

# USER MANUAL – PCM-FSD PRELIMINARY DESIGN

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## LIST OF ABBREVIATIONS

City	City of Colorado Springs
CDPHE	Colorado Department of Public Health and Environment
CDPS	Colorado Discharge Permit System
C.R.S.	Colorado Revised Statutes
DCM	Drainage Criteria Manual
EPA	Environmental Protection Agency
EDB	Extended Detention Basin
EURV	Excess Urban Runoff Volume
FSD	Full Spectrum Detention
GB	Grass Buffer
GS	Grass Swale
MS4	Municipal Separate Storm Sewer System
PCM	Permanent Control Measure
PPS	Permeable Pavement Systems
RG	Rain Garden
RP	Retention Pond
SWMM	Storm Water Management Model
WB	Wetland Basin
WQCD	Water Quality Control Division
WQCV	Water Quality Capture Volume

# CHAPTER 1

## INTRODUCTION

<b>1.0 Introduction</b>	<b>a</b>
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## 1.0 INTRODUCTION

Protecting the quality of stormwater runoff is important to the City of Colorado Springs (City), and is required by the Colorado Discharge Permit System (CDPS) Regulations. The policies and guidance described in this user manual is pursuant to the **Municipal Code of the City, Colorado, Chapter 7, Article 7, Part 15.** The Colorado Department of Public Health and Environment (CDPHE), Water Quality Control Division (WQCD), through the Municipal Separate Storm Sewer System (MS4) permit issued to the City, requires the City to control and reduce the discharge of pollutants to protect stormwater quality and to satisfy the appropriate water quality requirements of the Colorado Water Quality Control Act (§ 25-8-101 et seq., C.R.S.) and the Colorado Discharge Permit Regulations (Colorado Regulation No. 61). The City's MS4 permit requires the City to implement a program to reduce the discharge of pollutants from public and private **construction sites, and the process described herein is a part of the approved construction program.**

## 2.0 PURPOSE OF MANUAL

This manual, entitled *User Manual – PCM-FSD Preliminary Design*, provides the workbook user with instructions for user input requirements and a description of calculated results. Results in the workbook are typically calculated based on user inputs in one column and the adjacent column represents the calculated results based on City DCM requirements and recommendations. When the two columns are identical, the second column will be greyed out for simplicity. However, where results differ, the second column will remain prominent to help reviewers identify where discrepancies occur. If the differences are significant enough and the user input values are outside of City requirements or recommendations the results will be flagged. Orange flagged messages are used when the user input value is not within City DCM recommended guidance. Red flagged messages are used when the user input value does not meet City DCM requirements.

This document contains both requirements and recommended guidance. Requirements are denoted by verbs such as "shall" and "must," while guidance is denoted by the use of "should" or is specifically called out as guidance or recommendations.

Revisions to this document may be incorporated as necessary. The policies and procedures herein may be subject to change if they are found to no longer be effective or compliant with the City's MS4 requirements. It is the responsibility of applicants to obtain the latest revision to this document.

City staff will review project submittals for compliance with this manual and with the ultimate goal of reducing the pollution of state surface waters. The provisions in this manual shall be regarded as the minimum requirements for Permanent Control Measures and Detention Facilities. The City does not and will not assume liability for design and construction deficiencies by others.

### 3.0 RELATIONSHIP OF THIS USER MANUAL TO OTHER PUBLISHED CRITERIA AND REGULATIONS

In the event of a direct and irreconcilable conflict between this user manual, the PCM-FSD Preliminary Design Workbook and other published City criteria, the City Drainage Criteria Manual shall prevail.

Compliance with this manual does not affect a Permittee's obligations to comply with other applicable local, state, and federal criteria and regulations.

### 4.0 REQUEST FOR VARIANCE

Permittees may request variances from the requirements outlined in the PCM-FSD Preliminary Design Workbook and this User Manual. The procedure for requesting variances is described in the City Drainage Criteria Manual. A variance cannot be granted which would create a condition of non-compliance with the City's MS4 permit. Any variance approved by the City will be documented, including a description of the reasons for the approval and a finding that the variance does not create a condition of non-compliance with the City's MS4 Permit.

### 5.0 DEFINITION OF TERMS

Commonly used terms in this manual have been defined as follows for convenience, but this is not intended to be an exhaustive list.

# CHAPTER 2

## PRELIMINARY DESIGN FORM – GRASS BUFFER (GB)

- 1. **Design Discharge** ..... 1
- 2. **Width of Grass Buffer** ..... 1
- 3. **Length of Grass Buffer** ..... 1
- 4. **Grass Buffer Slope** ..... 1
- 5. **Flow Characteristics (sheet or concentrated)** ..... 2
- 6. **Flow Distribution for Concentrated Flows** ..... 2
- 7. **Soil Preparation** ..... 2
- 8. **Vegetation** ..... 3
- 9. **Irrigation** ..... 3
- 10. **Outflow Collection** ..... 3



Installing a Grass Buffer (GB) PCM helps reduce the effective imperviousness of the tributary catchment and reduces the volume of runoff reaching downstream receiving waters. A Grass Buffer does not provide a WQCV/EURV capture basin or FSD flood routing. Instructions for the Grass Buffer are organized to be consistent with the section numbering seen on the Grass Buffer worksheet.

## 1. DESIGN DISCHARGE

The design discharge for a Grass Buffer is based on the 2-year peak flow rate (cfs) from the tributary drainage area that will be directed across the Grass Buffer.

## 2. WIDTH OF GRASS BUFFER

The width of the grass buffer is measured normal (perpendicular) to the flow direction and is ideally the same width as the contributing basin. It is recommended that the width be a minimum of 20 feet for each 1 cfs of design discharge. For example, if the design discharge is 2.5 cfs, the minimum recommended width would be 50 feet. The larger the width per unit flow, the greater the opportunities for infiltration and reduction in surface runoff. If the user input width does not meet this recommendation, a warning message will be displayed.

## 3. LENGTH OF GRASS BUFFER

The length of the grass buffer is measured in the flow direction and should be a minimum of 14 feet long. Research has shown that pollutant removal continues throughout a length of 14 feet. Beyond this length, a point of diminishing returns in pollutant reduction was found. Shorter lengths will still provide some level of pollutant removal where site constraints limit the available length, so providing some grass buffer is still better than none. If the user input length is less than 14 feet, a warning message will be displayed.

## 4. GRASS BUFFER SLOPE

The slope of the grass buffer is measured in the direction of flow and is input in units of vertical distance / horizontal distance (ft/ft). The grass buffer slope shall not exceed 0.10 ft/ft (10%) in order to prevent erosion and encourage infiltration. If the user input slope is greater than 10%, a warning message will be displayed. It is also recommended that a minimum slope of 0.02 ft/ft (2%) be used in order to facilitate positive drainage. For slopes less than 2%, it is recommended that an underdrain system be installed to mitigate nuisance drainage and a warning message will be displayed stating this.

