CITY AND BOROUGH OF SITKA
STORMWATER DESIGN STANDARDS

BACKGROUND

These Stormwater Design Standards present acceptable methods for the analysis and design of conveyance systems and hydraulic structures within the City and Borough of Sitka (CBS). These standards encompass the following:

- Design and analysis methods
- Pipe systems
- Outfalls
- Culverts
- Open conveyances
- Private drainage systems.

Where space and topography permit, open conveyances are preferred for stormwater conveyance.

DESIGN EVENT STORM FREQUENCY

Hydraulic structures are analyzed and sized for a specific storm frequency to provide an acceptable level of service at an acceptable cost. When selecting a storm frequency for design, consideration is given to the potential degree of damage to adjacent properties, potential hazard and inconvenience to the public, the number of users, and the initial construction cost of the conveyance system or hydraulic structure.

The design event recurrence interval indicates the probability that such an event will occur in any one year. The greater the recurrence interval, the lower the probability that the event will occur in any given year. For example, a peak flow having a 25-year recurrence interval has a 4 percent probability of being equaled or exceeded in any future year. A peak flow having a 2-year recurrence interval has a 50 percent probability of being equaled or exceeded in any future year. Table 1 shows the design event for each conveyance system category.

TABLE 1.
DESIGN EVENT FREQUENCIES

Type of Structure	Design Return Period (Exceedance Probability)
Roadway Culverts - tributary drainage area > 25 acres	100 years (1%)
Roadway Culverts – tributary drainage area < 25 acres	50 years (2%)
Driveway Culverts	25 years (4%)
Trunk Storm Sewer System and Storm Sewer Feeder Lines	25 years (4%)
Outfall Energy Dissipation	100 years (1%)
Side Ditches, Storm Water Inlets and Gutter Flow	25 years (4%)
Bridges in Designated Flood Hazard Areas	100 years (1%)

DETERMINATION OF DESIGN FLOWS

All existing and proposed conveyance systems shall be analyzed and designed using the peak flows from hydrographs developed using the methods set forth in the Alaska Highway Drainage Manual, Chapter 7, Hydrology, or other approved methodology. In general, either event-based or continuous runoff hydrologic modeling may be used for conveyance sizing.

For event-based hydrologic modeling, the 24-hour storm distributions for the 10-, 25-, 50- and 100-year frequency design storms are provided in Appendix A to these stormwater design standards.

Exception: For drainage sub-basins of 10 acres or less, the capacity of conveyance elements may be determined using the culvert sizing table provided in Table 2.

Figure 1 illustrates the application of design event frequencies to various culvert conditions.

