# CHAPTER 1

# INTRODUCTION

## 1.1 PURPOSE

The ***Drainage Manual*** sets forth drainage design standards for Florida Department of Transportation (FDOT) projects.

## 1.2 AUTHORITY

Central Office establishes the Department's policies, rules, procedures, and standards. This ***Manual*** derives authority from ~~Chapter **334**~~ ***Sections 20.23(3)(a)*** and ***334.048(3), Florida Statute (F.S.)***.~~,~~ ~~Sections 20.23(4)(a) and 334.048(3).~~

## 1.3 SCOPE

The principal users of this ***Manual*** are consultants and FDOT personnel who prepare FDOT construction plans.

## 1.4 GENERAL

***Chapter 334, F.S.***, known as the ***Florida Transportation Code***, establishes the responsibilities of the state, counties, and municipalities for the planning and development of the transportation systems serving the people of Florida, with the objective of assuring development of an integrated, balanced statewide system. The ***Code's*** purpose is to protect the safety and general welfare of the people of the state and to preserve and improve all transportation facilities in Florida. Under ***Section 334.044, F.S.***, the ***Code*** sets forth the powers and duties of the Department of Transportation to develop and adopt uniform minimum standards and criteria for the design, construction, maintenance, and operation of public roads.

The standards in this ***Manual*** provide a basis for uniform design practice for typical roadway drainage design situations. Realizing that drainage design is primarily a matter of sound application of good engineering judgment, it is impossible to give precise rules that would apply to all possible situations which may arise. Thus, for proper drainage design, we must preserve flexibility to account for varying site conditions, permitting, and sustainable design solutions. Situations will exist where these standards will not apply. THE INAPPROPRIATE USE OF AND/OR ADHERENCE TO THESE STANDARDS DOES NOT EXEMPT THE ENGINEER FROM THE PROFESSIONAL RESPONSIBILITY OF DEVELOPING AN APPROPRIATE DESIGN. The engineer is responsible for identifying those standards that do not apply to a particular design, and for obtaining approval to deviate from those standards. Authority for project-specific changes from this ***Manual*** rests with the District Drainage Engineer, and deviation from a standard in this ***Manual*** must be approved by the District Drainage Engineer. The request for deviation must include the engineering justification.

The Federal Highway Administration (FHWA) policies and procedures for the location and hydraulic design of highway encroachments on floodplains are prescribed in ***23 Code of Federal Regulations (CFR) 650A*** (http://www.fhwa.dot.gov/legsregs/directives/fapg/cfr0650a.htm). While the standards presented in the FDOT ***Drainage Manual*** conform to federal requirements, drainage designers should become familiar with ***23 CFR 650A*** to develop a basic understanding of some of the design standards for cross drains and bridges.

Use partial duration time series rainfall depth and intensity data for Florida in the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 Rainfall Data. This data is available at https://hdsc.nws.noaa.gov/pfds/pfds_map_cont.html?bkmrk=fl. Users will find FDOT rainfall distributions in ***Appendix E***.

Various Department publications play an integral role supporting and supplementing the content of this ***Manual***. These publications include, but are not limited to, the ***FDOT Design Manual (FDM)***, ***Structures Design Guidelines (SDG)***, ***Standard Plans for Road and Bridge Construction (Standard Plans)***, and ***Standard Specifications for Road and Bridge Construction (Standard Specifications)***.

The shaded boxes labeled **"Modification for Non-Conventional Projects"** throughout this ***Manual*** are intended for design-build projects.

## 1.5 RESILIENCE CONSIDERATIONS

FDOT's policy on Resilience of State Transportation Infrastructure (Topic No. 000-525-053) states that resilience includes the ability of the transportation system to adapt to changing conditions and prepare for, withstand, and recover from disruption. This policy is incorporated throughout this ***Manual***. FDOT drainage systems are engineered to convey the design event without damage to facilities. Other resilience considerations include:

- Use of NOAA Atlas 14 Point Precipitation Frequency Estimates Partial Duration Time Series Rainfall Data, ***Section 1.4***
- Open channel design frequency, **Section 2.2**
- Adjustment of Manning's "n" values for increased vegetation growth between maintenance cycles, ***Section 2.4***
- Freeboard for open channels design, ***Section 2.4.5***
- Freeboard for stormwater management facilities, ***Section 5.4.4.2***
- Freeboard for storm sewer systems***, Section 3.6.2***
- Design tailwater determination, including sea level rise, ***Section 3.4*** *(Storm sewer outfalls),* ***Section 4.5*** *(Cross Drains & Bridges), and* ***Section 5.4.1.1*** *(Stormwater Management Facility outfalls)*
- Sea level rise analysis for vulnerability assessments, ***Section 3.4.1***

- Minimum storm sewer pipe diameter, ***Section 3.10.1***
- Cross drain design capacity analysis, ***Section 4.2.1***
- Scour considerations for foundation design, ***Section 4.2.2***
- Hydrologic analysis, ***Section 4.7***
- Minimum cross drain size considerations, ***Section 4.10.4.1***
- Considerations for future land use and environment changes when evaluating Design Service Life in Optional Pipe Materials*,* ***Section 6.2***
- Pipe service life requirements*,* ***Section 6.2.1***

Additional guidance can be found in the following publications:

- ***FDOT Drainage Design Guide*** **Appendix G - Risk Evaluations**
- ***Hydraulic Engineering Circular (HEC) 16, Highways in the River Environment: Roads, Rivers, and Floodplains, 2nd Edition*** **(FHWA, 2023)**
- ***HEC 17*****,** ***Highways in the River Environment – Floodplains, Extreme Events, Risk, and Resilience, 2nd Edition*** **(FHWA, 2016)**
- ***HEC 25 – Highways in the Coastal Environment, 3rd Edition (FHWA, 2020)***
- ***Nature-Based Solutions for Coastal Highway Resilience: An Implementation Guide (FHWA, 2019)***
- ***Synthesis of Approaches for Addressing Resilience in Project Development (FHWA, 2017)***

## 1.6 DOCUMENTATION OF DRAINAGE DESIGN

Include approvals of deviation from this ***Manual*** in the project drainage design documentation, along with supporting justifications. The hydraulic designer will provide a Drainage Design Report to accompany all phase submittals (signed and sealed for the Final Phase submittal) that addresses the entire project design. This is a record set of all drainage computations, both hydrologic and hydraulic, and includes all necessary support data. All phase submittals must include hydrologic and hydraulic models. The Drainage Design Report must include, at a minimum, pond routing, with justifications for the utilization of all tailwater stages, a clear description of the overall stormwater management system, storm drain tabulations, pond recovery calculations, hydraulic spread calculations, special gutter grade calculations, drainage structure and liner flotation calculations, ditch conveyance calculations, a node-reach diagram superimposed on Department drainage maps, skimmer calculations, cross drain calculations, base clearance calculations, and other calculations relative to drainage. Include resilience and adaptation considerations, corresponding economic analysis, and any additional decision-making considerations as an appendix to the Drainage Design Report.

## 1.7 APPENDICES

This ***Manual*** includes five appendices:

***Appendix A*** contains a general overview of drainage law, with a discussion of case histories in Florida. It appears as an appendix rather than a chapter since it is primarily informational and does not constitute a standard.

***Appendix B*** contains guidance on general FDOT practice pertaining to acquiring drainage easements, flood rights, etc.

***Appendix C*** contains minimum and maximum cover heights for design.

***Appendix D*** contains policy on the selection of pipes in proximity to structural walls.

***Appendix E*** contains the FDOT Rainfall Distributions.

## 1.8 DISTRIBUTION

This ***Manual*** is available for downloading from the website link: ~~Manuals and Handbooks (fdot.gov)~~ FDOT Drainage Criteria and Guidance (fdot.gov).

## 1.9 PROCEDURE FOR REVISIONS AND UPDATES

FDOT invites comments and suggestions for changes to the ***Manual.*** ~~Submit~~ To provide comments and suggestions for consideration by the State Drainage Engineer ~~by e-mailing the State Drainage Engineer~~submit a ***Revision Request Intake Form*** found on FDOT's Drainage Design website (fdot.gov). Appropriate Roadway Design or Drainage Design staff will review each idea or suggestion received in a timely manner.

Statewide meetings of the District Drainage Engineers and the State Drainage Engineer are held at least annually, and teleconferences are held monthly. A major agenda item at these meetings will be the review of planned revisions, and suggestions and comments that may warrant revisions. Based on input from these meetings, FDOT compiles official proposed revisions.

The State Drainage Engineer will coordinate the proposed revisions with all the affected offices and with FHWA. The State Drainage Engineer officially adopts the proposed revisions, with input from the District Drainage Engineers.

Prior to release, the Forms and Procedures Office coordinates all revisions to ensure conformance with and incorporation into the Department's ***Standard Operating System***.

## 1.10 TRAINING

There is no mandatory training required.

## 1.11 FORMS ACCESS

~~There are no forms related to this ***Manual***.~~Forms associated with this ***Manual*** are located at FDOT's Drainage Manual Forms webpage.

# CHAPTER 2

# OPEN CHANNEL

# LIST OF TABLES



# LIST OF FIGURES

## 2.1 INTRODUCTION

This chapter presents standards for the design of artificial or manmade open channels, including roadside ditches, median ditches, interceptor ditches, outfall ditches, and canals.

## 2.2 DESIGN FREQUENCY

Design open channels to collect and convey without damage, and to confine within the ditch, stormwater flow with standard design frequencies as follows:

**Table 2.1: Design Storm Frequencies for Open Channels**

| TYPE CHANNEL | FREQUENCY |
|---|---|
| Roadside, Median, and Interceptor Ditches or Swales | 10-year |
| Outfalls | 25-year |
| Canals | 25-year |
| Temporary Roadside and Median Ditches or Swales | 2-year |
| Temporary Outfalls and Canals | 5-year |

Site-specific factors may warrant the use of an atypical design frequency. Acquire flood rights where offsite stages increase and impact land use values.

Design sidewalks adjacent to channels (ditches) to be above the design stage.

## 2.3 HYDROLOGIC ANALYSIS

As appropriate for the site, base hydrologic data used for the design of open channels on one of the following methods:

1. A frequency analysis of observed (gage) data, when available. If insufficient or no observed data are available, use one of the procedures below, as appropriate. However, calibrate the procedures below to the extent practicable with available observed data for the drainage basin, or nearby similar drainage basins.
    a. Regional or Local Regression Equations developed by the USGS
    b. Rational Equation for drainage areas up to 600 acres
    c. For outfalls from stormwater management facilities, use the method for the design of the stormwater management facility; see ***Chapter 5*** for hydrologic methods to design stormwater management facilities
2. For regulated or controlled canals, request hydrologic data from the controlling entity; prior to use for design, verify these data to the greatest extent practical

## 2.4 HYDRAULIC ANALYSIS

Use Manning's Equation for the design of open channels. Provide ditch computations for all changes in ditch slope, cross section, lining type, or quantity of flow. The flow shown as contributing to the point of interest include all contributions upstream of that point of interest.

### 2.4.1 Manning's "n" Values

Manning's n values for channels with bare soil and vegetative linings are presented in ***Table 2.2***. Manning's n values for rigid linings are presented in ***Table 2.3***.

In selecting a Manning's n value, consider the probable condition of the channel during the design event may occur. To account for increased vegetation growth between extended maintenance periods, use higher “n” values for ditches with bottoms at or near the seasonal high groundwater level.

### 2.4.2 Slope

Provide a minimum physical slope of 0.0005 feet/feet for all conveyance ditches.

### 2.4.3 Channel Linings and Velocity

***Standard Plans, Index 524-001*** and ***Standard Specification 985*** provide standard lining types. ***Tables 2.4*** and ***2.5*** present maximum velocities for the various forms of soils and channel linings. When design flow velocities do not exceed the maximum permissible for bare earth as given in ***Table 2.4***, standard treatment of ditches consists of grassing and mulching. For higher design velocities, provide sodding, ditch paving, or other forms of lining consistent with ***Tables 2.4*** and ***2.5***.

Check shear stress at locations of steep slopes (>1 percent), such as ditch flow down a pond slope, gore drainage, and offsite flow entering the right-of-way via the back slope of a roadside swale.

The ***Drainage Design Guide (DDG)*** provides additional guidance on types of lining materials, as well as the proper application of various types of linings.

## 2.4.3.1 Limitations on Use of Linings

### 2.4.3.1.1 Grassing and Sodding

Do not use grassing or sodding under the following conditions:

1. Continuous standing or flowing water
2. Areas that do not receive the regular maintenance necessary to prevent domination by taller vegetation
3. Non cohesive sandy soils with excessive soil drainage
4. Excessively shady areas

### 2.4.3.1.2 Concrete Lining

To prevent cracking or failure, place concrete lining on a firm, well-drained foundation. Avoid concrete linings where expansive clays are present.

When using concrete linings where soils may become saturated, design for the potential for buoyancy. Acceptable countermeasures include:

1. Increasing the thickness of the lining to add additional weight
2. For sub-critical flow conditions, specifying weep holes at appropriate intervals in the channel bottom to relieve the upward pressure on the channel
3. For super-critical flow conditions, using subdrains in lieu of weep holes

### 2.4.3.1.3 Turf Reinforcement Mat (TRM)

Do not use turf reinforcement mats where you expect high siltation. During desilting operations, damage can occur to the TRM.

## 2.4.4 Channel Bottom

The minimum channel bottom width is five feet to accommodate mitered end sections and maintenance mowers. Do not use V-bottom ditches unless both front and back slopes are 1:6 or flatter.

The minimum ditch bottom elevation is one foot above the estimated seasonal high groundwater elevation for maintainability. To enable mowing, fine-grained soils may require more than one foot of clearance from the seasonal high groundwater.

### 2.4.5 Channel Freeboard

Provide a minimum of one foot of channel freeboard above the design stage within the channel if in a fill slope and 0.5 foot if the channel is in a cut slope. Freeboard is measured to the ditch top of bank or low edge of shoulder, whichever is lower. If a channel connects hydraulically to or is part of the stormwater management facility, provide no less than one foot of channel freeboard above the peak design stage of the downstream, hydraulically connected pond. Apply downstream tailwater in freeboard calculations.

- Install inlets, flumes, or embankment protection when pavement runoff is sufficient to cause erosion of the shoulder. (See **Section 3.7** for inlet placement criteria)
- Install inlets to properly collect stormwater runoff for curbed roadway driveways.

## 2.5 CONSTRUCTION AND MAINTENANCE CONSIDERATIONS

Design open channels consistent with the standard construction and maintenance practices of the Department. The ***Standard Plans*** and ***Standard Specifications*** present details on standard ditch linings. In the event the ***Standard Plans*** and ***Standard Specifications*** are not suitable for a specific project need, develop a detailed design. Specify this information in the design documents.

Provide berms and other physical access devices that facilitate maintenance activities in ditches, outfall ditches, retention/detention areas, and other drainage-related features. Consider future expansion of the facilities and possible increased maintenance requirements. Use absolute minimum values only in extremely stable areas, in areas requiring infrequent maintenance, or in areas where existing physical constraints require their use. Base berms at the narrowest point; keep right-of-way reasonably uniform. If the design specifies double ditches, the minimum berm width between the two ditches for maintenance access is 10 feet if the ditches are dry or 15 feet if the ditches are wet. Contact the local maintenance office for minimum access requirements when the minimum berm width is not feasible.

## 2.6 SAFETY

### 2.6.1 Protective Treatment

Review drainage designs to determine requirements regarding some form of protective treatment to prevent entry to facilities that present a hazard to children and, to a lesser extent, all persons. ***Section 3.7*** provides general criteria. Provide protective treatment for open channels in the form of fencing when a potential hazard exists.

### 2.6.2 Roadside Safety

The design and location of open channels will comply with roadside safety and clear zone requirements. See the ***FDM*** for clear zone requirements, including special clearance criteria for canals.

## 2.7 DOCUMENTATION

Design documentation for open channels will include hydrologic and hydraulic analyses, calculated freeboard and channel lining requirements. For roadside ditches, ***Figure 2-1*** provides the required standard format for documentation.