## 5. FLOW CHARACTERISTICS (SHEET OR CONCENTRATED)

5.A) Does runoff flow into the grass buffer across the entire width of the buffer – Select Yes or No from the option buttons to answer this question. If the width of the grass buffer entered in Section 2 above is greater than or equal to the width of the tributary drainage area, then select Yes and proceed to Sections 5.B and 5.C to determine if sheet flow or concentrated flow conditions exist. However, if the grass buffer width is less than the width of the tributary drainage, concentrated flow conditions exist and flow distribution will be required in Section 6.

5.B) Watershed Flow Length – The watershed flow length refers to the flow path length from the furthest upstream point in the tributary drainage area to the interface with the upstream edge of the grass buffer.

5.C) Interface Slope – The interface slope is the slope normal to the flow direction at the boundary of the tributary drainage area and the grass buffer. The flatter the interface slope, the more likely the runoff to the grass buffer is sheet flow. For steeper interface slopes, the runoff is most likely concentrated flow at the lower side.

The program will then multiply the user inputs for Watershed Flow Length and Interface Slope to determine the flow characteristics of the site. If the product is less than or equal to 2.0, sheet flow conditions exist. For a product greater than 2.0, concentrated flow conditions exist. If concentrated flow conditions exist the user will need to select a flow distribution method in Section 6.

## 6. FLOW DISTRIBUTION FOR CONCENTRATED FLOWS

In order to achieve the desired water quality benefits, flows delivered to a grass buffer must exhibit sheet flow conditions. If sheet flow is indicated in Section 5, the user can select “None” from the available option buttons. However, if concentrated flow conditions exist, the user must select a flow distribution method to spread the flow uniformly across the upstream edge of the grass buffer. Options include “Slotted Curbing”, “Level Spreader”, or “Other”. After selecting a method, a more detailed description should be provided in the space below.

## 7. SOIL PREPARATION

Describe soil preparation and/or soil amendments that will be used to promote the initial growth of the grass buffer and to ensure its long-term health. When the site is graded, topsoil should be stockpiled and reused when possible. When topsoil is inadequate or not available, soil amendments may be necessary. Typically, 3 to 5 cubic yards of soil amendment (compost) per 1,000 square feet, tilled 6 inches into the soil is necessary in order for vegetation to thrive and to enable sufficient infiltration capacity.



## 8. VEGETATION

Select the type of vegetation that will be used for the Grass Buffer from the available options. Available options include "Existing Xeric Turf Grass" (e.g. drought tolerant native grasses), "Irrigated Turf Grass", and "Other". Durable, dense, and drought tolerant grasses are ideal. The effectiveness of grass buffers starts to decline significantly when the vegetation density falls below 80%. Provide a detailed description of the seed mix being used in space available.

## 9. IRRIGATION

Select the type of irrigation that will be used for the grass buffer. "Temporary" indicates that irrigation will be provided long enough to help establish the vegetative cover. "Permanent" indicates that a long-term irrigation system will be installed to establish and maintain the vegetative cover during periods of drought. If the grass buffer will utilize an area with existing vegetation (minimum of 80% vegetation coverage) and will not be disturbed during construction, then "None" can be selected.

## 10. OUTFLOW COLLECTION

Explain where the outflow from the grass buffer will be conveyed. Available options include "Grass Swale", "Street Gutter", and "Other". Grass Swales are preferred because they provide additional water quality benefits. If a concrete swale is used to collect the outflow, select "Street Gutter" and describe in the space provided. For "Other" provide a description of the outflow collection method.

## CHAPTER 3

### PRELIMINARY DESIGN FORM – GRASS SWALE (GS)

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Installing a Grass Swale (GS) PCM helps reduce the effective imperviousness of the tributary catchment and reduces the volume of runoff reaching downstream receiving waters. A Grass Swale does not provide a WQCV/EURV capture basin or FSD flood routing. Instructions for the Grass Swale are organized to be consistent with the section numbering seen on the Grass Swale worksheet. Refer to the figures in the worksheet, located to the right of the preliminary design form, for guidance and explanation of the various terms used here.

## 1. HYDRAULIC PARAMETERS FOR DESIGN OF SWALE

1.A) Design Discharge for 2-Year Return Period – The design discharge for a Grass Swale is based on the 2-year peak flow rate (cfs) from the tributary drainage area that will be directed to the Grass Swale. This serves as a surrogate for the sizing and velocity control of the water quality swale.

1.B) Max 2-Year Flow Velocity – Enter the maximum allowable velocity for the design discharge. The City DCM requires a velocity  $\leq 1.0$  fps. Below this velocity, fine sand-sized and larger particles will settle out and erosion potential is limited. Velocities greater than 1.0 fps will be flagged.

1.C) Max 2-Year Flow Depth – Enter the maximum allowable depth for the design discharge. The City DCM requires a depth  $\leq 1.0$  ft. Below this depth, particles will have time to settle to the bottom while still within the swale. Depths greater than 1.0 foot will be flagged.

## 2. AVERAGE HYDRAULIC RESIDENCE TIME

The average hydraulic residence time is calculated for informational purposes only and is not used in subsequent sizing or design calculations. Increased hydraulic residence time in a grass swale improves water quality treatment.

2.A) Length of Grass Swale – Enter the approximate length of the grass swale. If flow enters at the upstream end of the swale then enter the full length. However, if flow enters the grass swale laterally along its length then it is recommended that the length used to calculate the residence time be shortened.

2.B) Calculated Average Residence Time – The residence time is calculated based on the swale length divided by the calculated design velocity (from Section 15, discussed below). The residence time can be increased by increasing the swale length. If the swale length is limited due to site constraints, the residence time can be increased by decreasing the velocity. This can be achieved by flattening the slope or increasing the cross-sectional area.

### 3. LONGITUDINAL SLOPE

The Grass Swale Preliminary Design Form allows the user to enter upper and lower bounds on the design slope in order to constrain the program calculations within reasonable limits. All slopes are entered as vertical distance / horizontal distance, V/H (ft/ft).

3.A) Maximum Available Slope – Enter the maximum available overland slope based on the site topography. This is constrained by the site grading at the inlet to the swale and the elevation of the swale outfall.

3.B) Minimum Design Slope Specified by User – Enter the minimum allowable design slope (lower bound of program calculations). A minimum slope of 0.001 ft/ft is recommended as a lower bound on calculations. However, it should be noted that if the design slope is less than 0.02 ft/ft, an underdrain will be required to maintain positive drainage.

3.C) Maximum Design Slope Specified by User – Enter the maximum allowable design slope (upper bound of program calculations). The maximum design slope cannot exceed the maximum available slope in 3.A. For water quality enhancement and to maximize infiltration, a maximum slope of 0.03 ft/ft is recommended. Use drop structures as necessary to accommodate site constraints.

### 4. SWALE GEOMETRY

Provide the grass swale geometry. The cross section should be either triangular or trapezoidal. Increase the wetted area of the swale to reduce velocity and improve pollutant removal efficiency and volume reduction.

4.A) Channel Side Slope #1 – Enter the side slope for one side of the swale. The City DCM recommends side slopes not exceeding 4:1 H:V, or flatter. If one or both sides of the grass swale will be used as a grass buffer, follow grass buffer criteria.