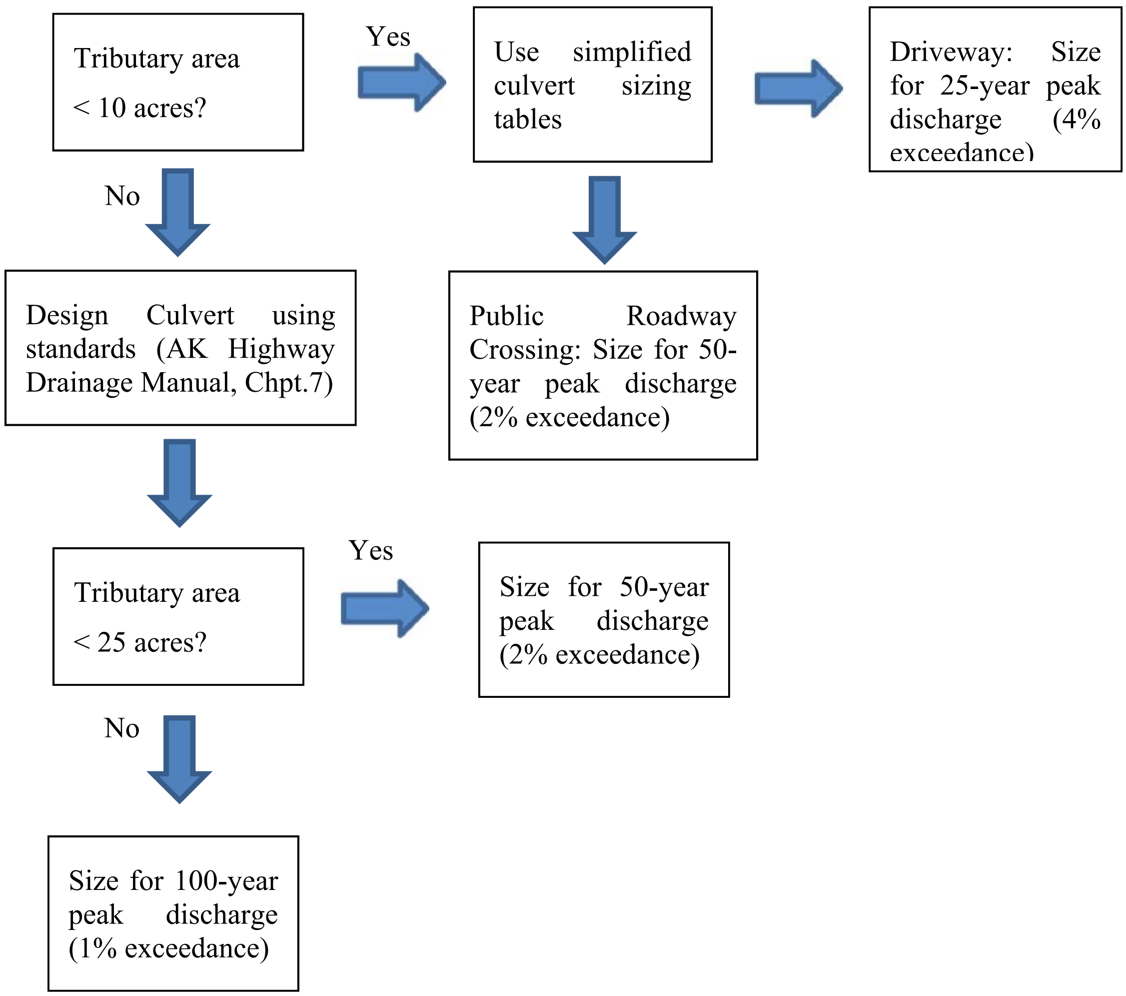

Figure 1. Determination of Design Flows

TABLE 2. SIMPLIFIED CULVERT SIZING TABLE		
Public Roadway Culvert (50-year / 2% Exceedance)		
Contributing Land-Use	**Pipe Diameter (inches)**	**Range of Tributary Area (Acres)**
Low Density Development	18"	0-10
Medium Density Development	18"	0-7.8
	24"	7.9-10
High Density Development	18"	0-4.1
	24"	4.2-8.8
	36"	8.9-10
Driveway Culvert (25-year / 4% Exceedance)		
Contributing Land-Use	**Pipe Diameter (inches)**	**Range of Tributary Area (Acres)**
Low Density Development	18"	0-10
Medium Density Development	18"	0-8.8
	24"	8.9-10
High Density Development	18"	0-4.6
	24"	4.7-9.8
	36"	9.9-10

Figure 2 is excerpted from the Stormwater Master Plan and provides an illustration of the contributing land use densities listed in Table 2.

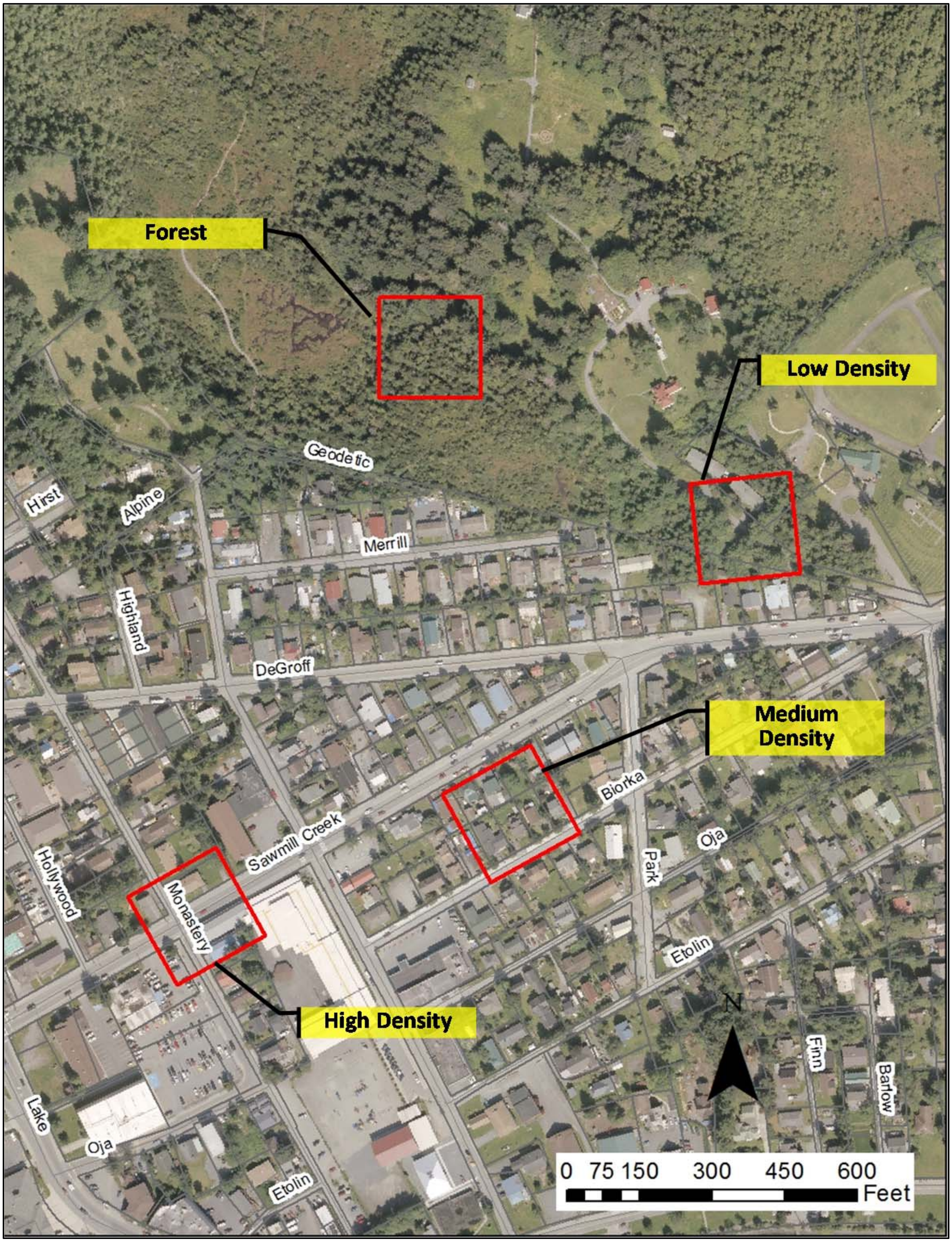

Figure 2. Examples of Land Use Densities referred to in Table 2

OFF-SITE ANALYSIS

Off-site analysis shall initially consist of a qualitative assessment of existing and potential flooding and erosion problems upstream and downstream of the site and of the conveyance capacity of the primary and overflow stormwater runoff flow paths. If conditions warrant, a more detailed quantitative analysis shall be required. Areas with steep slopes or erosive soils warrant increased review of runoff conveyance.