**Table 2.2: Manning's "n" Values for Artificial Channels with Bare Soil and Vegetative Linings**

| Channel Lining | Description | Design "n" |
|---|---|---|
| Bare Earth, Fairly Uniform | Clean, recently completed | 0.02 |
| Bare Earth, Fairly Uniform | Short grass and some weeds | 0.03 |
| Dragline Excavated | No Vegetation | 0.03 |
| Dragline Excavated | Light Brush | 0.04 |
| Maintained Grass or Sodded Ditches | Good stand, well maintained 2 to 6 inches | 0.06* |
| Channels not Maintained | Clear bottom, brush sides | 0.08 |
| Channels not Maintained | Dense weeds to flow depth | 0.10 |
| Maintained Grass or Sodded Ditches | Fair stand, length 12 to 24 inches | 0.20* |

* Decrease 30 percent for flows > 0.7 ft depth (max flow depth 1.5 ft)

**Table 2.3: Manning's "n" Values for Artificial Channels with Rigid Linings**

| Channel Lining | Description | Design "n" |
|---|---|---|
| Concrete Paved | Broomed* | 0.016 |
| Concrete Paved | “Roughened” - Standard | 0.020 |
| Concrete Paved | Gunite | 0.020 |
| Concrete Paved | Over Rubble | 0.023 |
| Rubble Riprap | Ditch Lining | 0.035 |

* Broomed is not the standard finish and must be specified when used (see ***Standard Specification 524-7***)

**Table 2.4: Maximum Shear Stress Values and Allowable Velocities for Different Soils**

| Soil Type | Shear Stress (psf$^+$) | *Allowable Velocity (fps$^\#$) |
|---|---|---|
| Silt or Fine Sand | 0.027 | 1.50 |
| Sandy Loam | 0.037 | 1.75 |
| Silt Loam | 0.048 | 2.00 |
| Firm Loam | 0.075 | 2.50 |
| Stiff Clay | 0.260 | 3.75 |
| Hardpans | 0.670 | 6.00 |

* For a flow depth of approximately 3 ft
$^+$ psf is pounds per square foot
$^\#$ fps is feet per second

Reference: University of Florida (1972)

**Table 2.5: Maximum Velocities for Various Lining Types**

| Lining Type | Maximum Velocity (fps) |
|---|---|
| Grass with Mulch | Bare Soil (***Table 2.4***) |
| Sod | 4*** |
| Lapped Sod | 5.5 |
| Erosion Control Blanket | 6.5 |
| (Biodegradable, ***Standard Specification 104-6***) | |
| Plastic Erosion Mat | |
| (Permanent, ***Standard Specification 571 and 985***) | |
| – Type 1 | 10 |
| – Type 2 | 14 |
| – Type 3 | 18 |
| Riprap (Rubble) (Ditch Lining) | 6 |
| Other flexible | ***FHWA HEC-15*** |
| Geogrid | 4 – 8* |
| Rigid | 10** |

* Varies with grid

** Higher velocities acceptable with provisions for energy dissipation

*** If long term turf density is expected to be poor, use 3 fps maximum velocity

FLORIDA DEPARTMENT OF TRANSPORTATION

HYDRAULIC WORKSHEET FOR ROADSIDE DITCHES

Sheet ______ of ______

Road: ________________________________ Prepared by: ____________ Date: ____________

Project Number: ________________________ Checked by: ____________ Date: ____________

| STATION TO STATION | SIDE | % Slope | Drain Area (acres) | "C" | $t_c$ (minutes) | $i_{10}$ (iph) | Q (cfs) | Ditch Section | | | "n" | "d" (ft) | "$d_{allowed}$" (ft) | Calculated Freeboard (ft) | Velocity (fps) | Ditch Lining | Side Drain Pipe Dia. (inches) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F.S. (1:_) | B.W. (ft) | B.S. (1:_) | | | | | | | | |
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Note: F.S. = Front Slope B.W. = Bottom Width B.S. = Back Slope

**Figure 2.1: Hydraulic Worksheet for Roadside Ditches**

# CHAPTER 3

# STORM DRAIN HYDROLOGY AND HYDRAULICS

# LIST OF TABLES



# LIST OF FIGURES

## 3.1 INTRODUCTION

This chapter presents minimum standards for the design of FDOT storm drain systems.

## 3.2 PIPE MATERIALS

Pipe material selection must follow ***Chapter 6*** of this ***Manual***.

## 3.3 DESIGN FREQUENCY

***Table 3.1*** presents standard design storm frequencies for the design of storm drain systems.

***Table 3.1: Design Storm Frequencies for Storm Drain Systems***

| TYPE STORM DRAIN | FREQUENCY |
|---|---|
| • General design | 5-year |
| • General design that involves replacement of a roadside conveyance with a pipe system<br>• General design on work to Interstate Facilities | 10-year |
| • Outfalls | 25-year |
| • Interstate Facilities for which roadway runoff would have no outlet other than a storm drain system, such as in a sag inlet or cut section<br>• Outlets of systems requiring pumping stations | 50-year |

Acquire flood rights where offsite stages increase and impact land use values.

~~For a m~~Mixed systems~~, (a system which~~ ~~has~~ are comprised of both closed conveyance systems (***Chapter 3***) with ~~curb inlets~~roadside inlets ~~(***Chapter 3***)~~ and inlets that collect runoff from open ditch systems (***Chapter 2***).~~ditch bottom inlets (DBIs)), check the hydraulic grade line (HGL) for the DBIs for a 10-year design frequency. All structures in these mixed systems must meet the 5-year design frequency.~~

## 3.4 DESIGN TAILWATER

For the determination of hydraulic gradient and the sizing of storm drain conduits, use a tailwater elevation coincident with the design storm event and that can be reasonably expected to occur. Standard design tailwater conditions for the design of storm drain systems are as follows:

Crown of pipe at the outlet, or if higher:

| | |
|---|---|
| Lakes --------------------- | Normal High Water |
| Rivers and Streams -- | Normal High Water |
| Stormwater Ponds ---- | Peak stage in the pond during the storm drain design event; see ***Chapter 5*** for routing requirements; assume all orifices and v-notches to be clogged for the purposes of establishing the design tailwater for storm drain systems connected to ponds |
| Tidal Waterbody --------- | Mean High Tide + Sea Level Rise (See ***Section 3.4.1***) |
| Ditches, Free Flowing -- | Normal depth flow in the ditch at the storm drain outlet for the storm drain design storm event; may differ from ditch design storm event |
| Downstream Control -- | The higher of: (1) the stage due to free-flow conditions (described above) or, (2) the maximum stage at the storm drain outlet due to backwater from the downstream control using flows from the storm drain design storm event |
| Existing Systems ------ | Elevation of hydraulic grade line of the system at the connection for the design storm event |
| French Drains ---------- | Design head over the outlet control structure |

| | |
|---|---|
| Closed Basin ----------- | Varies, depending on site-specific conditions |
| Regulated Canals ----- | Agency regulated control elevation |

### 3.4.1 Sea Level Rise

The design of coastal projects (including new construction, reconstruction, and projects rebuilding drainage systems) must incorporate sea level rise analysis to assess the vulnerability of flooding over the design life of the facility. Use the relative sea level trend data from historical tidal records gathered by the National Water Level Observation Network (NWLON) and managed by NOAA:

https://tidesandcurrents.noaa.gov/sltrends/sltrends_states.html?gid=1238

NOAA manages tidal gage stations located around the state of Florida. Use the station nearest the site for analysis. Analysis must consist of straight-line extrapolation based on the design service life of the project. Consider existing system criticality/vulnerability and project costs when implementing this best practice analysis.

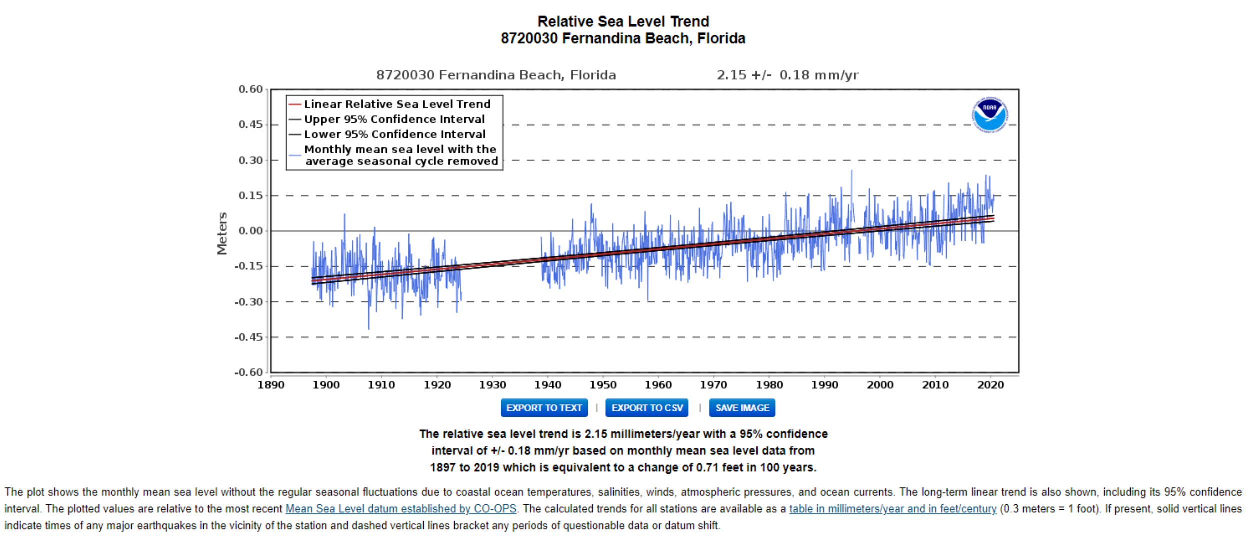



***Figure 3-1: Relative Sea Level Trend Data Example***

## 3.5 HYDROLOGIC ANALYSIS

The Department requires use of the Rational Method for performing hydrologic calculations for storm drains. When storm drain systems are integrated with French drain systems or ditch storage systems, perform calculations using hydrographs to account for storage.

### 3.5.1 Time of Concentration

The minimum allowable time of concentration is 10 minutes.

## 3.6 HYDRAULIC ANALYSIS

Base hydraulic calculations for determining storm drain conduit sizes on open channel and pressure flow, as appropriate, using Manning's equation.

### 3.6.1 Pipe Slopes

Use a physical slope that will produce a velocity of at least 2.5 fps and no greater than 15 fps when the storm drain is flowing full.

For pressure flow storm drain systems, the minimum physical slope is 0.1 percent.

### 3.6.2 Hydraulic Gradient

Include all major losses in computing the design hydraulic gradient for all storm drain systems. Major losses include, but are not limited to:

- pipe friction losses,
- energy losses associated with special pollution control structures (weirs, baffles, separator units, etc.), and
- losses caused by utility conflict structures or backflow preventors.

Include minor losses in hydraulic calculations when the velocity is greater than 7.5 fps. Check total minor losses for systems longer than 2,000 feet to ensure that the minor losses do not exceed the one-foot allowance. If greater than one foot, use calculated minor losses to design the system. Minor losses include entrance, exit, junction and manhole, expansion, contraction, and bend. Refer to ***HEC-22*** for guidance.

***Table 3.2: Hydraulic Grade Line (HGL) Clearance Criteria***[1]

| | | Curb Inlets[2], Gutter Inlets, Barrier Wall Inlets | Ditch Bottom Inlets | Back of Sidewalk Inlets | Manholes |
|---|---|---|---|---|---|
| **With Major Losses Only** | General | 1-ft below Theoretical Gutter Elevation | 1-ft below Grate Elevation | 1-ft below Opening Elevation | 1-ft below Lid Elevation |
| **With Major and Minor Losses Computed** | General | At Theoretical Gutter Elevation | At Grate Elevation | At Opening Elevation | At Lid Elevation |
| | Ditch systems where surcharge[4] is allowable | Not Applicable | HGL Surcharge[4] + ditch normal depth meets freeboard requirements of ***Section 2.4.5*** | | Not Applicable[3] |

*[1] HGL of the mixed system's inlets are evaluated with the design storm events for the storm sewer collection system (**Table 3.1**) and the associated open conveyance system (**Table 2.1**). Verify that the HGL of the closed system roadside components (i.e. curb inlets, gutter inlets, barrier wall inlets) is at or below the Theoretical Gutter Elevation.*
*[2] Theoretical Gutter elevation is 0.13-ft below the Edge of Pavement (EOP) for Type E and Type F Curbs.*
*[3] If hydraulic calculations show that intermediate manholes are under pressure (i.e. HGL is above the lid elevation), specify that the manhole lids are bolted down. If temporary ponding is acceptable on a manhole lid location, consider using an inlet in lieu of a manhole or locating the structure along the berm.*
*[4] Surcharge is the height of the HGL above grate or opening elevation.*

~~For closed systems comprised of inlets along a roadway shoulder (e.g. curb, gutter, barrier wall inlets), when hydraulic calculations include only the major losses and do not include all minor energy losses, provide a minimum of 1 foot of clearance between the elevations of the hydraulic gradient for design storm conditions and the theoretical gutter elevation (i.e., 1.13 feet below the edge of pavement elevation for Type E or F Curb). If design includes all major and minor energy losses, it is acceptable for the hydraulic gradient to reach the theoretical gutter elevation.~~

~~For mixed systems, the 1-foot of clearance may not apply to the ditch bottom inlets where temporary ponding or overload is acceptable, if the following conditions apply:~~

- ~~these systems are evaluated using the design frequency for the corresponding ditch system it's collecting to determine the hydraulic gradient at these inlets,~~
    - ~~when only major losses are included, the HGL is at or below the grate elevation for inlets in the roadside ditch systems to maintain free flowing conditions for ditch freeboard requirements as determined by **Section 2.4.5**, and~~
    - ~~when major and all minor losses are included throughout the network, the hydraulic gradient may exceed the grate elevation only when the inlet's hydraulic gradient surcharge (HGL depth above the grate) plus the normal depth of the ditch maintains freeboard requirements as determined by **Section 2.4.5**,~~

~~any ditch bottom systems discharging to a stormwater management facility shall have grate elevations above the treatment elevation to maintain ditch free flow conditions and minimize standing water along the roadside.~~

~~If hydraulic calculations show that intermediate manholes are under pressure, specify that the manhole lids are bolted down.~~

### 3.6.3 Outlet Velocity

When the outlet velocity for the design storm discharge exceeds 4 fps, evaluate the need for special channel lining (revetment or armoring) and/or energy dissipation to protect against undesirable scour. To compute the outlet velocity, assume the lowest anticipated tailwater condition that can reasonably be expected to occur during a storm event.

In areas where turf sustainability may be an issue, coordinate with maintenance to determine appropriate channel lining material.

### 3.6.4 Manning's Roughness Coefficients

Values for Manning's roughness coefficient are as follows:

| | |
|---|---|
| Concrete Box Culverts | n = 0.012 |
| Concrete Pipes | n = 0.012 |

Metal Pipes:

Pipe and Pipe Arch—Helical Fabrication

Re-corrugated Ends—All Flow Conditions*

| | |
|---|---|
| 12” to 24” | n = 0.020 |
| 30” to 54” | n = 0.022 |
| 60” and larger | n = 0.024 |

Pipe and Pipe Arch—Spiral Rib Fabrication

Re-corrugated Ends—All Flow Conditions*

| | |
|---|---|
| All Sizes | n = 0.012 |

Plastic Pipes:

Polyvinyl Chloride-PVC (external rib/smooth interior)

| | |
|---|---|
| All Sizes | n = 0.012 |

Polyethylene (All Sizes)

| | |
|---|---|
| Single Wall | n = 0.024 |
| Double Wall (Smooth) | n = 0.012 |

Polypropylene (All Sizes)

| | |
|---|---|
| Single Wall | n = 0.024 |
| Double & Triple Wall (Smooth) | n = 0.012 |

* "Spiral" flow will not occur for most design situations. Therefore, the Department has not established "spiral" flow design values. Values for spiral flow, as recommended by the Southeast Corrugated Steel Pipe Association, are contained in the ***AISI Handbook of Steel Drainage & Highway Construction Products***.

## 3.7 HYDRAULIC OPENINGS AND PROTECTIVE TREATMENT

Select/design inlets and other hydraulic structures to satisfy hydraulic capacity, structural capacity, safety (vehicular, pedestrian, cyclist), and durability requirements.

Use alternate “G” (hot dipped galvanized) grates and frames when the structure is located on any barrier island, the Florida Keys, or within a half-mile of any brackish waterbody containing chlorides > 2,000 ppm.

Review drainage designs to determine if some form of protective treatment is necessary to prevent entry into long or submerged storm drain systems, steep ditches, or water control facilities. Also evaluate protection in systems that are partially submerged at the entrance and fully submerged at locations farther along in the system. If other modifications, such as landscaping or providing flat slopes, can eliminate the potential hazard and thus the need for protective treatment, evaluate them first. Because vehicular and pedestrian safety are achieved by differing protective treatments, this often requires the designer to make a compromise in which one type of protection is more completely realized than the other. In such cases, evaluate the relative risks and dangers involved to provide the design that gives the best balance. Remember that the function of the drainage feature will be essentially in conflict with total safety, and that only a reduction rather than elimination of all risk is possible.

The three basic types of protective treatment used by the Department are:

| Feature | Typical Use |
| --- | --- |
| Grates | To prevent persons from being swept into long or submerged drainage systems. |
| Guards | To prevent entry into long sewer systems under no-storm conditions, to prevent persons from being trapped. |
| Fences | To prevent entry into areas of unexpected deep standing water or high-velocity water flow, or into areas where grates or guards are warranted but are unsuitable for other reasons. |

Review the following when determining the type and extent of protective treatment:

- Establish the nature and frequency of the presence of children in the area, e.g., the proximity to schools, school routes, and parks.

- Consider drainage facilities located outside a limited access area or adjacent to a limited access highway to be unlimited access facilities; a limited-access highway typically does not warrant protective treatment.

- Require adequate debris and access control on all inlet points if guards or grates are used at outlet ends.

- Check the hydraulic function of the drainage facility and adjust it so the protective treatment will not cause a reduction in function.

- Design grates for major structures in a manner that allows items to be carried up by increasing flood stages to avoid debris or persons being trapped against the hydraulic opening.

- Use of a guard may result in a person being pinned against it. A guard is usually used on outlet ends.

- Locate and build fences to reflect the effect of debris-induced force; a fence may capture excessive amounts of debris, which could possibly result in its destruction and subsequent obstruction of the culvert.

