher than the rim elevation, flow will exit the storm drain and the design is unacceptable. The most common way to lower the HGL below the rim elevation is to lower the pipe inverts for one or more runs of the storm drain or increase the pipe diameter.

6-6.1 Friction Losses in Pipes

Head loss due to friction is a result of the kinetic energy lost as the flow passes through the pipe. The rougher the pipe surface is, the greater the head loss is going to be. Head loss from friction can be calculated with the following equation.

$$H_f = L\left[\frac{2.15Qn}{D^{2.667}}\right]^2 \text{ (English Units)} \qquad (6\text{-}4)$$

$$H_f = L\left[\frac{3.19Qn}{D^{2.667}}\right]^2 \text{ (Metric Units)}$$

Where: H_f = Head loss due to friction in feet (meters)

L = Length of pipe in feet (meters)

Q = Flow in pipe in cfs (cms)

n = Manning's roughness coefficient (see Appendix 4-1)

D = Diameter of pipe in feet (meters)

6-6.2 Junction Entrance and Exit Losses

When flow enters a junction, it loses all of its velocity. As a result, there is an associated head loss equal to one velocity head. Then when the flow exits the junction and accelerates into the next pipe, there is another head loss equal to approximately half of one velocity head. These two head losses can be represented with the following equations (Metric and English units use the same equations).

$$H_e = \frac{V_2^{\ 2}}{2g}$$

$$H_{ex} = 1.0\left(\frac{V^{\ 2}}{2g} - \frac{V_d^{\ 2}}{2g}\right) \approx \frac{V^{\ 2}}{4g} \qquad (6\text{-}5)$$

Where H_e = head loss from junction entrance in feet (meters)
H_{ex} = head loss from junction exit in feet (meters)
V = flow velocity in pipe in feet per second (m/s)
V_d = channel velocity downstream of outlet in feet per second (m/s)
g = gravitational acceleration constant

6-6.3 Losses From Changes in Direction of Flow

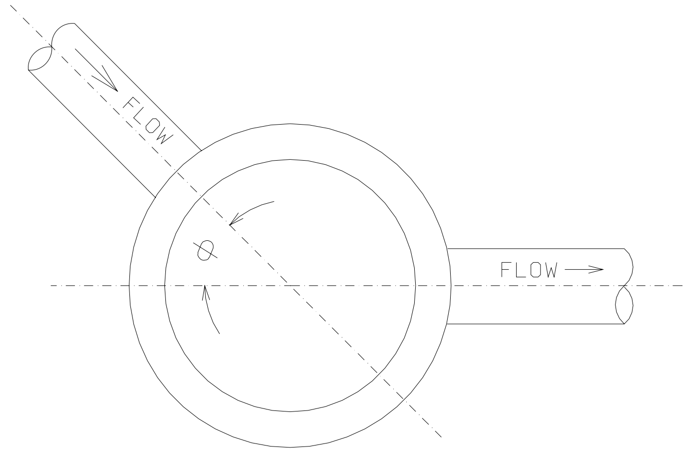
When flow changes direction inside of a junction, there is an associated head loss. The amount of head loss that will occur is dependent on how great the change is. As the angle between the inflow and outflow pipes increase, the amount of head loss increases. This head loss can be calculated with the following equation (metric and English units use the same equation).

$$H_b = K_b \frac{V^2}{2g} \qquad (6\text{-}6)$$

Where: H_b = Head loss from change in direction in feet (meters)

K_b = Head loss coefficient for change in direction, see below:

K_b	Angle of Change in Degrees
0.00	0
0.19	15
0.35	30
0.47	45
0.56	60
0.64	75
0.70	90 and greater



Changes in Direction of Flow

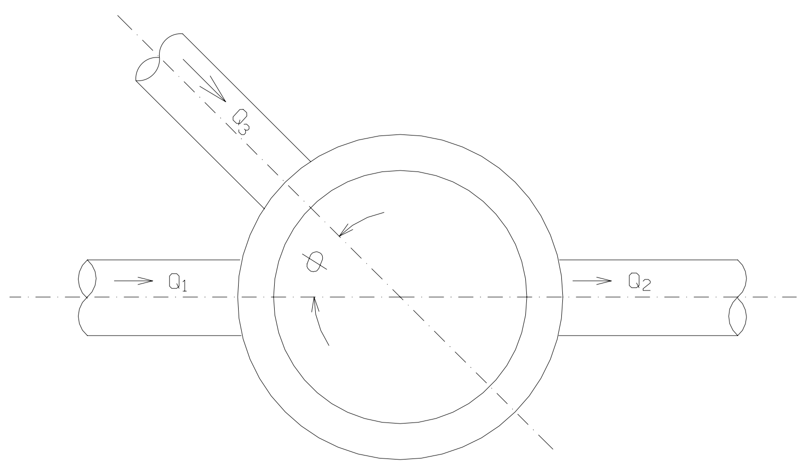
Figure 6-6.3

6-6.4 Losses From Multiple Entering Flows

When flow enters a junction from more than one pipe there is an associated head loss. The head loss is dependent on the amount of flow in each pipe and direction that each pipe enters the junction. This head loss can be calculated with the following equation (Metric and English units use the same equation).

$$H_m = \frac{Q_2V_2^{\ 2} - Q_1V_1^{\ 2} - \cos\phi Q_3V_3^{\ 2}}{2gQ_2} \qquad (6\text{-}7)$$

Where H_m = Head loss from multiple flows in feet (meters)



Multiple Flows Entering a Junction

Figure 6-6.4

6-7 Drywells

A drywell is a manhole or catch basin typically precast that is perforated to allow flow into the soil and in some situations when allowed in a storm drain to exit the system. Standard Plan B-20.20 of the WSDOT *Standard Plans for Road, Bridge, and Municipal Construction* depicts a typical drywell. Chapter 530 in the *Design Manual* also provides information on the appropriate geotextile (Class A Underground drainage with moderate survivability) to select for the installation of the drywell as well as *Standard Specifications* 9-12.7, 9-33, and 9-03.12(5).