Conveyance analysis shall be conducted for at least a quarter-mile downstream from the site to evaluate potential impacts as well as the adequacy of the downstream conveyance facilities to accommodate flow from the site and all other upstream sources. Conveyance analysis shall extend upstream of the site past any backwater conditions caused by the proposed development.

For the 25-year event, there shall be a minimum of one-half foot of freeboard between the water surface and the top of any manhole or catch basin.

BACKWATER ANALYSIS

A computer program capable of backwater profile analysis, such as Hydrologic Engineering Center-River Analysis System (HEC-RAS) for surface water conveyance or Storm Water Management Model (SWMM) for pipe conveyance, is recommended over hand calculations. However, hand calculations are acceptable.

CONVEYANCE SYSTEM ROUTE DESIGN

Where feasible, all pipes shall be located outside the travel lane, unless otherwise specified below. New conveyance system alignments that are not in dedicated tracts or rights-of-way shall be located in drainage easements that are adjacent and parallel to property lines. The width of the permanent easement must be completely within a single parcel or tract and not split between adjacent properties in new development. In existing developments, storm drain easements shall follow lot ownership lines to the maximum extent practical. Topography and existing conditions are conditions under which a drainage easement may be placed not adjacent and parallel to a property line. Requirements for conveyance system tracts and easements are discussed below.

Exceptions:

- This routing requirement shall not apply in cases where it would require relocation of streams or natural drainage channels.
- Perpendicular crossings and cul-de-sacs are exempted from this requirement.
- For curved sections only of local minor roads and local road cul-de-sacs, pipe placement may be located underneath pavement areas, but no closer than 6 feet from the roadway centerline.

EASEMENTS, ACCESS, AND DEDICATED TRACTS

Natural Channels and Stormwater Facilities

All man-made drainage facilities and conveyances and all natural channels (on the project site) used for conveyance of altered flows due to development (including swales, ditches, stream channels, lake shores, wetlands, estuaries, gullies, ravines, etc.) shall be located within easements or dedicated tracts as required by CBS. Easements shall contain the natural features and facilities and shall allow CBS access for purposes of inspection, maintenance, repair or replacement, flood control, water quality monitoring, and other activities permitted by law.

All drainage facilities such as wet ponds or infiltration systems to be maintained by the CBS shall be located in tracts dedicated to CBS. Conveyance systems can be in easements.

Maintenance Access

All storm drain easements shall have physical access from a public street or right-of-way. In cases where such access requires a road, the access easement shall be a minimum of 15-foot wide. Access easements shall be surfaced with a minimum 12-foot width of crushed rock, or other approved surface to allow year-round equipment access to the facility with a 15 percent maximum grade.

Maintenance access must be provided for all manholes, catch basins, vaults, or other underground drainage facilities to be maintained by CBS. Maintenance shall be through an access easement or dedicated tract. Drainage structures for conveyance without vehicular access must be channeled.

Access to Conveyance Systems

All publicly and privately maintained conveyance systems shall be located in dedicated tracts, drainage easements, or public rights-of-way in accordance with this manual.

Exception: roof downspout, minor yard, and footing drains unless they serve other adjacent properties.

Table 3 lists minimum easements for drainage facilities.

TABLE 3.
MINIMUM EASEMENT WIDTHS FOR CONVEYANCE SYSTEM ACCESS, INSPECTION AND MAINTENANCE

Conveyance Width	Easement Width
Channels	15 feet from top of slope on one side for access, 5 feet from top of slope for other side
Pipes/Outfalls ≤ 48” with up to 6’ cover (max)	10 feet centered on pipe[a]
Pipes/Outfalls ≤ 60” with up to 6’ cover (max)	15 feet centered on pipe[a]
Pipes/Outfalls ≤ 60” with greater than 6’ cover	20 feet centered on pipe[a]
Pipes/Outfalls > 60”	30 feet centered on pipe[a]

a. May be greater, depending on depth and/or number of pipes in easement.

Conveyance systems to be maintained and operated by CBS must be located in a dedicated tract or drainage easement granted to CBS. Any new conveyance system located on private property designed to convey drainage from other private properties must be located in a private drainage easement granted to the contributors of stormwater to the systems to convey surface and stormwater and to permit access for maintenance or replacement in the case of failure.

All drainage tracts and easements, public and private, must have a minimum width of 10 feet. In addition, all pipes and channels must be located within the easement so that each pipe face or top edge of channel is no closer than 5 feet from its adjacent easement boundary. Pipes greater than 5 feet in diameter and channels with top widths greater than 5 feet shall be placed in easements adjusted accordingly, so as to meet the required dimensions from the easement boundaries.

PIPE SYSTEM DESIGN CRITERIA

Pipe systems are networks of storm drain pipes, catch basins, manholes, and inlets designed and constructed to convey storm and surface water. The hydraulic analysis of flow in storm drain pipes typically is limited to “gravity flow”; however, in analyzing existing systems it may be necessary to address pressurized conditions.

Analysis Methods

Two methods of hydraulic analysis using Manning’s equation are used for the analysis of pipe systems. The first method is the Uniform Flow Analysis Method, commonly referred to as the Manning’s Equation, and is used for the design of new pipe systems and analysis of existing pipe systems. The second method is the Backwater Analysis Method and is used to analyze the capacity of both proposed, and existing, pipe systems. If off site analysis determines that, as a result of the project, runoff would cause damage or interrupt vital services, a backwater (pressure sewer) analysis shall be required. Results shall be submitted in tabular and graphic format showing hydraulic and energy gradient.

When using the Manning’s equation for design, each pipe in the system shall be sized and sloped such that its barrel capacity at normal full flow is equal or greater than the required conveyance capacity. Table 4 provides the recommended Manning’s “n” values for preliminary design for pipe systems. (Note: The “n” values for this method are 15 percent higher in order to account for entrance, exit, junction, and bend head losses.) Manning’s “n” values used for final pipe design must be documented in the Stormwater Site Plan.