- Design protective treatments to prevent entry of certain wildlife, such as manatees.

## 3.7.1 Entrance Location and Spacing

### 3.7.1.1 Inlets

The following items determine inlet type, location, and spacing:

1. Inlet capacity and width of spread
2. Movement of vehicles to and from adjacent property on driveways
3. Pedestrian and bicycle safety
4. Maximum pipe length without maintenance access (***Section 3.10.1***)
5. Roadway geometry (e.g., super-elevation transitions, roadway profile, etc.)
6. Hydraulic efficiency of the system
7. Potential for flooding of off-site property

8. Potential for ponding at turn lanes, bus bays and driveways

9. Maintenance accessibility

10. Potential for concentrated flow to cause erosion when it leaves the pavement (including driveways)

Utilize curb inlet types 1-4 to the maximum extent practicable to accommodate maintenance. Curb inlet types 5-10 should only be used when types 1-4 cannot be accommodated. Inlet types 5, 6, 9 and 10 are not permitted in concrete pavement sections.

Locate inlets at all low points in the gutter grade and/or ditch, and as appropriate at intersections, median breaks, driveways and on side streets where drainage would adversely flow onto the highway pavement. Base inlet spacing on spread standards and maximum allowable pipe lengths provided below in ***Section 3.9 and Section 3.10***. Position inlets 10 feet prior to the level section in super-elevation transitions to avoid concentrated flows across the pavement.

Do not locate curb inlets, including inlet transitions, within handicap drop curb locations or on curb returns.

Do not place inlets in bridge approach slabs.

When an inlet is located behind a guardrail post, offset the inlet structure a minimum of 15 inches from the post. For the additional option of mounting special guardrail posts on top of inlet structures, see ***Standard Plans, Index 536-001***.

Inlets in sag vertical curves that have no overflow outlet other than the storm drain system (i.e., barrier wall, bridge abutment, cut sections) must have flanking inlets on one or both sides. Locate the flanking inlets to satisfy spread criteria when the sag inlet is blocked.

Consider the following items pertaining to parking lot drainage:

1. Do not use curb inlets in areas of heavy pedestrian traffic; specifically, service plaza parking lots. Alternately, use ditch bottom inlets with pedestrian-rated grates.

2. Consider positioning ditch bottom inlets in the center of the travel lanes and not in hidden locations, such as parking spaces.

3. Grade parking lots away from the heaviest pedestrian areas to remote locations for better safety. Alternately, use cuts in the curb to allow pavement to drain into grassed swales prior to entering ditch bottom

inlets.

### 3.7.2 Manholes

Place manholes outside of the wheel path of vehicles. Manholes are not allowed in the travel lanes of interstate facilities.

### 3.7.3 Shoulder Gutter Inlets

Do not place shoulder gutter inlets within the alignment curb or curb transition to shoulder gutter, see ***Standard Plans, Index 536-001***.

### 3.7.4 Inlet Placement

***Table 3.3: Curb and Gutter Inlet Application Guidelines***

| STANDARD PLANS INDEX | INLET TYPE | TYPE CURB/ GUTTER | GRADE CONSIDERATION | BICYCLE COMPATIBLE | ACCEPTABLE IN AREAS OF OCCASIONAL PEDESTRIAN TRAFFIC [6] | Notes |
|---|---|---|---|---|---|---|
| 425-020 | 1 | E & F | Continuous | Yes | Yes | |
| | 2 [1] | E & F | Sag | Yes | Yes | |
| | 3 | E & F | Continuous | Yes | Yes | |
| | 4 [1] | E & F | Sag | Yes | Yes | |
| 425-021 | 5 | E & F | Continuous | Yes | Yes | |
| | 6 [1] | E & F | Sag | Yes | Yes | |
| 425-022 | 7 | Separator I & II | Continuous or Sag | Yes | Yes | |
| 425-023 | 8 | Separator IV & V | Continuous or Sag | Yes | Yes | |
| 425-024 | 9 [2] | D & F | Continuous or Sag | Yes | Yes | |
| 425-025 | 10 [2] | D & F | Continuous or Sag | Yes | Yes | |
| 425-030 | 1 | Median Barrier Wall | Continuous or Sag | No | Yes [4] | |
| | 2 [3] | Median Barrier Wall | Continuous or Sag | No | Yes [4] | |
| 425-031 | - | Barrier Wall | Continuous or Sag | No [5] | Yes | See Index 425-031 Detail “A” |
| 425-032 | - | Barrier Wall (Rigid, C & G) | Continuous or Sag | No [5] | Yes | See Index 425-032 Grate Details |
| 425-040 | S [7] | Shoulder | Continuous | No [5] | Yes | See Index 425-040 Bar Stub Detail “C” |
| 425-041 | V | Valley | Continuous or Sag | No [5] | Yes | |

[1] Double-throated inlets usually are not warranted unless the minor gutter flow exceeds 50 ft in length or 0.5 cfs.
[2] Use curb inlets 9 and 10 <u>only</u> where flows are light <u>and</u> right-of-way does not permit the use of throated curb inlets.
[3] These are double inlets; one on each side of the barrier wall.
[4] Specify the reticuline grate.
[5] Bicycle compatible as long as a minimum 4-foot riding surface is provided around the inlet, with a preferred 1-foot offset from the inlet. Consider use of pavement markings shown in the 2009 MUTCD to alert cyclists to the inlet in the bicycle lane or shoulder pavement.
[6] Do not place these inlets in pedestrian ways, but may be used in areas subject to occasional pedestrian traffic near pavement, grassed, or landscaped areas where pedestrians are not directed over the inlet and can walk around the inlet.
[7] Intended for use in shoulder gutter on facilities subject to heavy wheel loads.

### *Table 3.4 : Ditch Inlet Application Guidelines*

| STANDARD PLANS INDEX | INLET TYPE [1], [2] | TRAFFIC | BICYCLE COMPATIBLE | ACCEPTABLE IN AREAS OF OCCASIONAL PEDESTRIAN TRAFFIC [5] |
|---|---|---|---|---|
| 425-050 | A | Heavy Wheel Loads | No | No |
| 425-051 | B | Heavy Wheel Loads | No | Yes |
| 425-052 | C [3] | Infrequent Traffic | Yes [6] | Yes [4] |
| | D | Infrequent Traffic | Yes [6] | Yes [4] |
| | E | Infrequent Traffic | Yes [6] | Yes [4] |
| | H | Infrequent Traffic | Yes | Yes |
| 425-053 | F | Heavy Wheel Loads | Yes | Yes |
| | G | Heavy Wheel Loads | Yes | Yes |
| 425-054 | J | Heavy Wheel Loads | No | Yes |
| 425-055 | K | N/A | N/A | N/A |

[1] Specify alternate G grates when in salt-water environment.
[2] Inlets with slots are more debris tolerant than inlets without slots. Debris may buildup on Type B fence of Type K inlet.
[3] For back of sidewalk location, see ***Standard Plans, Index 425-060***.
[4] Slotted inlets located in areas accessible to pedestrians must have traversable slots.
[5] Do not place these inlets in pedestrian ways but may be used in areas subject to occasional pedestrian traffic near pavement, grassed, or landscaped areas where pedestrians are not directed over the inlet and can walk around the inlet.
[6] Do not use inlets with traversable slots in areas subject to bicycle traffic.

### *Table 3.5: Drainage End Treatment - Lateral Offset Criteria*

| INDEX | STRUCTURE DESCRIPTION | LATERAL OFFSET CRITERIA [1] |
|---|---|---|
| 400-289 to 400-292 | Concrete Box Culvert - End Treatments | Outside Clear Zone |
| 425-020 to 425-041 | Curb, Barrier & Gutter Inlets | Permitted within Clear Zone |
| 425-050 to 425-051 | Ditch Bottom Inlets – (Types A [2] and B) [3] | |
| 425-052 | Ditch Bottom Inlets – (Types C, D, E and H) [3] [4] | Permitted within Clear Zone |
| | Ditch Bottom Inlet - Type H w/Slot | Outside Clear Zone |
| 425-053 & 425-054 | Ditch Bottom Inlets – (Types F, G and J) [3] | Permitted within Clear Zone |
| 425-055 | Ditch Bottom Inlet - Type K | Outside Clear Zone |
| 425-060 | Back of Sidewalk Drain | Permitted within Clear Zone for Urban Curb & Gutter Sections Only with Design Speed ≤ 45 mph |
| 430-010 | U-Type Concrete Endwalls With Grates - 15" to 30" Pipe | Permitted within Clear Zone for Low Design Velocities & Negligible Debris |
| 430-011 | U-Type Concrete Endwalls Baffles and Grate Optional - 15" to 30" Pipe | Permitted within Clear Zone w/Grate |
| 430-012 | U-Type Concrete Endwalls Energy Dissipator - 30" to 72" Pipe | Outside Clear Zone See Index for "Location Reference" |
| 430-020 | Flared End Section | ≤ 15" Diameter Inside Clear Zone > 15" Diameter Outside Clear Zone |
| 430-021 | Cross Drain Mitered End Section[6] | ≤ 24" Diameter Inside Clear Zone [5] > 24" Diameter Outside Clear Zone |
| 430-022 | Side Drain Mitered End Section | Permitted within Clear Zone |
| 430-030 to 430-034 | Straight Concrete Endwalls | Outside Clear Zone See Indexes for "Location Reference" |
| 430-040 | Winged Concrete Endwalls - Single Round Pipe | |
| 430-090 | Safety Modifications for Endwalls | Permitted within Clear Zone w/Grate |

[1] Lateral offset criteria for vehicular traffic only. Additional considerations may be needed for pedestrian or bicycle traffic. See Indexes for additional information.
[2] Designed for use on limited-access facilities where debris may be a problem.
[3] When slots are required due to debris considerations, the inlet must contain a traversable slot design to be located within a clear zone. See Indexes for traversable slot designs.
[4] Designs intended for areas of infrequent traffic loading.
[5] Equivalent size pipe arch or elliptical pipes are permitted within clear zone. Recommended MES slope is 1:4, otherwise steeper slopes require DDrE approval.
[6] Include slope and ditch transitions when the roadway slope must be flattened to place end section outside clear zone. See ***Standard Plans, Index 430-021*** for detail.

# 3.8 GRADES

## 3.8.1 Longitudinal Gutter Grade

The minimum longitudinal gutter grade is 0.3 percent.

# 3.9 PAVEMENT HYDRAULICS

## 3.9.1 Spread Criteria

The spread criteria listed is for permanent design and temporary construction conditions. Limit the spread resulting from a rainfall intensity of 4.0 inches per hour as follows.

***Table 3.6: Spread Criteria***

| Typical Section Condition | Design Speed*[1] (mph) | Spread Criteria**[2] |
|---|---|---|
| Parking Lane or Full Width Shoulders[3] | All | No encroachment into the lane |
| Left Turn Lanes | Design Speed > 45 | Keep 8' of lane clear |
| Right Turn Lanes | All | Keep ½ of lane clear |
| All Other | Design speed ≤ 45 | Keep ½ of lane clear |
| | 45 < Design Speed ≤ 55 | Keep 8' of lane clear |
| | Design Speed > 55 | No encroachment into the lane |
| Limited Access (Including Ramps) | All | No encroachment into the lane. |

* [1] Use the work zone speed shown in the Temporary Traffic Control Plans for temporary conditions. For more information on work zone speed, see FDM 240.
** [2] The criteria in this column apply to travel, turn, or auxiliary lanes adjacent to barrier wall or curb, in normal or super-elevated sections.
[3] Full Shoulder Width as defined by FDM 210.4 and FDM 211.4

In addition to the above standards, for sections with a shoulder gutter, the spread resulting from a 10-year frequency storm will not exceed one foot, three inches outside the gutter in the direction toward the front slope. This distance limits the spread width to 6 ft, to provide clearance to the face of guardrail posts. See ***Standard Plans, Index 536-001***.

For traffic diversions and construction phases, review temporary drainage patterns to assess drainage where construction activities may divert or trap water, potentially compromising the safety and efficiency of the travel lanes. Give additional attention to expected spread for areas that are: (1) flood sensitive, (2) high-speed facilities (Design Speed ≥ 55 mph), or (3) using barrier wall along the low side of the roadway. Bridge deck spread must be evaluated for all bridges including MOT phases.

The Bridge Development Report (BDR) must include preliminary spread calculations for the bridge deck in order to determine whether additional drainage conveyance is required. Typical drainage conveyance costs may include, but are not limited to, additional shoulder width during construction, bridge deck drains, and conveyance systems. Costs for the bridge deck drainage must be considered when comparing alternative bridge designs.

### 3.9.2 Trench Drain

Consider trench drains only when traditional inlets are not feasible. Do not place the trench drains in pedestrian paths unless ADA compliant grates are used. If placed adjacent to reinforced concrete barrier, provide the detail in plans showing the position of the drain relative to the barrier to avoid conflicts with the foundation.

Identify in the plans the type, the design flow of the drain, begin and end locations of the drain and the location of the outlet pipe (if the drain is not stubbed directly into a drainage structure).

Slope outlet pipes and preformed channel inverts at 0.6% or steeper toward the outlet regardless of the surface slope.

| **Modification for Non-Conventional Projects:** |
| --- |
| Trench drains are not allowed for the final constructed condition unless approved by the District Drainage Engineer. Trench drains are only allowed for temporary drainage. |

### 3.9.3 Evaluation of Hydroplaning Potential

The ***FDM***, ***Section 210.2.4.2 and 211.2.3, Hydroplaning Risk Analysis***, addresses policy for the analysis of hydroplaning potential when required for typical section approval.

Capture accumulated runoff from driveways, side streets and ramps to limit runoff into the mainline travel lanes or other areas where the additional sheet flow could contribute to potential hydroplaning. Design the inlet to capture 100 percent of the flow.

~~Use the hydroplaning web-based tool and the Design Guidance: Hydroplaning Risk Analysis to perform risk analysis to evaluate hydroplaning potential of typical section options. The hydroplaning tool is available online at:~~

~~https://www.fdot.gov/roadway/drainage/hydroplaning.~~

## 3.10 CONSTRUCTION AND MAINTENANCE CONSIDERATIONS

Design storm drain systems consistent with the standard construction and maintenance practices of the Department. The ***Standard Plans*** provide standard details for inlets, manholes, junction boxes, end treatments, and other miscellaneous drainage details. Specifications are provided in the ***Standard Specifications.*** In the event the ***Standard Plans*** are not suitable for a specific project need, develop a detailed design and include it in the plans; and, as appropriate, provide special provisions for inclusion with the project specifications. Consider maintenance concerns of adequate physical access for cleaning and repair in the design.

Except for gutter drain bends, provide topside access at all pipe junctions and bends. The use of junction boxes without topside access will require District Drainage Engineer approval. Consider the use of a new inlet in place of a junction box or manhole to capture roadway runoff.

Drainage structures with internal weirs must have manhole access on each side of the weir. For areas of expected frequent entry, ask FDOT Maintenance if a two-piece, three-foot diameter manhole cover is needed for maintenance access.

| **Modification for Non-Conventional Projects:** |
|---|
| Delete the last sentence in the paragraph above and see the RFP for additional requirements. |

Provide a four-foot minimum sump in outfall structures and structures with pollutionretardant baffles or skimmers installed inside the structure. When two or more baffles or skimmers are used in the same structure, provide a minimum horizontal distance of 2.5 feet between baffles for maintenance access. For submerged systems where cleanout velocity is not maintained, use a two-foot sump for all affected inlets.

For urban roadways with significant leaf drop potential and a posted speed limit of 40 mph or less, consider using a curb inlet screen to keep debris out of the storm drain system. If a curb inlet screen is used, use a catch basin pipe connection screen in conjunction with it.

All constructed inlets and manholes, excluding closed French drain systems, must not have storm drain pipe(s) exiting a drainage structure with a flow line higher than any storm drain pipe entering the same structure.

## 3.10.1 Pipe Size and Length

The minimum pipe size for trunk lines and laterals is 18 inches. The minimum pipe diameter for all proposed exfiltration trench pipes (French drain) is 24 inches.

The 18-inch minimum pipe size does not apply to connections from external, private stormwater management facilities. The pipe size for these connections is the size required to convey the Chapter 14-86, F.A.C. or other authoritative permitted discharge limitations.

The maximum pipe lengths without maintenance access structures are as follows:

<u>Pipes without French drains:</u>

| | |
|---|---|
| 18” pipe | 300 feet |
| 24” to 36” pipe | 400 feet |
| 42” and larger and all box culverts | 500 feet |

<u>French drains that have access through only one end:</u>

| | |
|---|---|
| 24” to 30” pipe | 150 feet |
| 36” and larger pipe | 200 feet |

French drains that have access through both ends:

| | |
|---|---|
| 24” to 30” pipe | 300 feet |
| 36” and larger pipe | 400 feet |

## 3.10.2 Minimum Pipe Cover and Clearances

1. If a material option is listed in the plans, the minimum cover must adhere to the criteria shown in ***Appendix C***. If this is not possible, District Drainage Engineer approval will be required.

2. Storm drain systems that cross railroad tracks must meet special below-track clearance requirements and must use special strength pipe. Coordinate early with the District Rail Administrator and the railroad company to determine the specific pipe and clearance requirements.