The primary advantage of drywells is that they reduce flooding by discharging flow into ground water instead of discharging it to surface waters such as rivers and creeks.

A secondary advantage of drywells when allowed is to reduce the flow in a storm drain system and thus reduce the sizes of the pipes in the system. For installation of a drywell to be practical, the surrounding soil should have an infiltration that follow the guidance in the Soil Suitability Criteria section of Chapter 4 in the *Highway Runoff Manual*. Soil infiltration rates should always be determined using soil analysis by a licensed geotechnical engineer. Designing with incorrect soil infiltration rates is a primary cause of failure for systems with drywells.

When allowed, drywells can be designed with inlet and outlets pipes or without pipes. In either case, the designer must first determine the maximum amount of flow that will leave the system through the drywell, see Chapter 4 of the *Highway Runoff Manual* provides guidance on how to establish this flow. The flow rate is then used in one of two ways.

1. **Stand alone drywells -** If the drywells are standing alone, that is there are no pipes connecting them and the only flow into them is through a grate on top of each drywell, the design is performed by simply calculating the amount of flow that enters the drywell through the grate and comparing it with the peak rate of flow that will infiltrate from the drywell. The designer must limit the amount of area draining to each drywell such that the flow out of the drywell through infiltration always exceeds the amount of flow entering the drywell.

2. **Drywells that are part of a storm drain system -** When allowed, drywells can be connected to a storm drain system. To calculate the flow leaving the junction, subtract the rate of infiltration flow leaving the drywell from the flow entering the drywell. When using Figure 6-4.1 to perform the calculations, the flow

infiltrating out of the drywell should be shown in Column 12 as a negative value to indicate that there is a constant flow leaving the system at this point. The designer should note that normally pipe sizes are not allowed to decrease in the downstream direction; however, if the flow value in Column 13 becomes less than zero, there may be no need for an outlet pipe since all flow will leave the drywell through infiltration.

Designers should be aware of potential impacts drywell infiltration may have on ground water. Removing pollutants from stormwater, also referred to as runoff treatment, before discharging to ground water is always advisable. In many areas of western Washington and areas of eastern Washington, runoff treatment is required prior to infiltrating runoff. Uncontaminated or properly treated stormwater must be in accordance with Ecology's Underground Injection Control Program UIC (WAC 173-218). See Chapters 4 and 5 of the *Highway Runoff Manual* for a complete discussion on drywells, runoff treatment, and flow control.

6-8 Pipe Materials for Storm Drains

There are various pipe materials that are acceptable to WSDOT for storm drains. Designers should consult Storm Sewers in Chapter 8 of this manual and Section 7-04.2 and Section 9-05 of the *Standard Specifications*, for the acceptable alternates. WSDOT's policy is to allow and encourage all possible alternates that will ensure a properly functioning storm drain at a reasonable cost. If at any specific location one or more of the alternates are not satisfactory, the unacceptable alternate or alternates shall be so stated on the plans usually in the structure note sheet. Storm drainpipe is subject to some use restrictions, which are detailed in Chapter 8.

Pipe flow capacity depends on the roughness coefficient, which is a function of pipe material and manufacturing method. Fortunately, most storm drainpipes are 24 inches (600 millimeters) in diameter or less. Studies have shown that all the common pipe materials have a similar roughness coefficient in these sizes. For calculations, the designer should use a roughness coefficient of 0.013 for all pipes 24 inches (600 millimeters) or smaller. For larger diameter pipes, the designer should calculate the required pipe size using the Mannings Roughness Coeffient values in Appendix 4-1 of this manual.

In estimating the quantity of structure excavation for design purposes at any location where alternate pipes are involved, estimate the quantity of structure excavation on the basis of concrete pipe since it has the largest outside diameter.

6-9 Subsurface Drainage

Subsurface drainage is provided for control of ground water encountered at highway locations. Ground water, as distinguished from capillary water, is free water occurring in a zone of saturation below the ground surface. The subsurface discharge depends on the effective hydraulic head and on the permeability, depth, slope, thickness, and extent of the aquifer.

The solution of subsurface drainage problems often calls for specialized knowledge of geology and the application of soil mechanics. The designer should work directly with the Region Materials Engineer as subsurface conditions are determined and recommendations are made for design in the Soil's Report.

Typical subdrain installations would be those provided for control of seepage in cuts or side hills or the lowering of the ground water table for proper subgrade drainage.

Subsurface drainage pipe size is determined by the same method used to design regular storm drainpipes. The only difference is that the flow used for the calculations is the predicted infiltration from groundwater into the system instead of flow entering the system from roadway drainage. When subsurface drainage is connected to a storm drain system, the invert of the underdrain pipe shall be placed above the operating water level in the storm drain. This is to prevent flooding of the underdrain system and defeating its purpose.