Nomographs may also be used for sizing the pipes. For pipes flowing partially full, the actual velocity may be estimated from engineering nomographs by calculating Q_{full} and V_{full} and using the ratio of Q_{design}/Q_{full} to find V and d (depth of flow).

TABLE 4. RECOMMENDED MANNING'S "N" VALUES FOR PRELIMINARY PIPE DESIGN		
	Analysis Method	
Type of Pipe Material	Backwater Flow	Manning's Equation Flow
A. Concrete pipe and CPP-smooth interior pipe	0.012	0.014
B. Annular Corrugated Metal Pipe or Pipe Arch:		
1. 2⅔ x ½ inch corrugation (riveted)		
a. plain or fully coated	0.024	0.028
b. paved invert (40% of circumference paved):		
(1) flow full depth	0.018	0.021
(2) flow 0.8 depth	0.016	0.018
(3) flow 0.6 depth	0.013	0.015
c. treatment 5	0.013	0.015
2. 2.3 x 1-inch corrugation	0.027	0.031
3. 3.6 x 2-inch corrugation (field bolted)	0.030	0.035
C. Helical 2⅔ x ½-inch corrugation and CPEP-single wall	0.024	0.028
D. Spiral rib metal pipe and PVC pipe	0.011	0.013
E. Ductile iron pipe cement lined	0.012	0.014
F. High density polyethylene pipe (butt fused only)	0.009	0.009

Acceptable Pipe Sizes

All storm drainage pipes shall have a minimum 18-inch diameter unless approved by CBS. Cross-street connections from a concrete inlet to a Type III or IV catch basin or manhole (CB leads) may use corrugated polyethylene pipe 12-inch diameter if approved. Storm sewer pipe used for private roof/footing/yard drain systems can be less than 12-inch diameter if sized according to the application and approved by CBS.

Pipe Materials

Pipe materials shall meet the requirements of CBS standard specifications. All storm drainage pipe, except as otherwise provided for in these standards, shall be double-walled, corrugated, polyethylene pipe, minimum 18-inch diameter unless approved by CBS, with a smooth internal diameter (AASHTO M-294 Type S) or approved equal, with a joint meeting CBS standards, except for perforated pipe and major underground detention facilities. Drainage pipe shall have a minimum cover of 12 inches as measured from the top of pipe to the top of paved surface.

When extreme slope conditions or other unusual topographic conditions exist, other pipe materials and methods may be used with prior approval by CBS, such as, but not limited to, polyvinyl chloride (PVC) or high density polyethylene (HDPE).

All metal parts must be corrosion resistant. Examples of preferred materials include aluminum, stainless steel, and plastic. Zinc and galvanized materials are discouraged because of aquatic toxicity. Painted metal parts shall not be used because of poor longevity.

Pipe material, joints, and protective treatment shall be in accordance with CBS Standard Specifications and AASHTO and ASTM treatment standards as amended by the CBS. The applicant is responsible for contacting CBS to determine the allowable pipe materials which can be used.

Pipe Slope and Velocity

Minimum velocity is 2 feet per second at design flow. CBS may waive these minimums in cases where topography and existing drainage systems make it impractical to meet the standard.

Maximum slopes, velocities, and anchor spacings are shown in Table 5. Where flow velocities exceed 15 feet per second for the conveyance system design event, provide anchors at bends and junctions.

Pipe direction changes or size increases or decreases are allowed only at manholes and catch basins. This does not apply to detention tanks or vaults.

Downsizing of pipes is only allowed under special conditions as allowed by CBS (i.e., no hydraulic jump can occur; downstream pipe slope is significantly greater than the upstream slope; velocities remain in the 3 to 8 fps range, no debris blockage potential etc.).

TABLE 5.
MAXIMUM PIPE SLOPES AND VELOCITIES

Pipe Material	Pipe Slope Above Which Pipe Anchors Required and Minimum Anchor Spacing[a]	Max. Slope Allowed	Max. Velocity at Full Flow
Spiral Rib[b], PVC[b], CPEP-single wall	20% (minimum 1 anchor per 100 feet of pipe)	20%[d]	30 fps
Concrete[b] or CPP-smooth interior[b]	20% (minimum 1 anchor per 50 feet of pipe)	20%[d]	30 fps
HDPE[c]	50% (minimum 1 anchor per 100 feet of pipe; cross slope installations only)	None	None

a. As supported by engineering calculations.
b. Not allowed in landslide hazard areas.
c. Butt-fused pipe joints required. Above-ground installation is required on slopes greater than 40% to minimize disturbance to steep slopes.
d. Maximum slope of 200% allowed for these pipe materials with no joints (one section) with structures at each end and properly grouted.

Key: PVC = polyvinyl chloride pipe; CPP = corrugated high density polyethylene pipe; HDPE = high density polyethylene

Downsizing of downstream culverts within a closed system with culverts 18-inches in diameter or smaller will not be permitted.

Normally pipes connecting into a structure shall match crown elevations (see exceptions in the layout criteria below).

Pipes on Steep Slopes

Steep slopes (greater than 20 percent) shall require all drainage to be piped from the top to the bottom in HDPE pipe (butt fused). Additional anchoring design is required for these pipes.

Pipe System Layout Criteria

Pipes must be laid true to line and grade with no curves, bends, or deflections in any direction. Exceptions may include HDPE on steep slopes per CBS.

A break in grade or alignment or changes in pipe material shall occur only at catch basins or manholes.

Connections to a pipe system shall be made only at catch basins or manholes. No wyes or tees are allowed except on private roof/footing/yard drain systems on pipes 8-inches in diameter, or less, with clean-outs upstream of each wye or tee.