3. Utility Clearances:

   a. When a utility crosses a storm drain alignment, the minimum design clearance between the outside of the pipe and the outside of the conflict is 0.5 foot if the utility has been accurately located at the point of conflict. If the utility has been approximately located, the minimum design clearance is one foot. Utility company recommended clearances can vary from these design values, but electrical transmission lines and gas lines must never come into direct contact with the storm drain.

   b. Locate storm drain lines so they do not disturb existing utilities to the greatest extent practical. If a utility conflict occurs, contact the District Drainage Engineer and the Utilities Section to review potential problems and feasible solutions.

   c. When a sanitary line or other utility, including other storm drains, must pass through a manhole, provide minimum clearances in accordance with ***Standard Plans, Index 125-001***. Account for the head loss caused by an obstruction in the computation of the design hydraulic grade line.

(Note: Gas mains must not pass through inlet and manhole structures.)

d. Utility conflict structures must provide manhole access on both sides of the conflict when the conflicting utility is large (≥12 inches) or the conflict is close to the top of the structure. Maintenance vacuum trucks have a rigid suction pipe that cannot bend around obstructions. If the degree of access is uncertain, contact the local FDOT maintenance office for direction.

e. The distance between the bottom of the utility and the conflict structure bottom must be no less than the internal diameter of the outlet pipe. Use a two-foot or four-foot sump in areas where sedimentation is expected. Use of a sump will require that the system be designed to account for the head loss generated if the sump is completely blocked.

## 3.10.3 Pipe Joint Designs Greater than 5 psi

When the pipe joints are expected to withstand design conditions greater than 5 psi but no more than 10 psi, include a plan note requiring the pipe supplier to test the proposed pipe joint to 10 psi using the methodology described in the ***Standard Specifications***. If a pressure rating greater than 10 psi is required, call for a pressure pipe in the plans, including the needed ASTM(s) to clearly identify the pipe requirements.

## 3.10.4 Existing Pipe Inspection and Siltation

Contact the local maintenance office to obtain historic flooding information, pipe or culvert inspection reports and drainage related pavement structural deficiencies. Field reviews are required to assess the condition for all existing piped storm sewer systems and culverts that are being considered to "Remain in Service." Pipe inspections may include video inspection depending on access and complexity of the system. In most cases, pipe desilting is necessary to properly inspect pipe joints and other locations where pavement structural deficiencies have occurred. Develop and submit a summary report of the inspection findings to the District Drainage and Maintenance offices.

Based on the coordination and field review findings, coordinate with the District Drainage and local maintenance office to determine what actions are needed to maintain the required function of the existing piped and culverted systems. Coordinate and obtain approval from both the District Drainage and local maintenance offices prior to any desilting and/or dewatering activities.

Prior to extending any existing pipe that exhibits signs of corrosion and/or structural cracking, further evaluation is required to determine whether pipe repair or replacement is warranted to extend the service life of the extended system.

## 3.11 PIPES WITHIN OR ADJACENT TO RETAINED EARTH (WALLED) EMBANKMENT SECTIONS

The design requirements of this section pertain to all pipes that are within or adjacent to embankments confined by retaining walls. Avoid placing drainage pipes through retaining walls and similar structures when possible. If pipes must be placed within or adjacent to retaining walls, coordinate the design of the drainage system with the geotechnical and structural engineers.

The drawings in ***Appendix D*** detail three categories of pipes within retained earth (walled) embankments. Pipes proposed for installation within these embankments or existing pipes that will be located within proposed embankments are defined as Wall Zone Pipes. For Wall Zone Pipes, provide verification of wall zones in design calculations. See ***Chapter 6*** for additional requirements.

The Optional Materials Tabulation Sheet must note those pipes that are deemed Wall Zone Pipes. When steel pipes are listed as an option for Wall Zone Pipes also show the minimum pipe wall thickness, meeting the requirements of ***Appendix D*** on the Optional Materials Tabulation Sheet.

Pipes used as vertical drains passing under or through retaining walls must satisfy the structural requirements of the latest edition of the American Association of State Highway and Transportation Officials ***(AASHTO) Load and Resistance Factor Design Bridge Design Specifications, (LRFD – BDS), Chapter 12***.

## 3.12 ADDITIONAL DESIGN CONSIDERATIONS

### 3.12.1 Noise Walls

Evaluate the capacity of drainage openings in noise walls and locate them horizontally and vertically to ensure that offsite stormwater inflows are accommodated without increasing offsite stormwater stages for the appropriate regulatory design events. Document the existing drainage patterns, including taking photographs along the location of the proposed sound barrier. If the capacity and/or location of noise wall drainage openings are insufficient and cannot be amended to handle offsite inflows, design a drainage system to maintain historic flows and to minimize the maintenance required behind the wall, especially for locations with limited right-of-way behind the wall.

## 3.12.2 French Drains

Design exfiltration systems (French drains) using ***Standard Plans, Index 443-001***. Designs must include provisions for overflow resulting from floods exceeding the design storm condition.

Provide French drain details with dimensional changes or otherwise different from the standard cross-sections represented in ***Standard Plans, Index 443-001***. Generally, pipe invert is placed above water table.

Provide baffles, skimmers, and four-foot minimum sumps at inlet points to minimize the entrance of oil and sediments into the French drain system. Use skimmers in French drain catch basins and in other locations where there is a need to prevent oil, debris or other floating contaminants from exiting the catch basins through outlet pipes. Provide detailed geometry for the skimmers per ***Standard Plans, Index 443-002.***

Do not locate exfiltration trenches where there are contaminated soils and in well field protection zones with less than 30 days' travel time to potable water supply wells. French drains are not allowed in embankments/fill conditions (not natural or compacted soil material).

Provide a minimum of 10 feet between French drains and overhead sign foundations, drill shafts, light pole foundations, or retaining walls. If this minimum distance cannot be met, the segment of perforated pipe and trench within the 10 feet of influence of the drill shaft or foundation must be replaced with a solid segment of pipe.

Install stormwater exfiltration systems at least two feet from parallel underground utilities and 20 feet from existing large trees that will remain in place.

Establish the depth and location of the French drain trench based on prudent benefit/cost analysis, considering the following factors:

1. Depth of transmissive strata that satisfy design needs.
2. Safety, feasibility, and expected frequency of required French drain maintenance activities.
3. Loss of functionality of the French drain due to its being under impervious surfaces.
4. Location of trees, utilities, and other features that may compromise the integrity of the trench envelope.

5. The cost of providing other stormwater management infrastructure in lieu of the French drain.

6. Cost of replacing the French drain in the future.

7. Potential geotechnical failures in Karst areas.

## 3.12.3 Resilient Connectors

All storm drain manholes and inlets may utilize resilient connectors, as specified in ***Standard Specifications 430***.

Resilient connectors are required for:

- All structures within walled embankments or connected to wall zone pipe.

- All vertical pipes.

- To accommodate movement of the bridge collection piping.

Do not specify or require resilient connectors for the following conditions:

- The interface angle of connection between the structure and pipe is greater than 15 degrees in either the horizontal or vertical direction.

- The structure and all connections fall outside the 1:2 roadway template control line, as per ***Standard Plans, Index 120-001***.

- The remaining beam height of the single precast unit, from the top of that segment to the existing crown of pipe chosen, is less than eight inches.

- In projects where elliptical pipes are specified on the plans.

## 3.12.4 Flotation

Design structures larger than 10 feet by 10 feet, and greater than 14 feet below the anticipated groundwater table to prevent flotation under design conditions. Recognize that in sandy soils, the groundwater table may increase briefly but significantly during a large rainfall event.

# 3.13 DOCUMENTATION

## 3.13.1 Tabulation Form

***FDOT-Conduit-StormTab*** presents the required format for tabulating the results of hydrologic and hydraulic calculations for storm drain systems. File a copy of the completed table for permanent record as a part of the signed and sealed design documentation. You will find descriptions and examples of the form content in the ***DDG.***

Projects utilizing ***FDM 900 Series*** are required to provide the FDOT-Conduit-StormTab Flex table.

## 3.13.2 Other Documentation

File other supporting calculations and design documentation, including:

1. Existing Pipe Inspection and Siltation Report including correspondence with Maintenance Office regarding operations and maintenance concerns of facility
2. For complex systems, a narrative describing how the storm drain system will function.
3. Hydrologic computations:
   a. Time of concentration
   b. Runoff coefficients
4. Spread and inlet capacity analysis
5. Determination of design tailwater
   a. NOAA sea level rise trend supporting documentation
6. Optional materials evaluation
   a. Wall zone pipe identification
   b. LRFD calculations, if applicable
7. Computation of minor energy losses and design resource for the loss coefficient assigned
8. Completed drainage map with drainage areas to each inlet identified, and structures numbered consistent with drainage computations and tabs

9. Outlet scour protection analysis, if applicable

**FLORIDA DEPARTMENT OF TRANSPORTATION**
**STORM DRAIN TABULATION FORM**

Financial Project Identification: County: Network: Prepared: Date:
Description: Organization: State Road: Checked: Date:

| LOCATION OF UPPER END | | | STRUCTURE NO. | TYPE OF STRUCTURE | LENGTH (ft.) | DRAINAGE AREA (Acres) | | SUB-TOTAL (C*A) | TIME OF CONCENTRATION (min) | TIME OF FLOW IN SECTION (min) | INTENSITY (in/hr) | TOTAL (C*A) | BASE FLOW (cfs) * | TOTAL FLOW (cfs) | MINOR LOSSES (ft.) *** | INLET ELEVATION (ft.) | HGL CLEARANCE (ft.) * | HYDRAULIC GRADIENT | | | NUMBER OF BARRELS * | PIPE SIZE (in.) | SLOPE (%) | VELOCITY | FULL FLOW CAPACITY (cfs) * | NOTES AND REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | C= ** | | | | | | | | | | | | CROWN | | | | | | | | ZONE: |
| | | | | | | C= ** | | | | | | | | | | | | FLOWLINE | | | | RISE | HYD. GRAD. | ACTUAL VELOCITY (fps) | | FREQUENCY (Yrs): |
| ALIGNMENT NAME | | | UPPER | | | C= ** | | | | | | | | | | | | | | | | | PHYSICAL | | | MANNING'S "n": |
| STATION | DISTANCE (ft.) | SIDE | LOWER | | | INCREMENT | TOTAL | | | | | | | | | | | UPPER END ELEVATION (ft.) | LOWER END ELEVATION (ft.) | FALL (ft.) | | SPAN | MIN. PHYS. | PHYSICAL VELOCITY (fps) | | TAILWATER EL (ft): |

* Denotes optional information.
** A composite runoff coefficient may be shown in lieu of individual C-values, provided the composite C calculations are included in the drainage documentation.
*** Required if Minor Losses are included

***Figure 3-2: Storm Drain Tabulation Form (FDM 300 Series Projects)***

STORM DRAIN TABULATION FORM

| Label | -Node- Upstream Downstream | Length (Unified) (ft) | Upstream Inlet Area (acres) | System Drainage Area (acres) | System CA (acres) | System Flow Time (min) | Time (Pipe Flow) (min) | System Intensity (in/h) | System Additional Flow (cfs) | System Rational Flow (cfs) | Upstream Structure Headloss (ft) | Elevation Ground (Start) (ft) | HGL Clearance (ft) | -HGL- Upstream Downstream (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

| -Invert (Conduit)- Upstream Downstream (ft) | Headloss (ft) | Fall Inverts (ft) | Number of Barrels | Size (Display) | Rise (Unified) (ft) | Span (ft) | Manning's n | Friction Slope (%) | Slope (Calculated) (%) | Minimum Slope (%) | Velocity (ft/s) | Physical Velocity (ft/s) | Capacity (Full Flow) (cfs) | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

***Figure 3-3: FDOT Conduit Storm Tab for Projects Utilitizing the FDM 900 Series***

# CHAPTER 4

# CROSS DRAIN HYDRAULICS

## List of Tables

## 4.1 INTRODUCTION

This chapter presents standards and procedures for the hydraulic design of cross drains, including culverts, bridge-culverts[1], and bridges. The ***FDOT Project Development and Environmental Manual*** addresses preliminary planning and location studies for cross drains.

## 4.2 GENERAL

Prepare the hydraulic design of cross drains in accordance with good engineering practice and comply with ***23 CFR 650A*** and the ***National Flood Insurance Program (NFIP)***. Specifically:

1. Design all cross drains to have sufficient hydraulic capacity to convey the selected design frequency flood without damage to the structure and approach embankments, with due consideration to the effects of greater floods.

2. Perform scour calculations with normal safety factors to withstand the design flood condition listed in Section 4.9.2.2 and provide to the structural engineer for foundation design. Ensure that the design has a minimum factor of safety of one against failure due to the scour design check flood condition listed in Section 4.9.2.2.

3. Analyze the design of all cross drain structures for the Design Flood, Base Flood (100-year frequency flood), and the Greatest Flood (overtopping flood or the 500-year frequency flood where overtopping is not practicable) that you expect to flow to the structure. Include a summary of this analysis, showing the peak stages and discharges for these events on the final project plans.

4. For projects that encroach into a Regulatory Floodway, coordinate the design with the appropriate local government flood insurance program official.

5. Designers shall reference the latest edition of the ***AASHTO LRFD Bridge Design Specifications (LRFD – BDS), Section 2.6***.

[1] A culvert qualifies as a bridge if it meets the requirements of ***NBIS Bridge Length (112)*** in the FDOT Bridge Management System (BMS) Coding Guide.

## 4.3 DESIGN FREQUENCY

### 4.3.1 Permanent Facilities

Standard design frequencies for permanent culverts, bridge-culverts, and bridges are as follows:

**Table 4.1: Design Strom Frequencies for Permanent Facilities**

| FACILITY | FREQUENCY |
|---|---|
| Mainline Interstate | 50 years |
| High Use or Essential:<br>Projected 20-year AADT* > 1,500 | 50 years |
| Other:<br>Projected 20-year AADT* < 1,500 | 25 years |
| • Roadside ditch culverts<br>• Pedestrian and trail bridges | 10 years |

* AADT is preferred. If it is not available, use ADT.

Note: The flood frequencies used for scour analysis differ. See ***Section 4.9.2***.

### 4.3.2 Temporary Facilities

The 10-year design storm event is the minimum frequency for evaluation of temporary culverts, bridge-culverts, and bridges. The design storm event will cause no more than a one-foot increase in the flood elevation immediately upstream and no more than one tenth of a foot increase 500 feet upstream. If the existing structure has flooding or scour concerns, coordinate with the District Drainage Engineer for site specific considerations.

# 4.4 BACKWATER

Hydraulically design cross drains to meet the following backwater conditions:

1. Backwater created by the structure will be consistent with Flood Insurance Study requirements adopted by the local community in accordance with the ***NFIP*** and ***Federal Emergency Management Agency*** (***FEMA)*** guidelines in addition to other relevant sources.

2. Acquire flood rights where offsite stages increase and impact land use values.

3. Keep the backwater for design frequency conditions at or below the travel lanes.

# 4.5 TAILWATER

For the sizing of cross drains and the determination of headwater and backwater elevations, use the highest tailwater elevation coincident with the design storm event.

For culverts with tidally influenced tailwaters, adjust the **Mean High Water** elevation for sea level rise using the methodology in ***Section 3.4.1***.

# 4.6 CLEARANCES

Refer to the ***FDM, Section 260*** for the minimum vertical, horizontal, and regulatory clearance requirements for bridges.

# 4.7 HYDROLOGIC ANALYSIS

## 4.7.1 Freshwater Flow

Acquire or generate hydrologic data using one of the following methods, as appropriate for the site:

1. Use a frequency analysis of observed (gage) data when available. If insufficient or no observed data is available, use one of the procedures below as appropriate. To the extent practical, calibrate the procedures below with available observed data for the drainage basin or nearby similar drainage basins.

    a. Regional or local regression equation developed by the USGS

    b. Rational Equation for drainage areas up to 600 acres

2. For regulated or controlled canals, request hydrologic data from the controlling

entity. Prior to use for design, verify these data to the greatest extent practical.

### 4.7.2 Tidal Flow

When analyzing creeks and small rivers flowing into tidal waterbodies, consider hurricane rainfall runoff in conjunction with surge-driven tailwater. In such cases, since hurricane rainfall is largely independent of peak surge stage, use the U.S. Army Corps of Engineers (USACE) tropical storm rainfall runoff procedure from the ***1986 Engineer Manual - Engineering and Design Storm Surge Analysis (EM1110-2-1412),*** Chapter 4, to estimate runoff from any design surge regardless of the surge return frequency being analyzed. For procedure details, refer to the following manual.

https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/roadway/drainage/fchc/hurricanerainfall.pdf?sfvrsn=9eaa99df_0

Alternatively, you may use a steady discharge equal to the peak flow from a 10-year storm in lieu of the above ***USACE procedure***.

## 4.8 HYDRAULIC ANALYSIS

### 4.8.1 Riverine Crossings

#### 4.8.1.1 Bridges

***USGS Finite Element Surface Water Modeling System (FESWMS)***, ***USACE's HEC-RAS, U.S. Bureau of Reclamation (USBR) SRH-2D, StormWise/ICPR Version 4,*** and ***RMA-2*** are acceptable computer programs to analyze the hydraulic performance of bridges over riverine waterways.

Note, FESWMS software program has been archived by USGS.