4.B) Channel Side Slope #2 – Enter the side slope for the other side of the swale. The City DCM recommends side slopes not exceeding 4:1 H:V, or flatter

4.C) User Specified Minimum Bottom Width of Swale – Enter the minimum allowable bottom width for the grass swale. For a triangular swale, enter a bottom width of zero. For a trapezoidal swale, enter a bottom width greater than zero. It should be noted that if the bottom width needs to be larger to satisfy the maximum velocity and depth constraints, the program will calculate the necessary bottom width in Section 8 below.

## 5. VEGETAL RETARDANCE

The vegetal retardance defines the channel roughness based on selected condition of vegetation.

5.A) NRCS Curve – Select the appropriate NRCS Curve (C, D, or E) from the option buttons based on the anticipated long-term condition of the vegetation. The selected curve is used to determine the applicable Manning’s n based on the Velocity \* Hydraulic Radius product (VR) as explained in Section 13 below. The Curves reflect vegetation type, cover density and height when fully established. Descriptions of the various curves are provided in the worksheet to the right of the Preliminary Design Form.

**Once Sections 1-5 have been completed, click on the “Calculate Results” button to populate the results for Sections 6-18. If any of the inputs for 1-5 are changed, the button will need to be clicked again to populate the new results. The program uses an iterative approach to solve for the Manning’s n and flow depth necessary to meet the design constraints specified in Sections 1-5.**

## 6. CALCULATED LONGITUDINAL SLOPE

The program will calculate the longitudinal slope (within the specified min/max bounds) necessary to satisfy the user specified maximum velocity, maximum depth, swale geometry, and vegetal retardance.

## 7. CUMULATIVE HEIGHT OF GRADE CONTROL STRUCTURES REQUIRED

The cumulative height of grade control structures is calculated as the difference between the physically available slope (3.A) and the calculated design slope (6) multiplied by the length of the swale (2.A). This helps to identify how many vertical drop structures may be needed to maintain the design slope based on the site topography.

## 8. BOTTOM WIDTH

The user specifies the minimum allowable bottom width in Section 4.C. However, if the program determines that a larger bottom width is necessary to satisfy the maximum velocity and depth constraints, the new bottom width will be shown here.

## 9. FLOW AREA

The flow cross-sectional area is calculated based on the design discharge, swale geometry, and the calculated flow depth (Section 16 below).

## 10. TOP WIDTH OF SWALE AT WATER SURFACE

The water surface top width is calculated based on the design discharge, swale geometry, and the calculated flow depth (Section 16 below).

## 11. WETTED PERIMETER

The wetted perimeter is calculated based on the design discharge, swale geometry, and the calculated flow depth (Section 16 below).

## 12. HYDRAULIC RADIUS

The hydraulic radius is calculated as the flow area (Section 9) divided by the wetted perimeter (Section 11).

## 13. VELOCITY-HYDRAULIC RADIUS PRODUCT FOR VEGETAL RETARDANCE

The Velocity-Hydraulic Radius (VR) product is calculated by multiplying the calculated flow velocity (Section 15 below) by the hydraulic radius (Section 12). The VR product is then used by the program to find the effective Manning's n for the swale at the calculated velocity and depth.

## 14. MANNING'S N

Manning's n is calculated based on the VR product (Section 13) and the NRCS Curve selected (Section 5).

## 15. FINAL CALCULATED VELOCITY

The calculated flow velocity in the grass swale is typically less than or equal to the maximum allowable velocity specified (Section 1.B). The calculated velocity indicates how well the design meets the DCM recommendations and whether design adjustments may be warranted. If the calculated velocity exceeds 1.0 fps, the result will be flagged.

## 16. FINAL CALCULATED FLOW DEPTH

The calculated flow depth in the grass swale is typically less than or equal to the maximum allowable depth specified (Section 1.C). The calculated depth indicates how well the design meets the DCM recommendations

and whether design adjustments may be warranted. If the calculated depth exceeds 1.0 ft, the result will be flagged.

## 17. FROUDE NUMBER

The calculated Froude Number indicates if the flow in the grass swale is subcritical or supercritical. For water quality purposes, subcritical flow is essential and a value less than 0.5 indicates a mild and stable flow. If the calculated Froude Number exceeds 0.5, the result will be flagged.

## 18. FINAL CALCULATED FLOW

The Final Calculated Flow is based on the Manning's equation using calculated results for Manning's n, flow area, hydraulic radius, and slope. The calculated flow result is provided to show how close the iterative solution used by the program is to the 2-year design discharge specified in Section 1.A.

## 19. UNDERDRAIN

Select "Yes" or "No" to indicate whether an underlain is used. An underdrain is recommended when the longitudinal slope is less than 0.02 ft/ft (2%), particularly in fine-grained soils, to minimize the likelihood of developing boggy conditions along the bottom of the grass swale and creating a nuisance condition.

## 20. SOIL PREPARATION

Describe soil preparation and/or soil amendments that will be used to promote the initial growth of the grass swale and to ensure its long-term health. When the site is graded, topsoil should be stockpiled and reused when possible. When topsoil is inadequate or not available, soil amendments may be necessary. Typically, 3 to 5 cubic yards of soil amendment (compost) per 1,000 square feet, tilled 6 inches into the soil is necessary in order for vegetation to thrive and to enable sufficient infiltration capacity.

## 21. IRRIGATION

Select the type of irrigation that will be used for the grass swale. "Temporary" indicates that irrigation will be provided long enough to help establish the vegetative cover. "Permanent" indicates that a long-term irrigation system will be installed to establish and maintain the vegetative cover during periods of drought. If the grass swale will utilize an area with existing vegetation (minimum of 80% vegetation coverage) and will not be disturbed during construction, then "None" can be selected.



## CHAPTER 4

# PRELIMINARY DESIGN FORM – PERMEABLE PAVEMENT SYSTEMS (PPS)

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7.	Impermeable Geomembrane Liner and Geotextile Separator Fabric.....	4
8.	Outlet.....	5

Installing a Permeable Pavement System (PPS) can help to reduce the effective imperviousness of the tributary catchment and can reduce the volume of runoff reaching downstream receiving waters if partial or full infiltration is incorporated. A Permeable Pavement System also provides a WQCV/EURV capture basin. The current workbook does not link the PPS to the FSD Routing worksheet and therefore does not provide calculations for flood routing should a storage basin be provided above the PPS surface for larger storm events. Instructions for Permeable Pavement Systems are organized to be consistent with the section numbering seen on the PPS worksheet. Refer to the figures in the worksheet, located to the right of the preliminary design form, for guidance and explanation of the various terms used here.

## 1. TYPE OF PERMEABLE PAVEMENT SYSTEM

1.A) What type of infiltration approach is used – Based on subgrade conditions and soil/geology, select whether this installation will have full infiltration without underdrains (subgrade capable of providing continuous saturated infiltration rate  $> 1.0$  in/hr), have partial infiltration with underdrains used to carry away discharges exceeding infiltration rates, or will have underdrains with no infiltration because the subgrade is composed of expansive clays or the tributary land uses are likely to result in conditions that may contaminate the groundwater. Depending on the selection made by the user here, some sections below may not be applicable or choices within a section may be limited.