Provide 6 inches minimum vertical and 3 feet minimum horizontal clearance (outside surfaces) between storm drain pipes and other utility pipes and conduits.

Suitable pipe cover over storm pipes in road rights-of-way shall be calculated for HS-20 loading by the Engineer of Record. Pipe cover is measured from the finished grade elevation down to the top of the outside surface of the pipe. Pipe manufacturers' recommendations are acceptable if verified by CBS.

Pipe cover in areas not subject to vehicular loads, such as landscape planters and yards, may be reduced to an 18-inch minimum.

Debris barriers (trash racks) are required on inlets to closed concrete structures (see CBS Engineering Standard Specifications).

Where a minimal fall is necessary between inlet and outlet pipes in a structure, pipes must be aligned vertically by one of the following in order of preference:

- Match pipe crowns
- Match 80 percent diameters of pipes
- Match pipe inverts.

Where inlet pipes are higher than outlet pipes, drop manhole connections may be required or increased durability in the structure floor may be required.

HDPE pipe systems longer than 100 feet must be anchored at the upstream end if the slope exceeds 25 percent and the downstream end placed in a minimum 4-foot long section of the next larger pipe size. This sliding sleeve connection allows for the high thermal expansion/contraction coefficient of the pipe material.

Pipe Structure Criteria

Catch Basins and Manholes

For the purposes of this manual, all catch basins and manholes shall meet the requirements outlined in CBS Standard Specifications.

Catch basin (or manhole) diameter shall be determined by pipe diameter and orientation at the junction structure. A plan view of the junction structure, drawn to scale, will be required when more than four pipes enter the structure on the same plane, or if angles of approach and clearance between pipes is of concern. The plan view (and sections if necessary) must ensure a minimum distance (of solid concrete wall) between pipe openings of 8 inches for 48-inch and 54-inch diameter catch basins and 12 inches for 72-inch and 96-inch diameter catch basins.

Catch basin evaluation of structural integrity for H-20 loading will be required for multiple junction catch basins and other structures which exceed the recommendations of the manufacturers.

Catch basins shall be provided within 50 feet of the entrance to a pipe system for silt and debris removal.

Maximum surface runs between inlet structures on paved roadway surface shall be as listed in Table 6.

Minimum longitudinal roadway slope shall be 0.5 percent.

The Washington State Department of Transportation Hydraulics Manual can be used in determining the capacity of inlet grates when capacity is of concern. When verifying capacity, assume grate areas on slopes are 80 percent free of debris, and “vaned” grates are 95 percent free. In sags or low spots, assume grates are 50 percent free of debris, and “vaned” grates, 75 percent free.

A metal frame and grate for catch basin and inlet, that is deemed bicycle safe, shall be used for all structures collecting drainage from the paved roadway surface (see CBS Standard Specifications).

TABLE 6.
MAXIMUM SURFACE RUNS BETWEEN INLET STRUCTURES

Roadway Slope (%)	Maximum Spacing (feet)
0.5 to 1	200
1 to 8	350
8 to 12	150

OUTFALLS

All piped discharges to streams, rivers, ponds, lakes, or other open bodies of water are designated outfalls and shall provide for energy dissipation to prevent erosion at or near the point of discharge. Properly designed outfalls are critical to reducing the chance of adverse impacts as the result of concentrated discharges from pipe systems and culverts, both onsite and downstream. Outfall energy dissipation systems include rock splash pads, flow dispersal trenches, gabion or other energy dissipaters, and tightline systems. A tightline system is typically a continuous (i.e., joint-free, such as butt-fused HDPE pipe) length of pipe used to convey flows down a steep or sensitive slope with appropriate energy dissipation at the discharge end.

General Design Criteria for Outfall Features

All energy dissipation at outfalls shall be designed for peak flows from a 100-year, 24-hour storm event. For outfalls with a maximum flow velocity of less than 10 feet per second, a rock splash pad is acceptable. For velocities equal to or greater than 20 feet per second, an engineered energy dissipater must be provided. See Table 7 and Figure 3 for a summary of the rock protection requirements at outfalls. The following sections provide general design criteria for various types of outfall features.

TABLE 7.
ROCK PROTECTION AT OUTFALLS

Discharge Velocity at Design Flow (fps)	Minimum Dimensions for Required Protection				
	Type [a]	Thickness	Width	Length	Height
0 to 5	Class I Riprap	1 foot	Diameter + 6 feet	8 feet or 4 x diameter, whichever is greater	Crown + 1 foot
>5 to 10	Class II Riprap	2 feet	Diameter + 6 feet or 3 x diameter, whichever is greater	12 feet or 4 x diameter, whichever is greater	Crown + 1 foot
>10 to 20	Class III Riprap or Gabion outfall	As required	As required	As required	Crown + 1 foot
>20	Engineered energy dissipater required				

a. Riprap classes as specified by Alaska DOT Standard Specifications.

Note: Riprap sizing governed by side slopes on outlet channel is assumed to be approximately 3:1.

General Design Criteria to Protect Aquatic Species and Habitat

Outfall structures should be located where they minimize impacts to fish, shellfish, and their habitats. However, new pipe outfalls can also provide an opportunity for low-cost fish habitat improvements. For example, an alcove of low-velocity water can be created by constructing the pipe outfall and associated energy dissipater back from the stream edge and digging a channel, over widened to the upstream side, from the outfall to the stream. Overwintering juvenile and migrating adult salmonids may use the alcove as shelter during high flows. Potential habitat improvements should be discussed with the Alaska Department of Fish and Game (ADF&G) biologist prior to inclusion in design.

Bank stabilization, bioengineering, and habitat features may be required for disturbed areas. Outfalls that discharge to the ocean or a major water body may require tide gates. Contact the CBS for specific requirements.