#### 4.8.1.2 Bridge-Culverts and Culverts

Analyze the hydraulic performance of bridge-culverts and culverts at riverine waterways based on the techniques provided in ***FHWA Hydraulic Design Series (HDS) #5:*** Hydraulic Design of Highway Culverts, 3rd Edition.

### 4.8.2 Tidal Crossings

Use coastal engineering analysis, as typified by the USACE and consistent with current coastal engineering practice, in the analysis of astronomical tides and hurricane storm surges. The computer programs acceptable for hydraulic analyses at tidal crossing are ***HEC-RAS***, ***RMA-2***, ***ADCIRC***, and ***FESWMS***.

#### 4.8.2.1 Ocean Boundary Hydrographs

When ocean coast hurricane hydrographs are used for driving surge models inland, use stage/time hydrographs from the following website:

https://www.fdot.gov/roadway/Drainage/DHSH.shtm

Adjust the hurricane hydrograph for sea level rise using the methodology in ***Section 3.4.1***.

#### 4.8.2.2 Use of Qualified Coastal Engineers

If coastal hydraulics is significant to the bridge or culvert design, a qualified coastal engineer should review the complexity of the tidal conditions to determine the appropriate level of coastal engineering expertise needed in the design. Ideally, this assessment should be performed during the PD&E phase as specified in the ***FDOT PD&E Manual***, ***Chapter 4***. Conditions that typically require direct attention by a coastal engineer during the final design phase include:

- Hydraulic analysis of interconnected inlet systems
- Analysis of inlet or channel instability, either vertically or horizontally
- Determination of design wave parameters
- Prediction of overwash and channel cutting
- Design of countermeasures for inlet instability, wave attack, or channel cutting
- Prediction of sediment transport or design of countermeasures to control sediment transport
- Assessment of wave loading on bridges and other structures

| **Modification for Non-Conventional Projects:** |
| --- |
| Delete Section 4.8.2.2 and see the RFP for requirements. |

## 4.9 SPECIFIC STANDARDS RELATING TO BRIDGES

### 4.9.1 Berms for Spill-Through Abutment Bridges

To facilitate construction, reduce scour potential, and provide for abutment stability, provide a minimum berm width of 10 feet between the top edge of the main channel and the toe of spill-through at bridge abutments. See ***Section 4.9.3.2***. For manmade canals, the berm may be omitted at the direction of the maintaining agency.

### 4.9.2 Scour Estimates

#### 4.9.2.1 Coordination

Develop scour estimates for bridges using a multi-disciplinary approach (See ***FDM Section 250***) involving the hydraulics engineer, the geotechnical engineer, the coastal engineer (if needed per ***Section 4.8.2***, above), and the structures engineer.

#### 4.9.2.2 Scour Estimates

Develop scour elevation estimates for each permanent and temporary bent as follows:

**Table 4.2: Scour Estimates**

| Hydraulic Design Flood Frequency | Scour Design Flood Frequency | Scour Design Check Flood Frequency |
|---|---|---|
| $Q_{10}$ | $Q_{25}$ | $Q_{50}$ |
| $Q_{25}$ | $Q_{50}$ | $Q_{100}$ |
| $Q_{50}$ | $Q_{100}$ | $Q_{500}$ |

- "Long-term scour" for structures required to meet the extreme event vessel collision load.

Estimate scour depths using the procedures of ***FDOT Bridge Scour Manual*** and ***FHWA's Hydraulic Engineering Circulars (HEC) 18*** and ***20,*** except for the following:

- Follow ***Section 4.8.2*** for tidal hydraulics analysis methodology.
- Use ***Sheppard's Pier Scour Equation*** rather that the ***CSU Pier Scour Equation*** when the total scour (general scour, contraction scour, and local scour) is greater than six feet.
- Use the ***Florida Complex Pier Scour Procedure*** in lieu of the complex pier scour procedure in ***HEC 18***.
- ~~Use the Florida Rock/Clay Scour Procedure to evaluate scour in scour-resistant soils.~~
- Use SED-2D to evaluate contraction scour in the absence of a clearly defined upstream tidal floodplain.

~~You can find guidance on the above Florida procedure at the website: https://www.fdot.gov/roadway/Drainage/Bridge-Scour-Policy-Guidance.shtm~~

### 4.9.2.3 Scour Components

Scour estimates consist of the total scour resulting from the following:

1. Natural channel aggradation and degradation anticipated during the life of the structure
2. Channel migration anticipated during the life of the structure
3. Contraction scour
4. Local scour, including pier scour and abutment scour from currents and waves (Note: Abutment scour estimates are not required when the minimum abutment protection is provided.)

The "long-term scour" is the total design scour for structures subject to clear water scour. For structures subject to live bed scour, the "long-term scour" is the normal, everyday scour at the piers combined with the degradation scour anticipated during the life of the structure. The following inset provides criteria for determining normal, everyday scour at the piers.

## Normal, Everyday Scour at the Piers

Bridge inspection reports and the design survey are the primary basis for determining normal everyday scour for bridge replacements, parallel bridges, major widenings, etc.

If the proposed piers are the same as the existing, the normal, everyday scour elevation is that which is reflected in the inspection reports and the design survey. Slight differences in scour will likely exist between inspection reports and between the reports and the design survey. In these cases, an average scour elevation will be a reasonable estimate of normal, everyday scour. If there is a large difference, it may be due to an extreme storm event that occurred just before the inspection or survey was made. Investigate this and address these situations on a case by case basis.

For structures in which the proposed piers will be a different size or shape than the existing, adjust the pier scour depth. Using the inspection reports and the survey as discussed above, determine a normal, everyday scour depth at the pier. Adjust this depth using the following formula. The formula was derived by assuming only the pier width and shape change. Flow, velocity, and depth remain unchanged from existing to proposed.

$$y_{sp} = \frac{k_{1p}}{k_{1e}} \left[ \frac{a_p}{a_e} \right]^{0.65} y_{se}$$

where:

$y_{sp}$ & $y_{se}$ = Scour depth for proposed pier and existing pier, respectively

$k_{1p}$ & $k_{1e}$ = Pier nose shape correction factor for proposed and existing pier, respectively

$a_p$ & $a_e$ = Pier width for proposed and existing pier, respectively

For new bridges/new alignments where there are no historical records available, the drainage engineer should look for hydraulically similar bridges in the area (preferably on the same water body) and estimate scour using the above guidelines. If there are no similar structures to use for comparison, contact the District Drainage Engineer for guidance on other methods for estimating normal everyday scour.

### 4.9.3 Scour Protection Considerations

#### 4.9.3.1 General

Design pier spacing and orientation, along with abutment protection, in coordination with other bridge design concerns to minimize flow disruption and potential scour, subject to navigation requirements.

Design abutment and pier protection as follows:

1. For protection against the effects of scour conditions consistent with design requirements stated above
2. For the effects of wind-generated waves and boat wake

Document revetment options deemed to be inappropriate for the site in the Bridge Hydraulics Report (BHR). Write a Technical Specification, if a ***Standard Specification*** does not exist, based on the use of the most desirable revetment material, with the option to substitute the other allowable materials at no additional expense to the Department.

Specify the environmental classification for gabions based on the criteria found in the ***Structures Manual, Volume 1: Structures Design Guidelines*****,** ***Section 1.3***.

Follow the ***USACE Shore Protection Manual*** for design of coastal revetment.

#### 4.9.3.2 Minimum Abutment and Retaining/Sea Wall Protection

For wave heights greater than 2.4 feet (typically in coastal applications), use Specific Gravity (S.G.) = 2.65 or greater rubble. In such cases, extend abutment protection beyond the bridge along embankments and retaining/sea walls that may be vulnerable to wave attack during a hurricane. Design for both wave attack above the peak design surge elevation and wave rebound scour at the toe of bulkheads. In such cases, obtain the size and coverage of the revetment from a qualified coastal engineer

##### 4.9.3.2.1 Spill-through Abutments

For spill-through abutments, minimum protection consists of one of the following placed on a slope no steeper than 1(vertical) to 2 (horizontal):

- Rubble riprap (bank and shore), bedding stone, and geotextile: Rubble riprap (bank and shore) as defined in the ***Standard Specification 530*** where (1) design flow velocities do not exceed 7.7 fps, (2) Froude numbers are ≤ 0.80, and (3) wave heights do not exceed 2.4 feet

- Articulated concrete block (cabled and anchored), as defined in ***Standard Specification 530***

The ***Structures Detailing Manual*** provides typical details for standard revetment protection of abutments and extent of coverage. Determine the horizontal limits of protection using ***HEC 23***. Provide a minimum distance of 10 feet if ***HEC 23*** calculations show less than 10 feet.

Prepare site-specific details as stated in ***Standard Specification 530*** when using articulating concrete block abutment protection.

### 4.9.3.2.2 Bulkhead Abutments

When bulkhead abutments are protected by a structural wall, consult with the structural engineer to determine the need for toe protection below the wall and revetment protection above the wall. When the design velocity in the contracted section is less than or equal to 7.2 fps, use bank and shore rubble riprap. When the design velocity is above 7.2 fps, design the size and density of the rubble for site conditions. In all cases, design the spatial extent of the rubble protection for individual site conditions.

### 4.9.3.3 Pier Protection

For new construction, bridge foundations must be designed to withstand the effects of the design scour. Only bridge abutments and their associated foundation systems may be designed with scour countermeasures. For bridge rehabilitation or widening, scour countermeasures may only be designed for the existing portions of intermediate pier foundations. Reference FHWA Technical Advisory 5140.23.

Where revetment is deemed necessary to protect existing piers from scour, and upstream design flow velocities do not exceed 7.2 fps for rectangular piles or bascule piers, and 8.2 fps for round piling or drilled shafts, use one of the following for pier scour protection:

- Rubble riprap (bank and shore), bedding stone, and geotextile: Rubble riprap (bank and shore) is defined in the ***Standard Specification 530***
- Articulated concrete block (cabled)
- Gabions (rock-filled baskets)

### 4.9.3.4 Use of Bedding Stone with Revetments

Geotextile type and material referenced below is based on ***Standard Specification 985.***

Use bedding stone to cushion the underlying geotextile during installation of rubble and to keep the geotextile flat against the parent soil to avoid the piping of sheet flow cascading from the top side of the rubble.

## 4.9.4 Bridge Deck Drainage

### 4.9.4.1 Spread Standards

The spread standards in ***Section 3.9*** apply to bridge decks and bridge approaches.

### 4.9.4.2 Scupper Drains

The standard scupper drain is four inches in diameter and spaced on 10-foot centers, unless spread calculations indicate closer spacing is required. Design using a factor of safety of 2. Scuppers will not be directly discharging onto railroads, roadway travel lanes, shared-use paths, or sidewalks. Provide erosion protection, which could include splash pads or rubble, for scuppers discharging onto erodible surfaces.

### 4.9.4.3 Bridge Sidewalk Drainage

Where bridge sidewalks are sloped away from the travel lanes, no measures to capture runoff from the sidewalks are required, except at bridge ends. If bridge sidewalk drainage is installed, scuppers must satisfy Americans with Disabilities Act (ADA) requirements to have no more than a one-half inch hole in the walking surface.

## 4.9.5 Wave and Current Forces on Coastal Bridges

Where coastal bridges are not elevated at least one foot above the design wave crest elevation, a qualified coastal engineer with experience in wave mechanics must address the requirements of the ***AASHTO Guide Specifications for Bridges Vulnerable to Coastal Storms***.

### 4.9.5.1 Required Level of Analysis

Use a qualified coastal engineer as part of the PD&E scoping effort, especially with structures exposed to severe wave attack. Make determinations, including the appropriate level of analysis, as outlined in the ***SDG, Section 2.5***.

# 4.10 SPECIFIC STANDARDS RELATING TO ALL CROSS DRAINS EXCEPT BRIDGES

## 4.10.1 Culvert Materials

Select culvert material in accordance with ***Chapter 6*** of this ***Manual***.

## 4.10.2 Manning's Roughness Coefficients

Standard values for Manning's roughness coefficient are as follows:

| | |
|---|---|
| Concrete Box Culverts | n = 0.012 |
| Concrete Pipes | n = 0.012 |
| Metal Pipes: | |
| Pipe and Pipe Arch - Helical Fabrication | |
| Re-corrugated Ends - All Flow Conditions* | |
| 12" – 24" | n = 0.020 |
| 30" – 54" | n = 0.022 |
| 60" and larger | n = 0.024 |
| Pipe and Pipe Arch - Spiral Rib Fabrication | |
| Re-Corrugated Ends - All Flow Conditions* | |
| All sizes | n = 0.012 |
| Structural Plate - Pipe and Pipe Arch | |
| Annular Fabrication - All Flow Conditions* | |
| All - 6" x 2" | n = 0.033 |
| All - 9" x 2-1/2" | n = 0.034 |
| Plastic Pipes: | |
| Polyvinyl Chloride-PVC (external rib/smooth interior) | |
| All Sizes | n = 0.012 |
| Polyethylene | |
| Single Wall | n = 0.024 |
| Double Wall (Smooth) | n = 0.012 |

Polypropylene (All Sizes)

| | |
|---|---|
| Single Wall | n = 0.024 |
| Double & Triple Wall (Smooth) | n = 0.012 |

* "Spiral" flow will not occur for most design situations. Therefore "spiral" flow design values have not been established. Values recommended by the Southeast Corrugated Steel Pipe Association are contained in the ***AISI Handbook of Steel Drainage & Highway Construction Products.***

### 4.10.3 End Treatment

Select/design the choice of end treatment and other hydraulic structures to satisfy hydraulic capacity, structural capacity, and safety (vehicular, pedestrian, cyclist) requirements.

Treatments are presented in the ***Standard Plans***. Criteria on end treatment selection is in ***Table 3.4***.

#### 4.10.3.1 Protective Treatment

Review drainage designs to determine if some form of protective treatment will be required to prevent entry to facilities that present a hazard to children and, to a lesser extent, all persons or certain wildlife. ***Section 3.7*** presents direction on protective treatment. When grates are used, consider the effect of the grate and potential debris on the hydraulic capacity of the cross drain.

#### 4.10.3.2 Roadside Safety

The type and location of end treatments must consider roadside safety and clear zone requirements. See the ***FDM*** for clear zone requirements and ***Table 3.4*** for end treatment safety guidance.

### 4.10.4 Construction and Maintenance Considerations

Design culverts to be consistent with the standard construction and maintenance practices of the Department. Standard details for inlets, manholes, junction boxes, end treatments, and other miscellaneous drainage details are provided in the ***Standard Plans***. Specifications are provided in the ***Standard Specifications***. In the event the ***Standard Plans*** are not suitable for a specific project need, develop a detailed design and include it in the plans; and, as appropriate, provide special provisions for inclusion with the project specifications. Proper design also considers maintenance concerns of adequate physical access for cleaning and repair. Refer to the criteria in ***Section 3.10.1*** for the recommended maximum pipe lengths without maintenance access. Refer to Section ***3.10.4*** for criteria on existing pipe inspection.

#### 4.10.4.1 Minimum Culvert Sizes

Minimum culvert sizes are as follows:

| Culvert Type | Minimum Size |
|---|---|
| Cross Drain | 18” |
| Median Drain | 15” *,** |
| Side Drain | 15” * |
| Box Culvert (Precast) | 3’ x 3’ |
| Box Culvert (Cast in Place) | 4’ x 4’ |
| Drains from inlets on high fills (e.g., gutter drains) | 15” ** |

* Some locations require 18” minimum. Consider future improvements, hydraulic requirements, debris control, and maintenance access.

** When debris control is not provided by grates, use 18” minimum.

For culverts requiring more than a double line of pipe, investigate other alternatives.

## 4.11 DOCUMENTATION

### 4.11.1 Culverts (all culverts less than a 20-foot bridge culvert)

#### 4.11.1.1 Extensions of Culverts with No Known Historical Problems

For extensions of culverts that have no signs of undesirable scour at inlet and outlet ends, no excessive sedimentation, and no history of problems, include in the documentation, at a minimum, the following:

1. Evidence of contact with Maintenance Office
2. Evidence of Field Review
3. Discharge computations
4. Hydraulic computations (***HDS 5***), including any design assumptions

#### 4.11.1.2 New or Replacement Culverts and Extensions of Culverts with Known Historical Problems

At a minimum, include in the documentation:

1. Evidence of contact with a maintenance office
2. Evidence of Field Review
3. Drainage map
4. Hydrologic computations
5. Hydraulic computations (***HDS 5***), including any design assumptions
6. Assessment of the problem (for culverts with known problems)
7. Alternative analysis
8. Optional materials evaluation

### 4.11.2 Bridges

Document bridge hydraulic design computations and analyses in a permanent record file. The permanent record file will address all design standards provided herein. Provide documentation in detail commensurate with the complexity of the project. Documentation must be sufficient enough that an independent engineer with expertise in bridge hydraulics, but not involved with the design, can fully interpret, follow, and understand the logic, methods, computations, analysis, and considerations used to develop the final design.

#### 4.11.2.1 Bridges on Controlled Canals

Bridges on controlled canals not affected by hurricane surge may utilize the short-format BHR located in ***DDG Chapter 5***.