1.B) What type of wearing course is used – Select the type of permeable pavement being used on the site. There are four options, namely, Permeable Interlocking Concrete Pavement (PICP), Concrete Grid Pavement, Pervious Concrete, or Porous Gravel.

It has been observed that that pervious concrete constructed using #7, #8, and #9 stone tends to unravel at the surface within few years after installation at sites subject to freeze-thaw conditions. However, pervious concrete constructed using AASHTO #67 stone has been observed to be significantly more durable, but less visually attractive.

## 2. REQUIRED PORE STORAGE VOLUME

The entries in this section are used to determine the Impervious Tributary Ratio and the required WQCV.

2.A) Tributary Watershed Area – Enter the tributary watershed area (acres) including the permeable pavement area.

2.B) Effective Imperviousness of Tributary Area – Enter the effective imperviousness (percent) of the total tributary area including the permeable pavement area. Use 100% imperviousness for the PPS area when calculating the composite imperviousness for the total tributary area.

2.C) Area of Permeable Pavement – Enter the permeable pavement area (acres). It is recommended that the maximum ratio of tributary impervious area to permeable pavement area not exceed 2.0. The minimum recommended permeable pavement area required to meet the ratio of 2.0 based on the total area and effective imperviousness is shown in the description to the left of the input cell. The ratio of 2.0 is recommended to extend the life of pavement's infiltrating capacity between power vacuum cleanings and surface rehabilitation. If the permeable pavement area results in a ratio less than 2.0, the input value will be flagged.

2.D) Impervious Tributary Ratio – The impervious tributary ratio is calculated by dividing the contributing impervious area (2.A \* 2.B) by the permeable pavement area (2.C). If the impervious tributary ratio is greater than 2.0, the result will be flagged and the user should reevaluate the design.

2.E) Drain Time (DT) needed to completely empty WQCV – Enter the drain time needed to empty the WQCV from the available pore volume below the pavement. The City DCM requires a minimum drain time of 12-hours to provide sufficient residence time for removal of pollutants and to mitigate downstream impacts due to hydrologic changes of the catchment on the geomorphology of the downstream receiving waters. If a drain time less than 12 hours is used the input will be flagged.

2.F) Water Quality Capture Volume (WQCV) – Enter the design WQCV for the tributary area (watershed inches). The program will show the required WQCV specified by the DCM for comparison and will flag your entry if it is less than the DCM value.

2.G) Is flood control volume being included – Indicate by selecting "Yes" or "No" whether the PPS design will include flood control storage in excess of the required WQCV within the pore storage volume. When designing for flood control volumes, provide an overflow that will carry runoff in excess of the WQCV directly into the reservoir layer regardless of infiltration rates. A gravel strip or inlet that is connected to the reservoir can provide this overflow path.

2.H) Total Volume Required – If "Yes" was selected in Section 2.G, then enter the total volume (WQCV plus flood control volume) that will need to be stored in the pore space of the gravel media.

### 3. DEPTH OF RESERVOIR BELOW PERMEABLE PAVEMENT

3.A) Depth of Reservoir – The depth of the reservoir refers to the depth of the base coarse where pore storage volume is provided. This depth does not include the wearing course on the surface or the filter material placed below the base course. For design purposes, it is assumed that water storage is provided only in the base course. The minimum recommended depth for this base course storage layer is 6 inches; however, a deeper base course may be needed for additional flood control volume or if the structural design of the pavement requires it. It is recommended that a pavement designer be consulted if anything more than passenger vehicles will use the pavement. Also, the user should assume water saturated subgrade conditions when designing the total depth of the PPS cross-section.

3.B) Is the slope of the reservoir/subgrade interface flat – Select whether the subgrade under the PPS section is flat or sloped. Two design options are available if the subgrade is sloped and the user needs to choose if a stepped or a sloped installation will be used (see figures in the worksheet located to the right of the preliminary design form for reference). For practical reasons, when considering flow in gravel, the user can assume a “flat” installation if the subgrade’s slope is less than 0.005 ft/ft (0.5%). Depending on the type selected, Sections 3.D through 3.F will be greyed out when no longer applicable.

3.C) Porosity – The porosity of the base course is the ratio of void volume in the gravel divided by the total volume of the base course. It is recommended that the porosity be less than or equal to 0.3 in order to assure adequate storage volume. There is always a level of uncertainty in the base course materials being delivered during construction and there is also a need to provide space for sediment accumulation over time resulting in a loss of total pore volume.

3.D) Slope of the Base Course/Subgrade Interface – The user is only required to enter an input for the slope if “Sloped Installation” was selected in Section 3.B. For practical reasons, it is recommended that PPS have a subgrade that is no steeper than 0.04 ft/ft (4%), otherwise the spacing between the flow barriers will be quite small.

3.E) Horizontal Length Between Lateral Flow Barriers – The user is only required to enter a length between lateral flow barriers for stepped or sloped installations. The maximum length based on the user input reservoir depth and subgrade slope is shown in the description to the left of the input cell. The user can enter shorter length if desired. However, if the user enters a longer length the program will flag the entry and the user needs to reevaluate the design with respect to reservoir depth, slope, and lateral flow barrier spacing.

3.F) Number of Cells separated by lateral flow barriers – Enter the total number of storage cells separated by lateral flow barriers. This should equal the total length along installation slope divided by the distance between lateral flow barriers.

3.G) Storage Volume Provided – The program will calculate the approximate storage volume provided in the base course based on the user input cross-section values. If the calculated storage volume is less than the WQCV in Section 2.F (or the total volume including flood control in Section 2.H if selected), the result will be flagged.

## 4. LATERAL FLOW BARRIERS

4.A) Type of Lateral Flow Barriers – Select the type of lateral flow barrier that will be used in stepped or sloped installations to separate the different cells. Lateral flow barriers should be placed parallel to ground contours (normal to flow) and serve to prevent stormwater from resurfacing and washing out infill material. Available options include “Concrete Walls”, “PVC geomembrane installed normal to flow”, “PVC Sheet Piling driven a

minimum of 2 feet into the subgrade”, “N/A – Flat Installation”, and “Other”. If “Other” is selected, enter a description and justification for its use.

## 5. PERIMETER BARRIER

5.A) Is a structural perimeter barrier provided on all sides of the PPS – Indicate by selecting “Yes” or “No” whether the PPS design includes a structural perimeter barrier on all sides. For all “No Infiltration” sections, a reinforced concrete barrier should be provided on all sides. A concrete barrier is required for PICP to prevent separation of interlocking concrete blocks. It is also recommended for concrete grid pavement and for any other type of design using modular units. Explain if a perimeter barrier is not being provided and why.

## 6. FILTER MATERIAL AND UNDERDRAIN SYSTEM

6.A) Is underdrain placed below a 6-inch layer of CDOT Class C filter material – Select “Yes”, “No”, or “N/A” to indicate if a 6-inch layer of filter material has been placed above the underdrain. If “Full infiltration” has been selected in Section 1.A, then “N/A” will automatically be populated in this section. A sand filter layer is recommended when an underdrain is provided because it has been shown by field data to reduce nutrient and bacteria concentrations in the discharge. Also, Class C filter material is recommended when a PPS is located over fine-grained soils (clay, silt, and fine sand) to provide Terzaghi filtering between the layers.