Rock Splash Pad

At a minimum, all outfalls as defined above must be provided with a rock splash pad except as specified in Table 7.

Flow Dispersal Trench

The flow dispersal trenches should only be used when both criteria below are met:

- An outfall is necessary to disperse concentrated flows across uplands where no conveyance system exists and the natural (existing) discharge is unconcentrated.
- The 100-year peak discharge rate is less than or equal to one-half of a cubic foot per second.

PIPE/CULVERT DISCHARGE PROTECTION

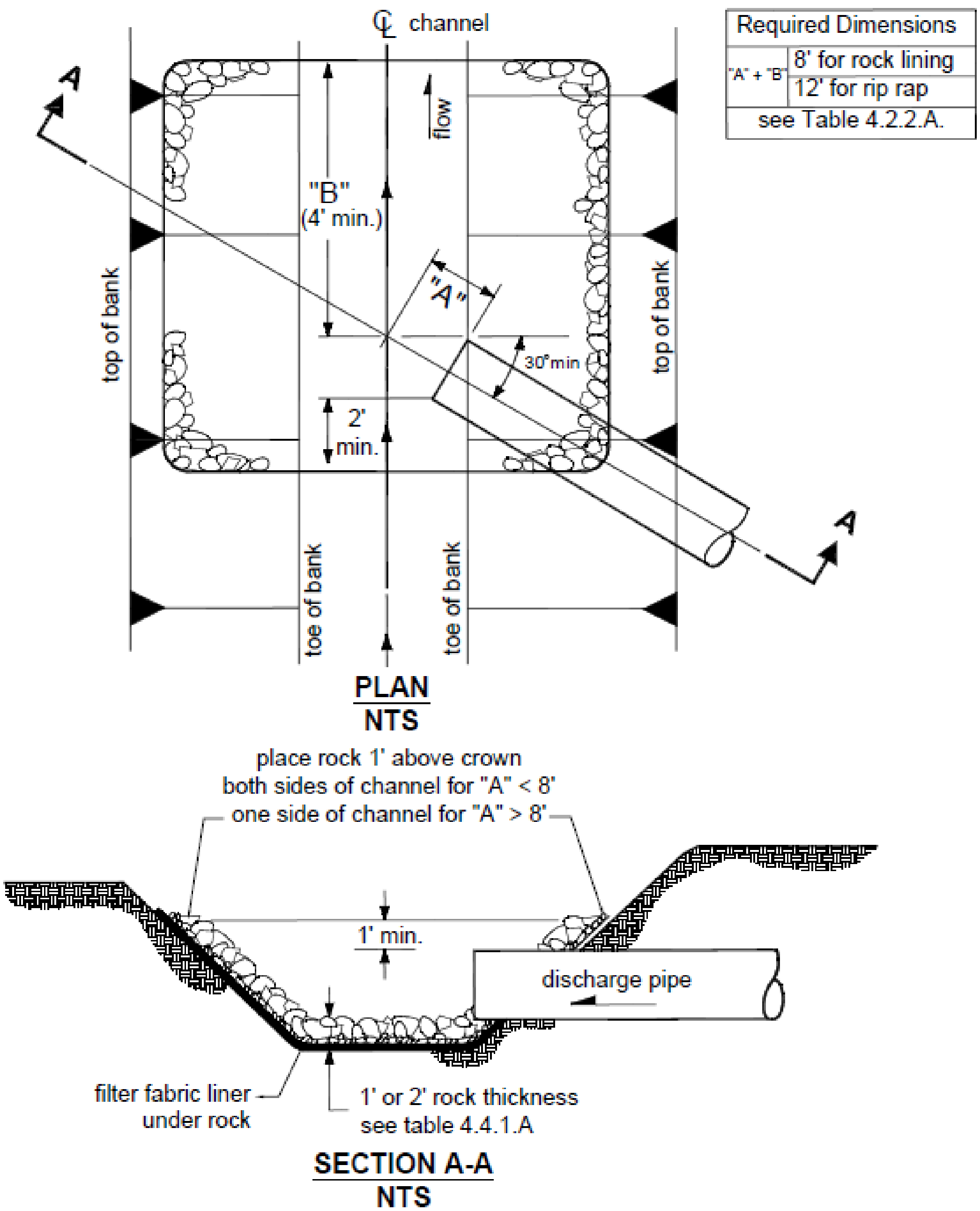

Figure 3. Outfall Discharge Protection

Tightline Systems

Tightline systems consist of continuous (i.e., joint-free, or restrained joint) pipe systems that traverse a steep slope and avoid introducing water to the slope. Such systems may be needed to prevent aggravation or creation of a downstream erosion problem. The following general design criteria apply to tightline systems:

- Outfall tightlines may be installed in trenches with standard bedding on slopes up to 20 percent. In order to minimize disturbance to slopes greater than 20 percent, it is recommended that tightlines be placed at grade with proper pipe anchorage and support.
- Except as indicated above, tightlines or conveyances that traverse the marine intertidal zone and connect to outfalls should be buried to a depth sufficient to avoid exposure of the line during storm events or future changes in beach elevation. If non-native material is used to bed the tightline, such material should be covered with at least 3 feet of native bed material or equivalent.
- HDPE tightlines must be designed to address the material limitations, particularly thermal expansion and contraction and pressure design, as specified by the manufacturer. The coefficient of thermal expansion and contraction for solid wall polyethylene (SWPE) pipe is on the order of 0.001 inch per foot per Fahrenheit degree. Sliding sleeve connections should be used to address this thermal expansion and contraction. These sleeve connections consist of a section of the appropriate length of the next larger size diameter of pipe into which the outfall pipe is fitted. These sleeve connections should be located as close to the discharge end of the outfall system as is practical.
- Due to the ability of HDPE tightlines to transmit flows of very high energy, special consideration for energy dissipation must be made. Flows of very high energy will require a specifically engineered energy dissipater structure.