#### 4.11.2.2 Bridge or Bridge Culvert Widening

At a minimum, include in the documentation:

1. Bridges require a completed Bridge Hydraulics Recommendations Sheet (BHRS), including complete design recommendations. Bridge-culverts require

a completed Flood Data Summary Table. ***FDM*** provides the format for the BHRS and the Flood Data Summary Table**.**

2. Evidence of Field Review
3. Hydrologic analysis, including sources of data and methodology
4. Hydraulic computations, including any design assumptions; provide an electronic copy with the input and output file(s) for the final computer run
5. Scour analysis:
   a) Scour computations
   b) Scour protection needs
6. Applicable regulatory agency documents that affect the final design; this may include documents from the Corps of Engineers, Coast Guard, Water Management District, DEP, etc.
7. Deck drainage analysis and computations

### 4.11.2.3 Bridge Culverts

At a minimum, include in the documentation:

1. Evidence of Field Review
2. Hydrologic analysis, including sources of data and methodology
3. Hydraulic computations, including any design assumptions; provide an electronic copy with the input and output file(s) for the final computer run
4. Scour analysis addressing the need for inlet and/or outlet protection
5. A summary of the alternatives considered, including cost estimates and reasons for selecting the recommended structure, and a clear explanation as to why it is the most economical structure for the site in question
6. Applicable regulatory agency documents that affect the final design; this may include documents from the Corps of Engineers, Coast Guard, Water Management District, DEP, etc.
7. For interstate system bridges over floodplains where a regulatory floodway has not been established, the documentation must include the evaluation required in ***Section 4.4*** of this Chapter.

### 4.11.2.4 Category 1 and 2 Bridges

At a minimum, include in the documentation:

1. A completed BHRS. ***FDM*** provides the format for the BHRS.
2. BHR:
   A. A summary of all design recommendations, including:
      1) Bridge length, including locations (stations) of abutments

2) Channel excavation requirements
3) Minimum vertical clearance
4) Minimum horizontal clearance
5) Abutment type and orientation
6) Pier orientation
7) Scour depths
    a. Scour design event
    b. Scour check event
8) Scour protection requirements for abutments, piers, and channel; for spill-through abutments, recommendations include:
    a. Abutment slope
    b. Type of protection (rubble riprap is standard)
    c. Horizontal and vertical extent of protection
    d. Consideration of wildlife connectivity
9) Deck drainage requirements
10) Wave and surge parameters and force determination (or calculation) and analysis (for coastal bridges not elevated one foot above the design wave crest elevation)

B. Evidence of field review

C. Hydrologic analysis, including sources of data and methodology

D. Alternative analysis or evaluation of structure sizes (length and vertical height/clearance) performed consistent with Department policy for bridge hydraulic design and including:
1) Cost
2) Design standards
3) Structure hydraulic performance, including backwater, velocity, and scour
4) Impacts of the structure on adjacent property
5) Environmental impacts

E. The alternative analysis will address the reasons for selecting the recommended structure, and a clear explanation as to why it is the most economical structure for the site in question; at a minimum, the following structure sizes will be evaluated:
1) The minimum structure size required to meet hydraulic standards for vertical and horizontal clearance, scour, and backwater
2) Existing structure size if applicable
3) The recommended structure size if different from (1) or (2)

F. Deck drainage analysis

G. Supporting hydraulic computations, including:

1) Computer analysis, if appropriate, including a plan view of cross section locations and an electronic copy with the input and output file(s) for the final computer run
2) Scour computations
3) Deck drainage computations
4) Design assumptions
5) Wave and surge parameters and force determinations and analysis (for coastal bridges not elevated one foot above the design wave crest elevation)

H. Applicable regulatory agency documents that affect the final design, which may include documents from the Corps of Engineers, Coast Guard, Water Management Districts (WMD), DEP, etc.

## 4.11.3 Document Processing

Process the BHR/BHRS and other supporting design documents in accordance with the ***FDM***.

# CHAPTER 5

# STORMWATER MANAGEMENT

## LIST OF TABLES



## LIST OF FIGURES

## 5.1 INTRODUCTION

This chapter presents standards for the design of stormwater management systems for Department projects. Guidance for drainage connection permits is provided in the ***FDOT Drainage Connection Permit Handbook***.

## 5.2 REGULATORY REQUIREMENTS

### 5.2.1 Chapter 14-86, Florida Administrative CodeFDOT's Stormwater Discharge Criteria

The design of stormwater management systems for Department projects will comply with the water quality, quantity (i.e. peak rate, and volumequantity), and recovery requirements of ***Section 334.044(15), Florida Statues (F.S.),*** and ***Chapter 14-86, Florida Administrative Code (F.A.C.)***, Rules of the Department of Transportation, only in basins closed during storms up to and including the 100-year storm event, or areas subject to historical flooding.

### 5.2.2 Section 373, Florida Statutes, Water Resources

***Section 373.4596, F.S.***, requires the Department of Transportation to fully comply with Florida Department of Environmental Protection (FDEP)state, Water Management District (WMD), and—when delegated by the state—local government stormwater management programs.

***Section 373.413(6), F.S.***, provides permitting flexibility associated with construction or alteration of stormwater management systems servicing linear state transportation projects and facilities to balance the expenditure of public funds for stormwater treatment with the benefits to the public in providing the most cost-efficient and effective method of achieving the treatment objectives. Governing boards and the Department [FDEP & WMDs] shall allow alternatives to onsite treatment, including but not limited to, regional stormwater treatment systems. FDOT is responsible for treating stormwater generated from state transportation projects but is not responsible for the abatement of pollutants and flows entering its stormwater management systems from offsite sources, unless receiving and managing such pollutants and flows is deemed cost effective and prudent.

### 5.2.3 Chapter 62-330, Florida Administrative CodeStatewide Environmental Resource Permitting (ERP)

The ERP rule is set forth in ***Chapter 62-330, F.A.C.***, of and is administered by the Florida Department of Environmental Protection (FDEP) and the five WMDs. In part, ***Chapter 62-330, F.A.C.***, including the ***ERP Applicant's Handbooks Volumes I and II***, specifies minimum water quantity and water quality treatment standards required by thefor issuance of an Environmental Resource Permit (ERP) program for new proposed development which results in new/additional impervious surfaces, with associated definitions listed in ***Section 373.403, F.S.*** and ***ERP Applicant's Handbook Volumes I and II***. An ERP is required for projects that exceed thresholds listed in ***Rule 62-330.020, F.A.C.***

Various activities are exempt from obtaining an ERP. A list of exempt activities are included in ***Sections 373.406*** and ***403.813, F.S.***, as well as ***Rule 62-330.051, F.A.C.*** Coordinate with the District's Environmental Permits Coordinator and the District Drainage Engineer for documentation requirements for projects that meet listed exemption(s). The project's exemption(s) will be included in the Drainage Design documentation within Project Suite Enterprise Edition (PSEE). If there is a question regarding project's exemption applicability, contact Central Office before filing for a formal Exemption Request with the regulatory agency under ***Rule 62-330.050, F.A.C.***

Evaluation and determination of whether a project exceeds the minimum thresholds and/or meets listed exemptions must be made in consultation with the District Environmental Permits Coordinator, District Drainage Engineer, and the ***FDOT Permit Handbook*** prior to coordination with the regulatory agency.

When a project warrants an Individual or Conceptual ERP, refer to ***Section 5.2.6*** for various Forms that assist with Statewide consistency for regulatory overlap between the ERP program and NPDES program.

## 5.2.4 ~~Chapter 62-40, Florida Administrative Code~~Water Resource Implementation Rule

The ***Water Resource Implementation Rule***, ***Chapter 62-40, F.A.C.***, ~~of the Florida DEP~~ outlines basic goals and requirements for surface water protection and management to be implemented and enforced by ~~the~~ F~~lorida~~ DEP and the ~~Water Management Districts~~ ~~(~~WMDs~~)~~, based on the statutory policies and directives of the ***Water Resources Act*** in ***Chapter 373, F.S.***, the ***Air and Water Pollution Control Act*** in ***Chapter 403, F.S.***, and the ***State Comprehensive Plan*** in ***Chapter 187, F.S.***

## 5.2.5 Ambient Water Quality

~~The surface water quality numeric criteria are identified in the table within ***Rule 62-302.530, F.A.C***. When a proposed project is located within the basin of an impaired water body, coordinate with the District National Pollutant Discharge Elimination System (NPDES)/Municipal Separate Storm Sewer System (MS4) Permits Coordinator. A mapping tool to help identify the presence of impaired water bodies is found at the following webpage:~~

~~https://ca.dep.state.fl.us/mapdirect/?webmap=3047d3c29d0e4feeade418bf85c420c2~~

~~Additional protection measures may be required for projects that discharge to Outstanding Florida Waters (OFW) or ONRWutstanding National Resource Waters. A full list of waters that require special protection are provided in ***62-302.700 F.A.C.***~~

~~Waters Not Attaining Standards (WNAS) are those that have been identified as not meeting quality standards for their associated classification as defined in ***62-302 F.A.C.*** Majority of WNAS may require additional protection measures if they are within a Basin Management Action Plan (BMAP), have a Total Maximum Daily Load (TMDL), included in a local Alternative Restoration Plan or Reasonable Assurance Plan (RAP), or are on the Verified Impaired List. However, the WNAS list also includes assessment categories for FDEP's Study List, which is not to be used for implementation of any regulatory program per ***62-303.150(1) F.A.C.***~~

Waters Not Attaining Standards (WNAS) are Waters of the State, defined by waterbody identifications (WBIDs), that have been determined as not meeting water quality standards for their associated designated use classification as defined in the ***Surface Water Quality Standards Rule (Chapter 62-302, F.A.C.),*** in accordance with the methodology prescribed in the ***Impaired Waters Rule (Chapter 62-303, F.A.C.),*** and are placed on the Clean Water Act (CWA) State 303(d) list submitted to U.S. Environmental Protection Agency (EPA). The majority of WNAS require additional protection measures if they have assessment categories associated with:

- Total Maximum Daily Load (TMDL) (assessment 4a),
- Reasonable Assurance Plan (RAP) (assessment 4b), or
- Verified Impaired (assessment 5).

However, the WNAS list also includes assessment categories for WBIDs placed on the Study List (assessment 4d), which includes local alternative restoration plans (assessment 4e) under ***Rule 62-303.390(2)(d) F.A.C.*** The WBIDs placed on the Study List are not to be used for implementation of any regulatory program per ***Rule 62-303.150(1) F.A.C.*** The assessment category 4c is used for natural impairments which must not be included in the WNAS database. Impaired Waters Listing Process | FDEP

Additional protection measures may be required for projects that discharge within designated Basin Management Action Plans (BMAP), RAP, or within designated sensitive waterbodies, such as Outstanding Florida Waters (OFW) and Outstanding National Resource Waters (ONRW) listed in ***Rule 62-302.700, F.A.C.*** These plans and sensitive waterbody designation boundaries do not follow WBID boundaries and may not be included in FDEP's WNAS database or Comprehensive Lists. The following links connect to FDEP webpages for these additional protection measure boundaries:

- Basin Management Action Plans (BMAPs) | FDEP
- Alternative Restoration Plans (RAPs) | FDEP
- Outstanding Florida Waters (OFWs) | FDEP

### 5.2.6 National Pollutant Discharge Elimination System (NPDES)

The ***NPDES permit program*** is administered in Florida by FDEP, as an approved program by the U.~~-~~S. ~~Environmental Protection Agency~~EPA~~ and delegated to Florida DEP~~. This program requires permits for stormwater discharges into surface waters of the State of Florida and ~~w~~Waters of the United States from certain industrial activities, construction activities, and ~~from large and medium~~ municipal separate storm sewer~~water~~ systems (MS4s).

#### 5.2.6.1 NPDES Municipal Separate Storm Sewer System (MS4)

FDOT operates both Phase I and Phase II MS4s throughout the state and is regulated by NPDES MS4 permits issued by FDEP that are approved by the U.S. EPA. Additionally, FDOT is a stakeholder in numerous TMDLs issued by FDEP and the US EPA and participates in many TMDL implementation plans under the ***Florida Watershed Restoration Act*** in ***Section 403.067, F.S.***, including the Basin Management Action Plan (BMAP), Reasonable Assurance Plan (RAP), and alternative restoration plan processes. Furthermore, in some cases, FDOT is required to develop supplemental stormwater management plans for TMDLs under its MS4 permits where FDEP has not, or is not planning, to develop a TMDL implementation plan.

When FDOT is identified as a stakeholder in a TMDL implementation plan, FDOT may be required to provide additional treatment measures beyond ERP requirements to meet pollutant reduction goals listed in the implementation.

Under the MS4 program, FDOT has developed a Comprehensive O&M Program for stormwater management systems. This Comprehensive O&M Program is being implemented statewide. The FDOT O&M Plan and Cost Estimate Forms listed in ***Section 1.11*** of this ***Manual*** are to be included within any ERP application package that requires meeting ***ERP AH Volume 1, Section 11 – Operations and Maintenance Criteria***.

A map of regulated MS4 areas can be found at:
Florida NPDES Stormwater MS4 Permits | FDEP Geospatial Open Data

#### 5.2.6.2 NPDES Construction Activities

NPDES program for construction activities requires a Construction Generic Permit (CGP) for projects that have at least 1.0-acre of disturbed land or discharge to a Waters of the State or through a permitted MS4 system. The CGP requires the contractor to maintain up-to-date Stormwater Pollution Prevention Plan (SWPPP) and Erosion and Sediment Control (E&SC) Plans on site.

The ERP Temprary Erosion & Sediment Control Plan Narrative (***FDM Form 251-A***) provides a crosswalk to demonstrate how FDOT Specifications addresses the ***ERP AH Volume 1, Section 12 - Erosion and Sediment Control***, program requirements. This E&SC Plan Narrative Form must be included within any ERP application required to demonstrate its temporary E&SC plan.

The design team must initiate the development of the NPDES SWPPP Template for FDOT Projects (***FDM Form 251-B***) and include within the Phased PS&E Submittals. This SWPPP Template is to support contractor compliance of NPDES CGP obligations. Refer to ***FDM 251*** for phased submittal requirements.

## 5.3 ~~ENVIRONMENTAL LOOK AROUNDS (ELA)~~REGIONAL CONSIDERATIONS FOR STORMWATER MANAGEMENT

Consistent with ***403.0611 F.S.*** and ***373.413(6), F.A.C.***, the Department has formalized the Watershed Approach to Evaluate Regional Stormwater Solutions (WATERSS) process, formerly known as Environmental Look Around (ELA). WATERSS is used to identify local community partnerships (cities, counties, water management districts, community organizations, etc.) for watershed specific opportunities for non-traditional, innovative stormwater management solutions (e.g. seagrass enhancements, septic-to-sewer projects, WWTF BNR upgrades, etc.) that can produce greater environmental benefits to Florida's waters.

The ***WATERSS Process Guidebook*** provides detailed guidance on how to develop and document regional options opportunities as well as perform a traditional pond siting analysis during the PD&E Study. The WATERSS process begins during the planning phase during ETDM Screenings, extends through the Project Development and Environment (PD&E) phase, and becomes solidified during the design and permitting phase. The intent of the WATERSS Process is to integrate stormwater management elements throughout all phases of FDOT projects, including Operations and Maintenance. Coordinate as early as possible with the District NPDES Coordinator if a project is located within an impaired WBID or an associated TMDL, BMAP, or RAP.

https://www.fdot.gov/environment/publications.shtm

~~After determining project stormwater management requirements and before planning stormwater management design decisions, convene a meeting with regional stakeholders to explore watershed wide stormwater needs and alternative permitting approaches. Evaluate the following opportunities for application on the project:~~

1. ~~WMDs/DEP issues: wetland rehydration, water supply needs, minimum flows and levels, flooding, Total Maximum Daily Load (TMDL) needs, acquisition of fill from DEP/WMDs lands, etc.~~

2. ~~City/County issues: stormwater re-use, flooding, discharge to golf courses or parks, NPDES needs, water supply needs~~

3. ~~FDOT project permitting: regional treatment, stormwater re-use, joint use facilities~~

The Office of Environmental Management (OEM) published the ***WATERSS Process Guidebook*** September 2021. Review project scope and specifics, coordinate with OEM and consult the PD&E Manual to determine the stormwater management approach for each individual project.

~~Appropriate personnel are as follows:~~

~~WMDs/DEP (Regional): ERP, water quality, water supply, wetland, and Minimum Flows & Levels personnel, BMAP coordinator(s)~~

~~FDOT: District Drainage Engineer, PD&E Planning, or Design Project Managers, permit coordinator, NPDES representative~~

~~City/County: (as decided by the city/county) City Engineer, Public Works Director, Stormwater Engineer~~

~~Document areas of potential cooperation in the project reports for future follow up as the design moves forward.~~

~~Hold these ELA meetings before identification of right-of-way acquisition in the PD&E phase. If no right-of-way acquisition or PD&E phase is scheduled, then target as early as feasible within the design phase.~~

# 5.4 DESIGN STANDARDS

## 5.4.1 Design of Systems

### ~~5.4.1.1 General~~

Design stormwater management facilities (SMFs) to provide the necessary quantity (i.e.~~,~~ peak rate and net volume)~~,~~ and quality control based on the presumption that the upstream discharge meets stormwater quantity~~, rate,~~ and quality criteria prior to reaching the FDOT right-of-way.

For facilities designed to be dry, or using underdrains or exfiltration systems, provide geotechnical analysis certified by the project Geotechnical Engineer.