6.B) Diameter of Slotted Underdrain Pipe – Select whether 4” or 6” diameter slotted underdrains will be used. Size the diameter of the underdrain using manufacturers recommendations of inflow, which is based on the area being served by the underdrain.

6.C) Distance from Bottom of Base Course to Center of Outlet Orifice – Enter the vertical distance in inches between the bottom of the base course (pore storage volume) and the centroid of the underdrain outlet control orifice. This should be greater than the depth of the filter media above the underdrain. See the figure on the PPS worksheet to the right of the preliminary design form for guidance.

## 7. IMPERMEABLE GEOMEMBRANE LINER AND GEOTEXTILE SEPARATOR FABRIC

This section is greyed out when “Partial Infiltration” or “Full Infiltration” is selected in Section 1.A. If “No Infiltration” is selected, this section must be completed.

7.A) Is there a minimum 30 mil thick impermeable PVC geomembrane liner – Select “Yes” or “No” to indicate if an impermeable liner will be installed on the bottom and sides of the basin, extending up to the top of the base course.

7.B) CDOT Class B Geotextile Separator Fabric – Select whether the CDOT Class B geotextile liner will be placed above, below, or on both sides of the impermeable liner. CDOT recommends the geotextile fabric to prevent puncture of the impermeable liner whenever it is placed above or below coarse gravel or a rock subgrade.

## 8. OUTLET

This section is greyed out when “Full Infiltration” is selected in Section 1.A. and no underdrains are used. Otherwise the program calculates the ponding depth of water in the storage reservoir and the outlet orifice diameter required to match the user specified drain time. The calculations assume that each cell has similar area, subgrade slope, and length between lateral barriers (unless subgrade is flat, in which case these values are for the entire PPS area). The designer needs to calculate the outlet orifice required for each cell individually when the cells are not equal in size. Explain how this is being done in the design report.

8.A) Depth of WQCV in the Reservoir – The program calculates the maximum ponding depth within the base course storage layer. This depth does not include the depth of the CDOT Class C filter material.

8.B) Orifice Diameter – The program also calculates the orifice diameter required to match the user specified drain time using the standard orifice equation.

## CHAPTER 5

### PRELIMINARY DESIGN FORM – RAIN GARDEN (RG)

1.	<b>Basin Storage Volume</b> .....	1
2.	<b>Basin Geometry</b> .....	1
3.	<b>Impermeable Geomembrane Liner (No Infiltration Design)</b> .....	3
4.	<b>Underdrain System</b> .....	3
5.	<b>Inlet Control at Inflow Point(s)</b> .....	4
6.	<b>Growth Media</b> .....	4
7.	<b>Vegetation</b> .....	5
8.	<b>Irrigation</b> .....	5

The Rain Garden (RG) PCM (also known as Bioretention) is an engineered, depressed landscape area designed to capture the WQCV above the infiltrating surface and then to slowly filter and infiltrate the WQCV. The design of a rain garden may also provide detention for events exceeding the WQCV. In this Workbook, the RG can be linked to the FSD Routing worksheet to provide flood routing for larger runoff events. Instructions for Rain Gardens are organized to be consistent with the section numbering seen on the RG worksheet. Refer to the figures in the worksheet, located to the right of the preliminary design form, for guidance and explanation of the various terms used here.

## 1. BASIN STORAGE VOLUME

1.A) Tributary Watershed Area – Enter the tributary watershed area (acres) including the rain garden area.

1.B) Effective Imperviousness of Tributary Area – Enter the effective imperviousness (percent) of the total tributary area including the rain garden area. Use 100% imperviousness for the RG area when calculating the composite imperviousness for the total tributary area since there is no surface runoff from it.

1.C) Drain Time (DT) needed to completely empty WQCV – Enter the drain time (hours) needed to completely empty the WQCV. The City DCM requires a minimum drain time of 12-hours to provide sufficient residence time for removal of pollutants and to mitigate downstream impacts due to hydrologic changes of the catchment on the geomorphology of the downstream receiving waters. If a drain time less than 12 hours is used the input will be flagged.

1.D) Water Quality Capture Volume (WQCV) – Enter the design WQCV for the tributary area (watershed inches). The program will show the required WQCV specified by the DCM for comparison and will flag your entry if it is less than the DCM value.

The RG design is not intended to capture and store the EURV since the extended drain time would be detrimental to maintaining living vegetative cover on the infiltrating surface.

## 2. BASIN GEOMETRY

This section is used to develop a preliminary design for the RG basin geometry.

2.A) Maximum Depth of WQCV – Enter the maximum ponding depth for the WQCV. The City DCM recommends a maximum depth of 12 inches to prevent the vegetation from being drowned out. If the user enters a depth greater than 12 inches the input will be flagged.

2.B) Average Side Slopes above growth surface – Enter the average of all side-slopes (Horizontal/Vertical) of the basin above the infiltration surface. The City DCM recommends that no side slope be steeper than 4H:1V. Enter "0" if vertical walls will be used.



2.C) Infiltrating Surface Dimensions – This section allows the user to choose how to define the RG bottom dimensions for purposes of preliminary design. Only one option can be used.

*2.C.i) Bottom Width* – This option allows the user to specify the bottom width of the infiltrating surface and the program will then determine the resulting bottom length necessary to provide the WQCV.

*2.C.ii) Length to Width Ratio* – This option allows the user to specify the Length to Width Ratio for the bottom infiltrating surface and the program will determine the width and length necessary to provide the WQCV.

2.D) Recommended Minimum Infiltrating Surface Area (Flat Bottom Area) – The minimum infiltrating surface area is calculated by the program when the user clicks the button “Calculate Minimum Bottom Area”. This bottom area is calculated based on storing the full WQCV within the user specified basin geometry (maximum depth, side slopes, bottom width and length).

2.E) Design (Available) Infiltrating Surface Area (Flat Bottom Area) – Section 2.D above determines the minimum bottom area required to store the full WQCV assuming it ponds up to the maximum depth. This section allows the user to specify an actual design bottom area which may be different. If the user enters a larger bottom area, the WQCV will not utilize the maximum allowable depth, but this allows the user to round off the basin dimensions to a convenient size. However, if the user enters a smaller bottom area, the WQCV ponding depth will exceed the maximum allowable depth and the results will be flagged. The user entered bottom area will be used in all subsequent calculations.

2.F) Calculated Rain Garden Properties – Once all inputs above have been entered, the user can click on the button “Calculate Rain Garden Geometry” and the program will calculate the basin geometry results as outlined below.

*2.F.i) Bottom Width of Growth Media Surface* – If the user specified a bottom width in Section 2.C then this value will match that input. If the user entered a L:W Ratio in Section 2.C then the bottom width will be calculated using the L:W Ratio and the bottom area entered in Section 2.E.

*2.F.ii) Bottom Length of Growth Media Surface* – If the user specified a bottom width in Section 2.C then the bottom length is calculated by dividing the bottom Area (2.E) by the bottom width. If the user entered a L:W ratio in Section 2.C then the bottom length will be calculated using the L:W Ratio and the bottom area entered in Section 2.E.