CULVERT CRITERIA

For the purpose of this manual, culverts are single runs of pipe that are open at each end and have no structures such as manholes or catch basins.

Approved pipe materials are detailed in the pipe system design criteria earlier in this chapter. Galvanized or aluminized pipe are not permitted in marine environments or where contact with salt water may occur, even infrequently through backwater events.

Culvert Design Criteria

Flow capacity shall be determined by analyzing inlet and outlet control for headwater depth. Nomographs used for culvert design shall be included in the submitted stormwater plan.

All culverts shall be designed to convey the flows for the design storm event. The maximum design headwater depth shall be 2.0 times the diameter of the culvert with no saturation of roadbeds. Culverts shall be a minimum 18 inches diameter unless approved by CBS.

Where design flow velocity exceeds 8 feet per second, inlets and outlets shall be protected from erosion by a CBS Culvert Headwall (see CBS Standard Specifications) or approved equal, and rock lining, riprap, or biostabilization as detailed in Table 7 and approved by CBS.

Debris barriers are required on the inlet end of all culverts greater than 18 inches in diameter. Culverts greater than 36 inches in diameter within stream corridors are exempt.

Minimum culvert velocity shall be 2 feet per second and maximum culvert velocity shall be 15 feet per second. A maximum velocity of 30 feet per second may be used with an engineered outlet protection designed. No maximum velocity for HDPE pipe shall be established but outlet protection shall be provided.

All CPP and PVC culverts and pipe systems shall have concrete headwalls at exposed pipe ends.

Bends are not permitted in culvert pipes.

If the minimum cover cannot be provided on a flat site, pipe shall be designed for loadings by a licensed engineer.

- Maximum culvert length: 150 feet
- Minimum separation from other pipes:
  - 6 inches vertical (with bedding) and in accord with the CBS design criteria
  - 3 feet horizontal

Trench backfill shall be per CBS Standard Specifications.

All driveway culverts shall be of sufficient length to provide a minimum 3:1 slope from the edge of the driveway to the bottom of the ditch. Culverts shall have beveled end sections to match the side slope.

Fish Passage

Fish passage shall be accommodated as required by ADF&G and/or the U.S. Army Corps of Engineers.

OPEN CONVEYANCES

Open conveyances can be either roadside ditches, grass lined swales, or a combination thereof. Consideration must be given to public safety when designing open conveyances adjacent to traveled ways and when accessible to the public. Where space and topography permit, open conveyances are the preferred means of collecting and conveying stormwater.

Open conveyances shall be designed by one of the following methods:

- Manning's Equation (for uniform flow depth, flow velocity, and constant channel cross-section)
- Direct Step Backwater Method (utilizing the energy equation)
- Standard Step Backwater Method (utilizing a computer program).

Velocities must be low enough to prevent channel erosion based on the native soil characteristics or the compacted fill material. For velocities above 5 feet per second, channels shall be either rock-lined across the bottom and on the side slopes up to the roadway shoulder top with a minimum thickness of 8 inches, or shall be stabilized in a fashion acceptable to the CBS. Water quality shall not be degraded due to passage through an open conveyance. See Table 8.

Channels having a slope less than 6 percent <u>and</u> having peak velocities less than 5 feet per second shall be lined with vegetation.

Channel side slopes shall not exceed 2:1 for undisturbed ground (cuts) as well as for disturbed ground (embankments). All constructed channels shall be compacted per CBS standard specifications and standard details. Channel side slopes adjacent to roads shall not exceed 2:1 and will meet all other AASHTO and CBS road standards.

Channels shall be designed with a minimum freeboard of one-half-foot when the design flow is 10 cubic feet per second or less and 1 foot when the design discharge is greater than 10 cubic feet per second.

Check dams for erosion and sedimentation control may be used for stepping down channels and swales being used for biofiltration.

TABLE 8.
OPEN CONVEYANCE PROTECTION

Velocity at Design Flow (fps) Greater Than	Velocity at Design Flow (fps) Less Than or Equal To	Protection [a]	Thickness	Minimum Height Required Above Design Water Surface (feet)
0	5	Ditch Lining	0.5 feet	0.5
5	8	Class I Riprap	1 feet	2
8	12	Class II Riprap	2 feet	2
12	20	Slope mattress, gabion, etc.	Varies	1

a. Ditch Lining and Riprap materials as specified by CBS Standard Specifications.

Note: Riprap sizing governed by side slopes on channel, assumed no steeper than 2H:1V. Bioengineered lining allowed for design flow up to 8 fps.

Simplified Ditch Design

The Simplified Ditch Design method can be used when also using the Simplified Culvert Sizing Table. This method allows the designer the option of employing a ditch design driven by the size and capacity of the upstream culvert (selected using the Simplified Culvert Sizing Table) and the longitudinal slope of the ditch.

The optional method is provided as a convenient guide to designers. Because the size of the ditch is based on the inlet capacity of the upstream culvert, the resulting ditch design from this method may be conservative, and a more efficient design may be achievable on a given site using more detailed design methods. The following assumptions were made in developing the Simplified Ditch Design tool:

- Drainage tributary area limitations for Simplified Culvert Sizing Table apply
- Trapezoidal ditch cross section
- Ditch bottom width is twice the upstream culvert diameter, or greater
- Ditch side slopes are 2H:1V or flatter
- Ditch minimum depth, based on upstream culvert diameter:
  - 18-inch diameter culvert 2.0 feet deep
  - 24-inch diameter culvert 2.5 feet deep
  - 36-inch diameter culvert 3.0 feet deep
- Assumed peak discharge from upstream culvert (consistent with Simplified Culvert Sizing Table):
  - 18-inch diameter 14 cfs
  - 24-inch diameter 30 cfs
  - 36-inch diameter 36 cfs

Armoring of channels designed using the Simplified Ditch Design tool must conform to the requirements in Figure 4. Based on the diameter of the upstream culvert (18-, 24- or 36-inch curve), and the longitudinal slope of the ditch, the flow velocity is determined. The flow velocity defines the type of armoring required (Ditch Lining, Class I Riprap, or Class II Riprap); armoring thickness shall be as defined in Table 8. Where velocity exceeds 12 feet per second, an engineered lining must be designed.