Accommodate all offsite runoff in accordance with the Department's criteria and all regulatory agency criteria. Maintain all historical flow patterns for offsite flows. If economically prudent, the Department's wet detention facilities may accept (co-mingle) offsite discharges into them without increasing the required water quality treatment design; in such cases, avoid hydraulic impacts on upstream property owners. For co-mingling offsite discharges into the Department's SMFsdry retention facilities, consult with the District Drainage Engineer for direction on whether to co-mingle or bypass offsite inflows.

| **Modification for Non-Conventional Projects:** |
| --- |
| Delete the previous paragraph and see the RFP for requirements. |

#### 5.4.1.1 Treatment Requirements

If a proposed project is located within a regulated NPDES MS4 area and within a WBID that is classified as verified impaired or associated with a TMDL, BMAP, RAP, or Alternative Restoration Plan, coordinate as early as possible with the District's NPDES Coordinator, Environmental Permits Coordinator, and the District Drainage Engineer while developing a stormwater management strategy. Determine the Department's MS4 stakeholder obligations and any potential water quality enhancement coordination efforts with other stakeholders.

Some districts have used existing ERP stormwater management systems excess treatment capacity to meet pollutant load reduction requirements for their MS4 obligations. When a project is proposing to use the excess treatment capacity of an existing SMF, verify with the District NPDES Coordinator that the treatment capacity is still available for use in ERP.

##### 5.4.1.1.1 Compensatory Treatment

For projects where proper treatment (volume, rate, water quality criteria) cannot be feasibly obtained for the proposed impervious area, treatment of existing untreated areas that discharge to the same receiving water-body may be substituted in lieu of treating the proposed sections of the project. Use of off-site compensatory treatment methods must still comply with attenuation requirements listed in ***Section 5.4.1.2*** of this ***Manual*** and appropriate regulatory requirements.

#### 5.4.1.1.2 Structural Stormwater Best Management Practices

Structural Stormwater Treatment Best Management Practices (BMPs) should be evaluated within the Right-of-Way wherever possible prior to providing treatment in large SMFs (i.e. stormwater ponds) that are typically used for attenuation and/or floodplain compensation volume storage. Enhance sustainability of the corridor by avoiding BMP systems that have limited life cycles wherever possible (e.g. proprietary tree wells, specialty media mixes, stormwater inserts, etc.).

Various roadway BMPs are listed in ***Table 5-1*** along with their long-term operations and maintenance (O&M) considerations. The O&M of structural stormwater BMPs are maintained through the ***Maintenance Rating Program (MRP) Handbook*** and ***FDOT Statewide Stormwater Management Plan (SSWMP)*** in conjunction with ***FDOT Stormwater Asset Maintenance (SWAM) Guidance***. Use the FDOT O&M Plan and Cost Estimate Forms listed in ***Section 1.11*** within this ***Manual*** to demonstrate compliance with ERP AH Volume 1, Section 12.0.

Springshed stormwater treatment BMPs must maximize the usage of roadside linear conveyance systems as much as possible. This allows for a diffused runoff load throughout the corridor to enhance vegetation uptake and microbial nutrient cycling processes, as well as enhance distributed recharge to the aquifer while minimizing surface water head on karst formations.

**Table 5-1: Structural Stormwater Treatment BMP Options**

| Location | BMP(1) | Maintenance(2) |
|---|---|---|
| Roadside Collection and Conveyance<br>*(small or linear drainage areas, initial treatments)* | Vegetated Filter Strips | Low |
| | Bioswales<br>*(ditches, swales with/without blocks/control structures, linear ponds)*<br>Retention<br>Detention with filtration | <br><br>Low<br>Medium |
| | Bioretention Systems<br>*(landscaped areas or planters, rain gardens, stormwater trees)*<br>Retention<br>Detention with filtration | <br><br>Low<br>Medium |
| | Exfiltration Trench/French Drain Systems | Medium |
| | Pollution Control Boxes<br>*(Baffle boxes, hydrodynamic separators, catch basin inserts/ inlet filter cleanouts, up-flow filters)* | High |
| Attenuation Storage<br>*(larger drainage areas, secondary treatments)* | Retention Pond | Low |
| | Detention Pond | Low |
| Pond Add-Ons | Littoral Zone (Wet detention ponds) | Medium |
| | Floating Managed Aquatic Plant Systems (MAPS) | High |
| | Underdrains or Side Bank Filters | Medium |
| Outfalls | Vegetated Natural Buffers<br>*(sheet flow within riparian/forested buffers)* | Low |

1. Any BMP not listed herein must be approved by the District Drainage Engineer and consulted with the District Maintenance Office prior to implementation in design plans.
~~1.~~2. High Maintenance activities must have District Maintenance Office consultation prior to proposing for permitting.

## 5.4.1.2 Attenuation Requirements

### 5.4.1.2.1 Watersheds with Positive Outlets

Projects discharging to offsite areas subject to reported historical flooding, up to the 100-year, 24-hour storm event, must assess the discharge requirements of ***Chapter 14-86, F.A.C***. Additionally, any Department projects discharging into drainage systems with heightened public safety risks, such as roadway drainage systems, must comply with ***Chapter 14-86, F.A.C***.

### 5.4.1.~~3~~2.2 Watersheds without Positive Outlets

For projects that are located within a watershed that contributes to a depressed low area, or a lake that does not have a positive outlet such as a river or stream to provide relief (i.e., closed basin or isolated depression), a detention/retention system is required.

Design the detention/retention systems to meet the discharge requirements of ***Chapter 14-86, F.A.C***. The retention volume must recover at a rate such that one-half of the volume is available in seven days, with the total volume available in 30 days. A sufficient amount must be recovered within the time necessary to satisfy applicable water quality treatment requirements.

#### ~~5.4.1.4 Exceptions~~

#### 5.4.1.~~4.1~~2.3 Tidal Areas

Water quantity ~~and~~ (volume and rate control) criteria are not applicable for projects that discharge directly into tidal waterbodies. This is subject to permission of the appropriate permitting authority.

#### 5.4.1.~~4.2~~2.4 Downstream Improvement

Water quantity ~~and~~ (volume and rate control) criteria are not applicable where it can be demonstrated that downstream conveyance and storage systems have adequate capacity or will be improved to have adequate capacity increased quantity and rate of runoff created by the project.

#### 5.4.1.~~4.4~~2.5 Permission from the Downstream Property Owner

Water quantity and rate control criteria can be waived when the downstream property owner(s) agrees to accept the increased quantity and rate of runoff created by the project. This will require flood rights coordination with legal and R/W. Refer to **Appendix B – Acquisition of Real Property Rights**.

### 5.4.1.3 Control Structure Design

~~Stormwater~~SMF pond control structures consist of ditch bottom inlets in conjunction with outfall pipes. Do not use trapezoidal weirs, shaped into the pond berm, as primary control structures except where inlets and pipes are not feasible~~.~~, and has been approved by District Drainage Engineer.

Start initial pond routing at the control elevation unless otherwise required by the Water Management District permit.

No pump or any other mechanical means may control any component of a permanent stormwater system.

With facilities designed to be wet, provide a minimum permanent pool depth of six feet to minimize aquatic growth.

Provide skimmer(s) on the last control structure of a Structural Stormwater BMP series prior to discharge to off-site property or waterbody. Follow ***Standard Plans Instructions Index 425-070.***

Adjust the tailwater elevation for coastal pond outfalls to account for sea level rise using the methodology in ***Section 3.4.1***.

### 5.4.1.4 Pond Liners

While the Department does not encourage the use of pond liners, unique project conditions may necessitate their use. Consult the District Drainage Engineer prior to beginning designs which utilize pond liners. The following are representative design scenarios where the consideration of a pond liner may be appropriate:

- The stormwater facility is located within a Sensitive Karst Area Basin or the surrounding geography is susceptible to sinkholes due to excessive stormwater runoff.
- If the stormwater facility is in proximity to hazardous environmental conditions, and water seeping from the pond risks mobilizing existing contaminants in the soil or groundwater.
- When there is a need to preserve groundwater flows into the facility from adjacent wetlands.

### 5.4.1.5 Base Clearance

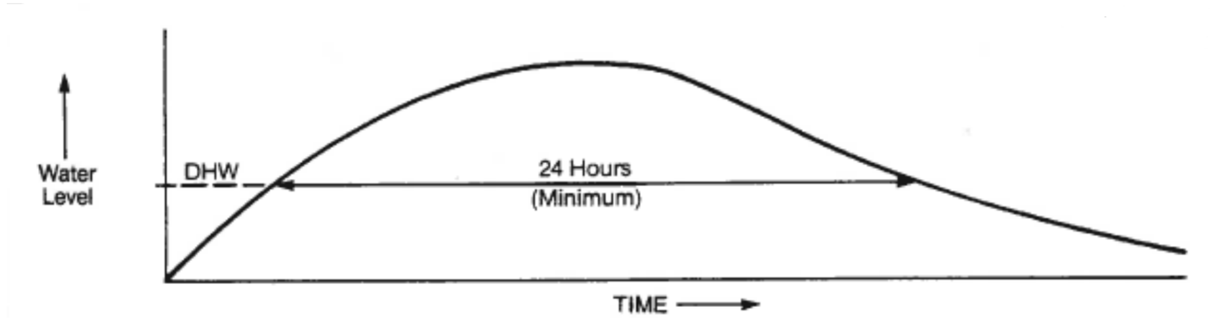
Base clearance is the distance between the bottom of the roadway base and the top of the base clearance water elevation (BCWE). The BCWE is considered the long-term standing water which could negatively affect the structural integrity of the roadway base. Allowable base clearances are based on the roadway's classification and are provided in **FDM 210.10.3** (Vertical Clearances).

The BCWE for roadside treatment swales ~~should~~ will be set at the weir elevation. A lower elevation may be used if all of the following apply:

- In-situ soils are classified as Hydrologic Soil Group A,
- Geotechnical investigation reveals there is no confining layer to impede drawdown, and
- Construction activities are limited within the treatment swale to avoid compaction and tracking of silt and muck.

For roadside ditches where the 24-hour stage of the pond's design storm high water elevation stages into the roadside ditch, ~~conveyed to ponds,~~ set the BCWE at the 24-hour stage of the design storm's high water elevation.

In the absence of treatment swales and ditch conveyances to ponds, such as closed pipe conveyance systems or offsite roadside ditch systems, set the BCWE at the Seasonal High Water Table (SHWT) elevation. Consult the ***Flexible Pavement Design Manual*** or ***Rigid Pavement Design Manual*** as appropriate.




**A) DHW Determination**

**Figure 5.1: Determination of Pond's Design Storm 24-hour BCWE**

## 5.4.1.6~~5~~ Aviation

When designing stormwater facilities within five miles of airports, coordinate with the District Aviation Administrator to determine if stormwater facilities are within Federal Aviation Administration (FAA) oversight. If ponds are within FAA oversight and cannot be prudently moved, these facilities must be designed using FAA guidelines, found primarily in the FAA Advisory Circular titled ***Hazardous Wildlife Attractants on or near Airports***. These FAA design guidelines are intended to reduce plane/bird strikes by making stormwater facilities less attractive to birds.

## 5.4.2 Hydrologic Methods

The hydrologic method used will consider one of the following:

1. Natural Resources Conservation Service (NRCS) Unit Hydrograph Method
   a. For projects that are required to meet ~~the~~ ***Chapter 14-86, F.A.C.***, criteria, use FDOT unit hydrographs provided in ***Appendix E*** of this Manual
   b. For all other projects, use the unit hydrograph as required by the regulatory agency.

2. Modified Rational Method for basins having a time of concentration of 15 minutes or less

## 5.4.3 Protective Treatment

Design stormwater management facilities with due consideration of the need for protective treatment to prevent hazards to persons. General guidance on protective treatment is provided in ***Section 3.7***. Use flat slopes when practical. Only fence retention areas in accordance with ***Section 5.4.4.2 (4)***.

## 5.4.4 Construction and Maintenance Considerations

### 5.4.4.1 General

Design stormwater management systems consistent with the standard construction and maintenance practices of the Department. Standard details for inlets, manholes, junction boxes, end treatments, and other miscellaneous drainage details are provided in the ***Standard Plans***. Specifications are provided in the ***Standard Specifications***. In the event the ***Standard Plans*** are not suitable for a specific project need, develop a detailed design and include it in the plans; and, as appropriate, provide special provisions for inclusion with the project specifications. Proper maintenance access for cleaning and repair will be addressed.

### 5.4.4.2 Detention and Retention Ponds

Design ~~stormwater management facilities~~SMFs consistent with the Highway Beautification Policy and Context Sensitive Solutions Policy. Integrate facilities with existing and proposed landscaping and adjoining land uses. Depending on the availability of time, space, and funding, consider attractive pond shapes, tree plantings, selective clearing, and other strategies to preserve or improve aesthetics. Rely on an interdisciplinary team consisting of the Landscape Architect, Drainage Engineer, and local maintenance office. Collaborate with the Landscape Architect to address an aesthetic design approach early enough within the project production schedule to include it in the determination of pond right-of-way acquisition needs.

Standard design features for detention/retention ponds~~ and any proposed borrow excavation sites~~ are shown in ***Figure 5.2~~1~~*** and are as follows:

1. Maintenance Berm:

   Design ponds to provide a minimum 20 feet of horizontal clearance between the top edge of the control elevation and the right-of-way line. Provide at least 15 feet adjacent to the pond at a slope of 1:8 or flatter. Create the inside edge of the maintenance berm to have a minimum radius of 30 feet toward the pond and be a minimum of one foot above the maximum design stage elevation. Sod the berm area. Discuss maintenance needs with the Department before acquiring additional right-of-way to construct maintenance access around the full perimeter.

2. Slopes:

   For facilities designed to be wet, sod pond slopes to the control elevation of the pond. For facilities designed to be dry, sod pond slopes to the bottom of the slope.

3. Freeboard:

As a safety factor for hydrologic inaccuracies, grading irregularities, control structure clogging, and downstream stage uncertainties, at least one foot of freeboard is required above the maximum design stage of the pond. The freeboard is the vertical distance between the maximum design stage elevation of the pond and the inside edge of the berm, as illustrated in ***Figure 5~~-1~~.2***.

For linear treatment swales, the minimum freeboard is 0.5 foot.

4. Wet Detention Permanent Pool Volume

With facilities designed to be wet, provide a minimum permanent pool depth of six feet to minimize aquatic growth.

~~4.~~5. Fencing:

Install fences around ponds only when a documented maintenance need for restricted access has been demonstrated. The installation of fencing around stormwater ponds requires a Design Variation approved by the State Roadway Design Engineer. Where approved, make sure fences are context sensitive and do not detract from the appearance of the ponds or adjoining property.

When requesting the approval of a Design Variation to install fence around stormwater management facilities, the conditions below, when properly documented, typically are acceptable justifications for ponds designed to be permanently wet (permanent design water depth of two feet or greater):

- Above-water pond slopes steeper than 1:4 are unavoidable. Note: Stormwater permits typically require wet ponds to be fenced when the above-water slopes of the pond are steeper than 1:4. Ponds that enjoy the benefit of fence at the right-of-way line need no additional fencing around them.
- A hidden hazard occurs within five feet of the water's edge. Examples of a hidden hazard are a sharp drop off, such as a 1:2 slope, sharp objects, or otherwise potentially injurious, hidden, underwater hazards.
- The site is likely to experience significant exposure to children or the elderly. Examples of such locations are ponds immediately adjacent to schools, daycares, assisted living facilities, nursing homes, public playgrounds, public basketball courts, etc.

In addition, when requesting the approval of a Design Variation to install fence around ponds of any water depth, the conditions below, when properly documented, are typically acceptable justifications:

- Livestock are expected to wander into the stormwater management facility
- Illicit dumping has historically occurred or is expected to occur

~~5.~~6. Access Easements:

When pond areas are not accessible directly from the road right-of-way, provide an access easement.

~~6.~~7. Seepage:

When diking or berming a stormwater pond above surrounding grade, evaluate seeping and piping and consult geotechnical expertise for the stability of the earthwork berm. Avoid planting woody species with developed root structures on embankment berms, as this can cause piping and geotechnical failures.

~~7.~~8. Traversable Pond Overflow:

Design and construct all berm-style weirs in pond or swale berms to be traversable. Berm-style weirs require a structural and geotechnical design to support the loading of maintenance vehicles without failure.

| **Modification for Non-Conventional Projects:** |
| --- |
| Do not use any proposed berm-style weirs, trapezoidal or otherwise, unless explicitly allowed in the RFP. |

#### 5.4.4.3 Floodplain Compensation Areas (FCA)

Ancillary stormwater storage facilities that are not designed for treatment or attenuation and are a separated feature from the SMF must meet the following minimum criteria:

1. When FCAs are not accessible directly from the road right-of-way, provide an access easement. Discuss maintenance needs with the Department before acquiring additional right-of-way to construct maintenance access around the full perimeter.
2. Provide side slopes 1:4 (Vertical to Horizontal) or flatter to the bottom of the floodplain compensation area.
3. When applicable, follow the fencing, seepage, and traversable pond overflow criteria listed in ***Section 5.4.4.2***.

## 5.5 DOCUMENTATION

The documentation for stormwater management facilities or alternative watershed regional approach must justify the facility and describe the design and operation. At a minimum, the documentation will include:

1. Stormwater Management Alternatives Report (SMARt), required only if regional stormwater approach is evaluated.
   a. Documentation of meetings of significance

i. Internal Communication: *District Stormwater Team* (PM, Champion, Drainage Engineer, Permit Coordinator, PD&E Engineer, NPDES Coordinator, Environmental Manager, ETDM Coordinator).
ii. External Communications: WMD/DEP Pre-Application Meeting(s), Stakeholders, etc.