*2.F.iii) Top Width of Basin at Maximum Depth* – The top width at the maximum depth is calculated based on the bottom width (2.F.i), side slopes (2.B), and maximum depth (2.A).

*2.F.iv) Top Length of Basin at Maximum Depth* – The top length at the maximum depth is calculated based on the bottom length (2.F.ii), side slopes (2.B), and maximum depth (2.A).

*2.F.v) Top Area of Basin at Maximum Depth* – The top area at the maximum depth is simply the product of the top width (2.F.iii) and top length (2.F.iv).

*2.F.vii) Available Volume of Basin at Maximum Depth* – This volume represents the total available volume in the rain garden based on the user specified maximum depth (2.A) and bottom area (2.E). If the user entered a larger bottom area than necessary ( $2.E > 2.D$ ), the available volume will be larger than the required WQCV. However, if the user entered a smaller bottom area than necessary ( $2.E < 2.D$ ), the available volume will be smaller than the required WQCV and the result will be flagged.

*2.F.vii) Ponding Depth needed to satisfy WQCV in Rain Garden* – The ponding depth represents the actual depth necessary to satisfy the WQCV within the basin geometry provided. If the user entered the same bottom area as recommended ( $2.E = 2.D$ ), the ponding depth will equal the maximum depth (2.A). If the user entered a larger bottom area than necessary ( $2.E > 2.D$ ), the ponding depth will be less than the maximum depth (2.A) and a message will notify the user of this fact. However, if the user entered a smaller bottom area than necessary ( $2.E < 2.D$ ), the ponding depth will exceed the maximum available depth (2.A) and the result will be flagged.

2.G) Calculated Average Infiltration Rate of WQCV through bottom of RG – The average infiltration rate is estimated by dividing the WQCV (ac-ft) by the bottom area (sq.ft.) and converting to inches, then dividing this depth by the drain time (hr) to determine infiltration rate (in/hr). For design purposes and long-term longevity of the sand filter media, it is recommended that bottom area be large enough to limit the infiltration rate to no greater than 2.0 in/hr. Faster infiltration rates indicate that the bottom area is too small and will require more frequent maintenance to prevent clogging.

### 3. IMPERMEABLE GEOMEMBRANE LINER (NO INFILTRATION DESIGN)

3.A) Is an impermeable liner provided – Select “Yes” or “No” to indicate if an impermeable liner will be installed below the rain garden due to proximity of structures, expansive soils, or potential for groundwater contamination. If an impermeable liner is included in the design, an underdrain system will automatically be required in Section 4 below. The City required specifications for an impermeable liner can be found in the DCM.

### 4. UNDERDRAIN SYSTEM

4.A) Are underdrains needed or provided – Select “Yes” or “No” to indicate if an underdrain system will be installed below the rain garden. If the rain garden design includes an impermeable liner in Section 3.A (no infiltration section), then the underdrain is automatically included. For partial infiltration sections, the user should select “Yes” to include an underdrain. However, for full infiltration sections, select “No” since an underdrain is not necessary and Sections 4.B and 4.C will be greyed out.

4.B) Does the underdrain pipe/aggregate system meet the required specifications – Select “Yes” or “No” to indicate if the underdrain system will meet the City required specifications outlined in the DCM. If “No” is selected, please explain how and why the underdrain system will be different.

4.C) Underdrain system orifice diameter for specified drain time – This section is used to calculate the orifice diameter on the outlet to the underdrain system that is necessary to empty the WQCV in the specified drain time.

*4.C.i) Vertical distance between top surface of media and centroid of underdrain outlet orifice* – Enter the vertical distance in inches between the top surface of the growth media and the centroid of the underdrain outlet control orifice. This City DCM requires a minimum depth of 18 inches of growing medium to enable the establishment of the roots for the planted vegetation. If a depth less than 18 inches is entered, the input will be flagged. See the figure on the RG worksheet to the right of the preliminary design form for guidance.

*4.C.ii) Discharge Coefficient of the underdrain orifice* – Enter the discharge coefficient for the outlet orifice. The City DCM defaults to 0.60 for a sharp crested orifice. Use appropriate value if a different orifice is used.

*4.C.iii) Orifice Diameter* – After the required inputs have been entered, the user can click the “Calculate Underdrain Orifice Diameter” button and the program will calculate the required orifice diameter necessary to drain the WQCV in the specified drain time (1.C). If the resulting orifice diameter is less than 3/8”, the program will default to a City DCM minimum of 3/8” and flag the result.

## 5. INLET CONTROL AT INFLOW POINT(S)

5.A) Type of Inlet Control – Select whether inflow to the rain garden is “Sheet Flow” or “Concentrated Flow”. For sheet flow conditions, no energy dissipation is required. For concentrated flow conditions, energy dissipation will be required and a concrete or rock forebay for sediment removal is recommended. Describe the energy dissipation approach used for concentrated flow in the available space.

## 6. GROWTH MEDIA

Select whether the growth media for the rain garden is at least 18 inches deep and meets the City DCM specification. Explain/describe if “Other” is selected.

## 7. VEGETATION

7.A) Will the Rain Garden be vegetated with seed or sod – Select whether the rain garden will be vegetated using seeding, sand-grown or other high infiltrations capable turf, or none. Explain any deviations from DCM requirements.

7.B) Will plantings be included in Rain Garden – Select whether there will be plantings of shrubs and/or trees on the side of the growth media. These are not permitted on the media itself because the deeper root structures can damage underdrain systems and overall maintenance becomes more difficult. Explain any deviations from DCM requirements

## 8. IRRIGATION

12.A) Will the Rain Garden be irrigated – Select whether the rain garden will have temporary irrigation, permanent irrigation, or whether no irrigation will be provided. Explain why there will be no irrigation. If a permanent irrigation system is installed, it is important that the sprinkler heads be located outside of the infiltration surface because sediment accumulations will tend to bury the sprinkler heads and create a maintenance burden when trying to remove accumulated sediment.

## CHAPTER 6

### PRELIMINARY DESIGN FORM – SAND FILTER (SF)

1.	<b>Basin Storage Volume</b> .....	1
2.	<b>Basin Geometry</b> .....	2
3.	<b>Impermeable Geomembrane Liner (No Infiltration Design)</b> .....	4
4.	<b>Underdrain System</b> .....	5
5.	<b>Inlet Energy Dissipation (Required)</b> .....	6
6.	<b>Embankment Design and Protection</b> .....	6
7.	<b>Maintenance Access</b> .....	6
8.	<b>Stage-Area-Volume-Discharge Relationships</b> .....	7

A Sand Filter (SF) is a filtering or infiltration PCM that consists of a surcharge zone designed to capture the WQCV (and optionally EURV) underlain by a sand bed with an optional underdrain system. The design of a sand filter may also provide detention for events exceeding the WQCV and EURV. In this Workbook, the SF can be linked to the FSD Routing worksheet to provide flood routing for larger runoff events. Instructions for Sand Filters are organized to be consistent with the section numbering seen on the SF worksheet. Refer to the figures in the worksheet, located to the right of the preliminary design form, for guidance and explanation of the various terms used here.