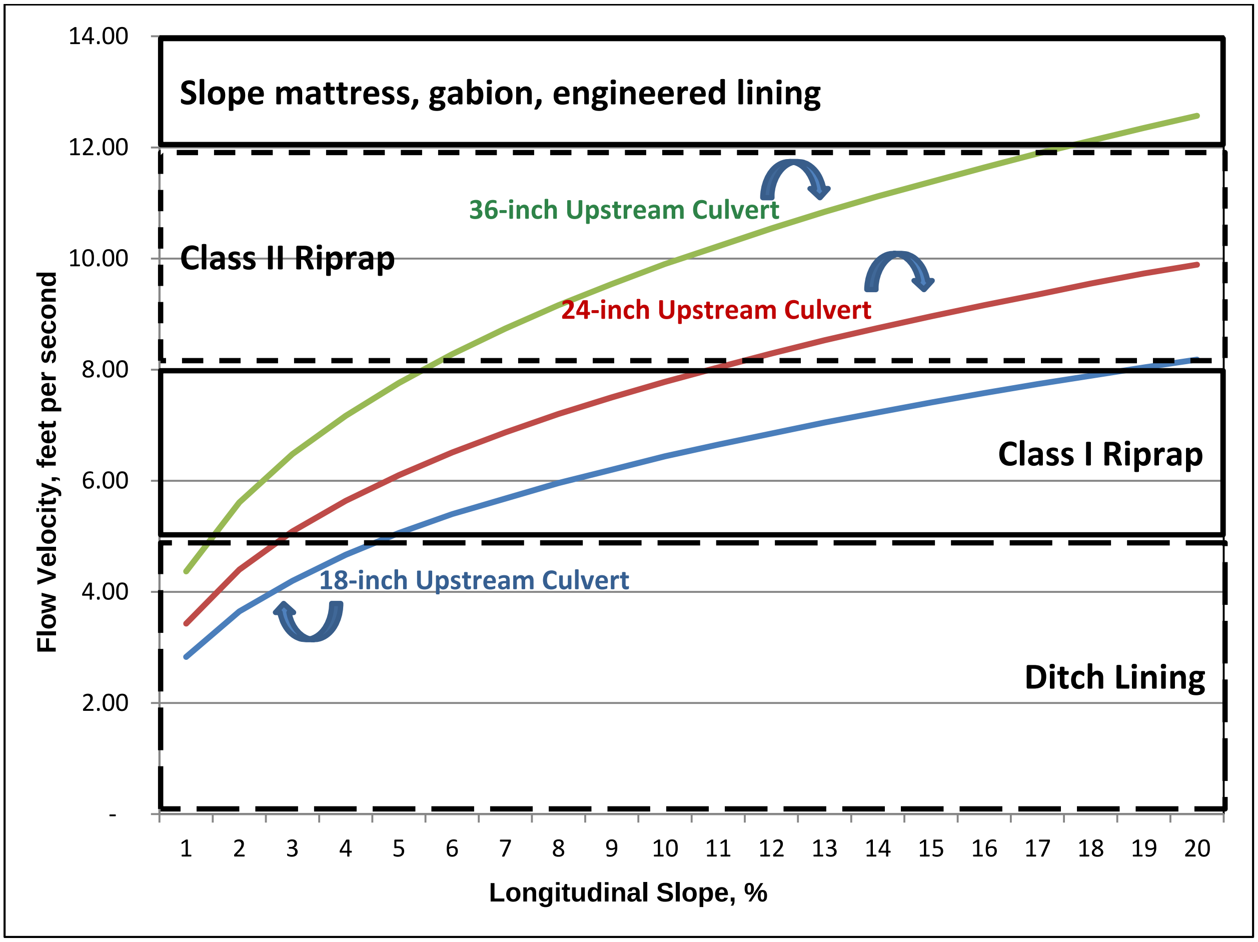

Figure 4. Armoring required for Simplified Ditch Design

PRIVATE DRAINAGE SYSTEMS

The engineering analysis for a private drainage system is the same as for a public system.

Discharge Locations

Stormwater will not be permitted to discharge directly onto CBS roads or system without the prior approval of the CBS. Discharges to a CBS system shall be into a structure such as an inlet, catch basin, manhole, through an approved sidewalk underdrain or curb drain, or into an existing or created CBS ditch. Concentrated drainage will not be allowed to discharge across sidewalks, curbs, or driveways.

Roof downspouts and subsurface drains are required to be directed to a dispersion system or to the stormwater drainage system.

Drainage Stub-Outs

If drainage outlets (stub-outs) are to be provided for each individual lot, the stub-outs shall conform to the following:

- Each outlet shall be suitably located at the lowest elevation on the lot, so as to service all future roof downspouts and footing drains, driveways, yard drains, and any other surface or subsurface drains necessary to render the lots suitable for their intended use. Each outlet shall have free-flowing, positive drainage to an approved stormwater conveyance system or to an approved outfall location.
- Outlets on each lot shall be located per CBS standard details.
- The developer and/or contractor is responsible for coordinating the locations of all stub-out conveyance lines with respect to the utilities (e.g., power, gas, telephone, television).
- All individual stub-outs shall be owned and maintained by the property owner to the storm drain main line.