~~1.~~2. Pond Siting Report (PSR), required only if additional right-of-way is obtained for the pond, consisting of:

a. Identification of alternate pond sites
b. For each alternate, at a minimum include preliminary information about:
   i. Right-of-way costs
   ii. Water quality and quantity volumes
   iii. Soil and groundwater conditions
   iv. Potential hazardous waste contaminations
   v. Estimated impacts to wetlands and other surface waters
   vi. Potential impacts to endangered species and wildlife habitats
   vii. Potential impacts to cultural resources
   viii. Potential impacts to utilities
   ix. Potential impacts to existing landscapes and adjoining land uses
   x. Aesthetic effects and landscaping opportunities
   xi. Construction costs including earthwork

~~2.~~3. Drainage Map

~~3.~~4. Evidence of Field Review

~~4.~~5. Description of applicable regulatory requirements, including but not limited to: how the project does not exceed permitting thresholds, applicable exemption(s), and/or criteria used for designing the stormwater management system.

~~5.~~6. Description of pre-developed runoff characteristics, such as basin boundaries, outfall locations, peak runoff rates, and methods of conveyance.

~~6.~~7. Description of post-developed runoff characteristics, such as those listed in item 5, above

~~7.~~8. Schematic of interconnected ponds (if applicable)

~~8.~~9. Description of the operation of the facility; this will be used by design reviewers, but is intended for maintenance personnel who may have to certify that the facility is operating as designed

~~9.~~10. Soils and groundwater information

~~10.~~11. Stage versus storage values

~~11.~~12. Documentation of the ~~facility~~ BMPs and/or SMFs meeting the treatment and attenuation criteria as required by the regulatory agency

~~12.~~13. Electronic file of routing, modeling, or calculations

14. Design deviations and variations

15. Coordination with District NPDES Coordinator, if applicable

~~13.~~16. Coordination with District Maintenance Office, if applicable

~~14.~~17. Any special maintenance requirements

~~15.~~18. Justification for ~~any~~ proposed pond fencing, if applicable

~~16. Documentation of ELA/WATERSS efforts and results~~

~~17.~~19. Description of how pond aesthetics are addressed

~~18.~~20. Additional information as requested by the District Drainage Engineer

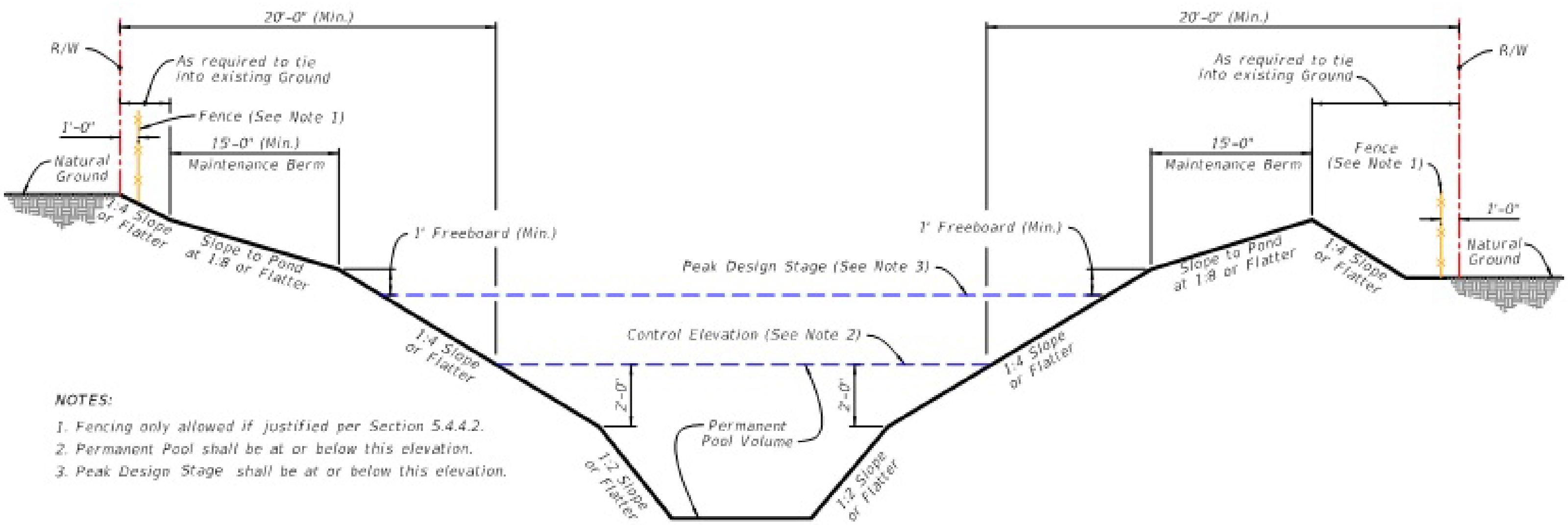



**Figure 5-~~1~~. 2: Minimum Clearance for ~~Retention-Detention Pond~~Stormwater Management Facilities**

# CHAPTER 6

# OPTIONAL CULVERT MATERIALS



## LIST OF TABLES

## 6.1 INTRODUCTION

Analyze optional culvert materials for all culvert applications including, but not limited to, storm drains, cross drains, side drains, gutter drains, vertical drains, and French drains. Evaluate all culvert materials shown in ***Table 6-1*** for the application being designed. Evaluate the functionally equivalent performance in three areas: durability, structural capacity, and hydraulic capacity.

## 6.2 DURABILITY

Design culverts for a design service life (DSL) appropriate for the culvert function and highway type. Department requirements for DSL are provided in ***Table 6-1***. The projected service life of pipe material options called for in the plans will satisfy, as a minimum, the DSL. Do not reduce pipe material standards when projected service life exceeds DSL.

In estimating the projected service life of a material, evaluate the actual performance of the material in nearby similar environmental conditions, its theoretical corrosion rate, the potential for abrasion, and other appropriate site factors. Base theoretical corrosion rates on the environmental conditions of both the soil and water. At a minimum, evaluate the following corrosion indicators:

1. pH
2. Resistivity
3. Sulfates
4. Chlorides

Base all tests for the above characteristics on FDOT-approved test procedures. For projects with a small amount of pipe, to avoid unnecessary site-specific testing, generalized soil maps may be used to delete unsuitable materials from consideration. When known, also evaluate the potential for future land use changes or other environmental changes that may change soil and water corrosion indicators such as saltwater intrusion.

### 6.2.1 Culvert Service Life Estimation

Use the latest web-based version of the Culvert Service Life Estimator (CSLE) Program, tables, and figures (found in ***Chapter 8*** and ***Appendix M*** of the ***Drainage Design Guide, DDG***), and criteria stated below to evaluate the estimated service life for the following culvert materials:

| | |
|---|---|
| Galvanized Steel: | ***DDG Figure M-1*** and ***DDG Table M-1*** |
| Aluminized Steel: | ***DDG Figure M-2*** and ***DDG Table M-2*** |
| Aluminum: | ***DDG Figure M-3*** and ***DDG Table M-3*** |
| Reinforced Concrete: | ***DDG Figure M-4*** and ***DDG Table*** **M-4** |
| Non-reinforced Concrete: | 100 Years (pH ≥ 4.0) |
| HDPE Class-II: | 100 Years |
| HDPE Class-I: | 50 Years |
| Polypropylene (PP) Class-II: | 100 Years |
| PP Class-I: | 50 Years |
| Steel Reinforced Polyethylene (SRPE)-Ribbed | 100 Years |
| SRPE-Corrugated | 50 Years |
| F949 PVC | 100 Years |
| Other Polyvinyl Chloride: | 50 Years |

Note: Estimated Service Life for metal pipe may be increased by 10 years if it is coated with a bituminous coating.

The Culvert Service Life Estimator Program is available here: FDOT Culvert Service Life Estimator Application

## 6.3 STRUCTURAL EVALUATION

***Appendix C*** provides minimum and maximum cover requirements. The Appendix C cover requirements do not include loadings from structural walls. ***Section 6.5*** addresses the structural adequacy of pipes in proximity to structural walls. Evaluate the minimum thickness established to meet durability requirements to assure structural adequacy and increase it if necessary. Evaluate materials and sizes not listed in ***Appendix C*** using the guidelines found within the latest edition of the ***AASHTO LRFD – BDS,*** and industry recommendations and modified as necessary to be consistent with ***Appendix C*** and any applicable specifications and installation procedures.

## 6.4 HYDRAULIC EVALUATIONS

The hydraulic evaluation is intended to establish the hydraulic size in accordance with the design standards provided in the ***Drainage Manual*** for specific culvert application. For storm drains and cross drains, use the Manning's roughness coefficient associated with concrete pipe, spiral rib pipe, polyethylene pipe, and polyvinyl chloride pipe.

For side drains, the hydraulic design considers a one-size design. If a material type is inappropriate, eliminate it as an option in the plans.

In addition, ***Standard Specification*** **430-4.1** requires hydraulic evaluation to verify that the standard joint performance, is sufficient. For situations where the minimum joint performance as required by the ***Standard Specifications*** is not sufficient, provide special provisions to specify the proper joint in the plans. For example, a pump station with a small-diameter pressurized storm drain should use a high-pressure joint. (Note: Joints are tested and rated by the State Materials Office.)

## 6.5 PIPES WITHIN WALLED EMBANKMENT SECTIONS

Wall Zone ~~pipes~~ Pipes are defined as pipes, existing or proposed, that are: (1) within or adjacent to embankment retaining walls, (2) connected to inlets that are within embankment retaining walls, or (3) beneath a bridge substructure element, such as an end bent or pier.

For proposed Wall Zone Pipes, ~~I~~increase the pipe diameter to accommodate future lining.

When incorporating existing pipes within or adjacent to proposed retained earth embankments sections, assess the condition of the pipe (both water tightness and structural adequacy under the proposed loading) and confer with the geotechnical and structural engineers. Existing pipes must meet the structural, hydraulic joint, and wall zone criteria listed within this Chapter and ***Specification 430***.

Identify ~~wall zone pipes~~ Wall Zone Pipes on the ~~optional materials sheet~~ Optional Pipe Materials Tabulation. Refer to ***Appendix D*** for wall types and criteria.

## 6.6 CULVERT MATERIAL TYPES

Consider the types of culvert materials for the various culvert applications from the list below.

Extend existing culverts (side drains, storm drains, and cross drains) with the existing pipe material. If the existing pipe material is no longer produced, use the most similar material available, i.e., extend fiber reinforced concrete pipe with concrete pipe (RCP or NRCP).

| Application | Materials to be Considered |
|---|---|
| Cross Drain<br>French Drain<br>Side Drain<br>Storm Drain | Aluminized Steel<br>Aluminum<br>Concrete (all approved types)<br>Corrugated Polyethylene (60” maximum)<br>Steel Reinforced Polyethylene (120” Maximum)<br>Polyvinyl Chloride (42” maximum)<br>Polypropylene (60” maximum)<br>Galvanized Steel |
| Gutter Drain | Corrugated Aluminized Steel (n > 0.020)<br>Corrugated Aluminum (n > 0.020)<br>Corrugated Steel (n > 0.020) |
| Vertical Drain | Ductile Iron (In saline environments, consider fiberglass reinforced pipe with welded joints, F949 PVC, and steel pipe) |
| Wall Zone Pipes | Polyvinyl Chloride (42” maximum)<br>Polypropylene (60” maximum)<br>Steel |

Present the acceptable pipe materials for side drains, storm drains, and cross drains in the plans. The ***FDM*** illustrates a method of presenting the acceptable pipe materials in the plan.

## 6.7 JACK AND BORE

When installing drainage structures using jack and bore, use the casing as the carrier pipe except under railroads or in high-pressure designs. You can find information on calculating pipe thickness for corrosion resistance in the ***CSLE*** (latest web-based version) and in the ***Drainage Design Guide.***

## 6.8 DOCUMENTATION

The documentation for optional pipe materials will justify eliminating material types. Include, at a minimum, the following:

1. DSL required
2. Soil and water corrosion indicators used in estimating service life
3. Estimates of service life at cross drains and at various locations of storm drain systems
4. Structural evaluation
   a. comparison of maximum and minimum cover heights to actual cover height.
   b. LRFD calculations for wall zone pipes, if applicable.

| **Modification for Non-Conventional Projects:** |
|---|
| The above documentation in Section 6.8 will be required only for the pipe materials selected for use. Document the selected materials on one of the following: Summary of Drainage Structures Sheets, Optional Materials Sheet, or the plan sheets during design. |

## Table 6-1: Culvert Material Applications and Design Service Life

| Application | | Storm Drain | | Cross Drain | | Side Drain[4] | Gutter Drain | Vertical Drain[10] | Wall Zone Pipe | French Drain | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Highway Facility (see notes) | | Minor | Major | Minor | Major | All | All | All | All | Replacement will Impact the Roadway[5] | | Other |
| | | | | | | | | | | Minor | Major | All |
| Design Service Life → | | 50 | 100 | 50 | 100 | 25 | 25[6] | 100 | 100 | 50 | 100 | 50 |
| Culvert Material | | An * indicates suitable for further evaluation | | | | | | | | | | |
| PIPE | Corrugated Aluminum Pipe | * | * | * | * | * | * | | | * | * | * |
| | Corrugated Steel Pipe | * | * | * | * | * | * | | | * | * | * |
| | Corrugated Aluminized Steel | * | * | * | * | * | * | | | * | * | * |
| | Spiral Rib Aluminum Pipe | * | * | * | * | * | | | | * | * | * |
| | Spiral Rib Steel Pipe | * | * | * | * | * | | | | * | * | * |
| | Spiral Rib Aluminized Steel | * | * | * | * | * | | | | * | * | * |
| | Steel Reinforced Concrete Pipe | * | * | * | * | * | | | | * | * | * |
| | Non-reinforced Concrete Pipe | * | * | * | * | * | | | | * | * | * |
| | Polyethylene Pipe – Class I | * | | * | | * | | | | * | | * |
| | Polyethylene Pipe – Class II[8] | * | * | * | * | * | | | | * | | * |
| | Polypropylene Pipe -Class I | * | | * | | * | | | | * | | * |
| | Polypropylene Pipe -Class II | * | * | * | * | * | | | * | * | * | * |
| | Steel Reinforced Polyethylene Pipe -Ribbed | * | * | * | * | * | | | | | | |
| | Steel Reinforced Polyethylene Pipe -Corrugated | * | | * | | * | | | | | | |
| | Polyvinyl-Chloride Pipe[7] | * | F949 | * | F949 | * | | F949 | * | * | F949 | * |
| | Fiberglass Pipe | | | | | | | * | | | | |
| | Steel pipe (per Spec 556-2.1) | | | | | | | * | * | | | |
| | Ductile Iron Pipe (per Spec 556-2) | | | | | | | * | | | | |
| STR PL | Structural Plate Aluminum Pipe | * | * | * | * | * | | | | | | |
| | Structural Plate Alum. Pipe-Arc | * | * | * | * | * | | | | | | |
| | Structural Plate Steel Pipe | * | * | * | * | * | | | | | | |
| | Structural Plate Steel Pipe-Arch | * | * | * | * | * | | | | | | |
| BOX | Aluminum Box Culvert | * | * | * | * | * | | | | | | |
| | Concrete Box Culvert CBC[11] | * | * | * | * | * | | | * | | | |
| | Steel Box Culvert | * | * | * | * | * | | | | | | |

Table notes are on the following page.

Notes for Table 6-1

1. A minor facility is permanent construction such as minor collectors, local streets and highways, and driveways, provided culvert cover is less than 10 feet. Additionally, this category may be called for at the discretion of the District Drainage Engineer where pipe replacement is expected within 50 years or where future replacement of the pipe is not expected to impact traffic or require extraordinary measures such as sheet piling.
2. A major facility is any permanent construction of urban and suburban typical sections and limited-access facilities. Urban facilities include any typical section with a fixed roadside traffic barrier such as curb or barrier wall. Additionally, rural typical sections with greater than 1,600 AADT also are included in this category.
3. Temporary construction normally requires a much shorter design service life than permanent does. However, treat temporary measures that will be incorporated as permanent facilities as though they are permanent construction with regard to design service life determination.
4. Although culverts under intersecting streets (crossroads) function as side drains for the project under consideration, design these culverts using applicable cross drain service life criteria, not the shorter side drain service life criteria. Use ***Standard Plans, Index 430-022*** for end treatment.
5. Replacing this pipe would require removal and replacement of the project's pavement or curb.
6. Use a 100-year DSL for gutter drains under retaining or through walls.
7. F949 PVC pipe service life is 100 years. Other PVC pipe has a 50-year service life. Do not use PVC pipe in direct sunlight unless it meets the requirements of ***Standard Specification 948-1.1***.
8. Class II HDPE pipe may not be used in the Florida Keys.
9. For any pipes under or adjacent to permanent structures such as retaining walls, MSE walls, buildings, etc., use a 100-year DSL.
10. Resilient connectors are required for all vertical pipes and wall zone pipes.
11. For wall zone pipe, concrete box culvert is only an option if cast in place with no joints.