## 1. BASIN STORAGE VOLUME

1.A) Tributary Watershed Area – Enter the tributary watershed area (acres) including the sand filter area.

1.B) Effective Imperviousness of Tributary Area – Enter the effective imperviousness (percent) of the total tributary area including the sand filter area. Use 100% imperviousness for the SF area when calculating the composite imperviousness for the total tributary area since there is no surface runoff from it.

1.C) Drain Time (DT) needed to completely empty WQCV – Enter the drain time (hours) needed to completely empty the WQCV. The City DCM requires a minimum drain time of 12-hours to provide sufficient residence time for removal of pollutants and to mitigate downstream impacts due to hydrologic changes of the catchment on the geomorphology of the downstream receiving waters. If a drain time less than 12 hours is used the input will be flagged.

1.D) Design Concept – Select whether the basin will provide “WQCV Only” storage or if it will provide “EURV and WQCV” storage. If “WQCV Only” is selected, Sections 1.F through 1.H will be greyed out since they only apply to the EURV.

1.E) Water Quality Capture Volume (WQCV) – Enter the design WQCV for the tributary area (watershed inches). The program will show the required WQCV specified by the DCM for comparison and will flag your entry if it is less than the DCM value. It should be noted that the WQCV is stored entirely above the sand filter surface and no storage is accounted for within the sand media.

1.F) NRCS Hydrologic Soil Groups of Tributary Watershed – The NRCS Hydrologic Soil Group percentages are only required when “EURV and WQCV” is selected in Section 1.D. The EURV is dependent on the percentage of each soil type in the tributary watershed. The total percentage of all three soil type entries needs to equal 100%.

*1.F.i) Percentage of Watershed consisting of Type A Soils* – Enter the percentage of the tributary catchment area that has Type A soils.

*1.F.ii) Percentage of Watershed consisting of Type B Soils* – Enter the percentage of the tributary catchment area that has Type B soils.

*1.F.iii) Percentage of Watershed consisting of Type C/D Soils* – Enter the percentage of the tributary catchment area that has Type C/D soils.

1.G) Excess Urban Runoff Volume (EURV) – The EURV is only required when “EURV and WQCV” is selected in Section 1.D. Enter the design EURV for the tributary area (watershed inches). The program will show the required EURV specified by the DCM for comparison and will flag your entry if it is less than the DCM value. It should be noted that the EURV is inclusive of the WQCV and is stored entirely above the sand filter surface and no storage is accounted for within the sand media.

1.H) Drain Time to completely empty EURV (includes WQCV) – The EURV drain time is only required when “EURV and WQCV” is selected in Section 1.D. Enter the drain time (hours) needed to completely empty the EURV. The workbook defaults to a drain time of 68 hours for the DCM recommendation, however the user can provide a shorter or longer drain time. A maximum of 72 hours is recommended to avoid complications with water rights regulations.

## 2. BASIN GEOMETRY

This section is used to develop a preliminary design for the SF basin geometry.

2.A) Maximum Depth of WQCV (or EURV) – This input depends on whether the design concept is “WQCV Only” or “EURV and WQCV” in Section 1.D. If “WQCV Only” is selected, enter the maximum ponding depth for the WQCV. The City DCM recommends a maximum depth of 3 feet for the WQCV to ensure bottom area of the sand filter doesn’t become too small and create clogging issues. If the user enters a depth greater than 3 feet the input will be flagged. If “EURV and WQCV” is selected, enter the maximum ponding depth for the EURV. The City DCM recommends a maximum depth of 5 feet for the EURV to ensure bottom area of the sand filter doesn’t become too small and create clogging issues. If the user enters a depth greater than 5 feet the input will be flagged.

2.B) Average Side Slopes above Filter Surface – Enter the average of all side-slopes (Horizontal/Vertical) of the sand filter basin above the infiltration surface. The City DCM recommends that no side slope be steeper than 4H:1V. Enter “0” if vertical walls will be used.

2.C) Infiltrating Surface Dimensions – This section allows the user to choose how to define the SF bottom dimensions for purposes of preliminary design. Only one option can be used.

*2.C.i) Bottom Width* – This option allows the user to specify the bottom width of the infiltrating surface and the program will then determine the resulting bottom length necessary to provide the WQCV (or EURV).

*2.C.ii) Length to Width Ratio* – This option allows the user to specify the Length to Width Ratio for the bottom infiltrating surface and the program will determine the width and length necessary to provide the WQCV (or EURV).

2.D) Recommended Minimum Infiltrating Surface Area (Flat Bottom Area) – The minimum infiltrating surface area is calculated by the program when the user clicks the button “Calculate Minimum Bottom Area”. This bottom area is calculated based on storing the full WQCV (or EURV) within the user specified basin geometry (maximum depth, side slopes, bottom width and length).

2.E) Design (Available) Infiltrating Surface Area (Flat Bottom Area) – Section 2.D above determines the minimum bottom area required to store the full WQCV (or EURV) assuming it ponds up to the maximum depth. This section allows the user to specify an actual design bottom area which may be different. If the user enters a larger bottom area, the WQCV (or EURV) will not utilize the maximum allowable depth, but this allows the user to round off the basin dimensions to a convenient size. However, if the user enters a smaller bottom area, the WQCV (or EURV) ponding depth will exceed the maximum allowable depth and the results will be flagged. The user entered bottom area will be used in all subsequent calculations.

2.F) Calculated Sand Filter Properties – Once all inputs above have been entered, the user can click on the button “Calculate Sand Filter Geometry” and the program will calculate the basin geometry results as outlined below.

*2.F.i) Bottom Width of Sand Filter Surface* – If the user specified a bottom width in Section 2.C then this value will match that input. If the user entered a L:W Ratio in Section 2.C then the bottom width will be calculated using the L:W Ratio and the bottom area entered in Section 2.E.

*2.F.ii) Bottom Length of Sand Filter Surface* – If the user specified a bottom width in Section 2.C then the bottom length is calculated by dividing the bottom Area (2.E) by the bottom width. If the user entered a L:W ratio in Section 2.C then the bottom length will be calculated using the L:W Ratio and the bottom area entered in Section 2.E.

*2.F.iii) Top Width of Basin at Maximum Depth* – The top width at the maximum depth is calculated based on the bottom width (2.F.i), side slopes (2.B), and maximum depth (2.A).

*2.F.iv) Top Length of Basin at Maximum Depth* – The top length at the maximum depth is calculated based on the bottom length (2.F.ii), side slopes (2.B), and maximum depth (2.A).

*2.F.v) Top Area of Basin at Maximum Depth* – The top area at the maximum depth is simply the product of the top width (2.F.iii) and top length (2.F.iv).

*2.F.vii) Available Volume of Basin at Specified Maximum Depth* – This volume represents the total available volume in the sand filter based on the user specified maximum depth (2.A) and bottom area (2.E). If the



user entered a larger bottom area than necessary ( $2.E > 2.D$ ), the available volume will be larger than the required WQCV (or EURV). However, if the user entered a smaller bottom area than necessary ( $2.E < 2.D$ ), the available volume will be smaller than the required WQCV (or EURV) and the result will be flagged.

*2.F.vii) Ponding Depth needed to satisfy WQCV in Sand Filter* – The ponding depth represents the actual depth necessary to satisfy the WQCV within the basin geometry provided. If the user selected “WQCV Only” and entered the same bottom area as recommended ( $2.E = 2.D$ ), the ponding depth will equal the maximum depth (2.A). If the user entered a larger bottom area than necessary ( $2.E > 2.D$ ), the ponding depth will be less than the maximum depth (2.A) and a message will notify the user of this fact. However, if the user entered a smaller bottom area than necessary ( $2.E < 2.D$ ), the ponding depth will exceed the maximum available depth (2.A) and the result will be flagged. If the user selected “EURV and WQCV”, then the ponding depth of the WQCV will be less than the EURV ponding depth.

*2.F.viii) Ponding Depth needed to satisfy EURV in Sand Filter* – If the user selected “WQCV Only” in Section 1.D then this row will be greyed out. Otherwise, the ponding depth represents the actual depth necessary to satisfy the EURV within the basin geometry provided. If the user entered the same bottom area as recommended ( $2.E = 2.D$ ), the ponding depth will equal the maximum depth (2.A). If the user entered a larger bottom area than necessary ( $2.E > 2.D$ ), the ponding depth will be less than the maximum depth (2.A) and a message will notify the user of this fact. However, if the user entered a smaller bottom area than necessary ( $2.E < 2.D$ ), the ponding depth will exceed the maximum available depth (2.A) and the result will be flagged.

2.G) Calculated Average Infiltration Rate of WQCV through bottom of SF – The average infiltration rate is estimated by dividing the WQCV (ac-ft) by the bottom area (sq.ft.) and converting to inches, then dividing this depth by the drain time (hr) to determine infiltration rate (in/hr). For design purposes and long-term longevity of the sand filter media, it is recommended that bottom area be large enough to limit the infiltration rate to no greater than 2.5 in/hr. Faster infiltration rates indicate that the bottom area is too small and will require more frequent maintenance to prevent clogging.

### 3. IMPERMEABLE GEOMEMBRANE LINER (NO INFILTRATION DESIGN)

3.A) Is an impermeable liner provided – Select “Yes” or “No” to indicate if an impermeable liner will be installed below the sand filter due to proximity of structures, expansive soils, or potential for groundwater contamination. If an impermeable liner is included in the design, an underdrain system will automatically be required in Section 4 below. The City required specifications for an impermeable liner can be found in the DCM.

## 4. UNDERDRAIN SYSTEM

4.A) Are underdrains needed or provided – Select “Yes” or “No” to indicate if an underdrain system will be installed below the sand filter. If the sand filter design includes an impermeable liner in Section 3.A (no infiltration section), then the underdrain is automatically included. For partial infiltration sections, the user should select “Yes” to include an underdrain. However, for full infiltration sections, select “No” since an underdrain is not necessary and Sections 4.B and 4.C will be greyed out.

4.B) Does the underdrain pipe/aggregate system meet the required specifications – Select “Yes” or “No” to indicate if the underdrain system will meet the City required specifications outlined in the DCM. If “No” is selected, please explain how and why the underdrain system will be different.

4.C) Underdrain system orifice diameter for specified drain time – This section is used to calculate the orifice diameter on the outlet to the underdrain system that is necessary to empty the WQCV (or EURV) in the specified drain time.

*4.C.i) Vertical distance between top surface of sand filter and centroid of underdrain outlet orifice* – Enter the vertical distance in inches between the top surface of the sand filter and the centroid of the underdrain outlet control orifice. This City DCM requires a minimum depth of 18 inches of sand filter material. If a depth less than 18 inches is entered, the input will be flagged. See the figure on the SF worksheet to the right of the preliminary design form for guidance.

*4.C.ii) Discharge Coefficient of the underdrain orifice* – Enter the discharge coefficient for the outlet orifice. The City DCM defaults to 0.60 for a sharp crested orifice. Use appropriate value if a different orifice is used.

**After the required inputs have been entered above, the user can click the “Size Orifice Area to Match Drain Time” button and the program will calculate the required orifice area and diameter necessary to drain the WQCV (or EURV) in the specified drain time. If “WQCV Only” is selected, the orifice will be sized to match the WQCV drain time and the EURV drain time row (4.C.vi) will be greyed out. If “EURV and WQCV” is selected, the same orifice is used to drain both the WQCV and EURV. Therefore, the EURV drain time will control the sizing of the underdrain orifice which may result in a WQCV drain time greater than specified.**

*4.C.iii) Orifice Area ( $A_o$ )* – The calculated orifice area is automatically determined by the program when the “Size Orifice Area to Match Drain Time” button is clicked. However, the user has the ability to override the calculated value with a smaller or larger orifice area and the new input will be flagged.

*4.C.iv) Orifice Diameter* – The calculated orifice diameter is calculated from the orifice area above. If the resulting orifice diameter is less than 3/8”, the program will default to a City DCM minimum of 3/8” and flag the result.

4.C.v) *Calculated WQCV Drain Time* – The calculated WQCV drain time is calculated using the Modified Puls Routing Method to determine how long it takes to drain 99% of the WQCV through the underdrain outlet orifice. The stage-area-volume-discharge and Modified Puls Routing tables are located within the SF worksheet hidden below and to the right of the preliminary design form.

4.C.vi) *Calculated EURV Drain Time* – The EURV drain time is only calculated when “EURV and WQCV” is selected in 1.D, otherwise the row is greyed out. The calculated EURV drain time is calculated using the Modified Puls Routing Method to determine how long it takes to drain 99% of the EURV through the underdrain outlet orifice. The stage-area-volume-discharge and Modified Puls Routing tables are located within the SF worksheet hidden below and to the right of the preliminary design form.

## 5. INLET ENERGY DISSIPATION (REQUIRED)

5.A) Select the Type of Energy Dissipation at Inlet – From the dropdown menu, select the type of energy dissipation provided at concentrated inflow locations. Provide a brief explanation for your selection and describe any specific characteristics.

## 6. EMBANKMENT DESIGN AND PROTECTION

6.A) Describe Embankment Protection – Select whether there is an emergency spillway or some other type of embankment protection. Describe embankment protection design and level of protection it provides, such as the 100-year or larger flood event.

11.B) Select Type of Material used for spillway or embankment hardening – From the dropdown menu, select whether the spillway or embankment hardening will use concrete lining, heavy riprap, heavy soil riprap, buried and vegetated turf reinforcement mats, geocell mats, or other type of erosion protection. For other, explain the type being used and the engineering behind its use.

11.C) Downstream Slope of Embankment – Enter the downstream slope of the embankment. DCM recommends no steeper than 4 feet horizontal for each 1 foot vertical).

Design engineer is required to file all appropriate paperwork with State Dam Safety Engineer.

## 7. MAINTENANCE ACCESS

7.A) Describe Routine & Restorative Maintenance Access – Check each box that applies for providing maintenance access to each of the elements of the Sand Filter. Applicable options include Basin Bottom, Inlet, Outlet Works, and Cleanouts. Describe how this access is being provided (e.g., Use adjacent public street to access overflow outlet).

## 8. STAGE-AREA-VOLUME-DISCHARGE RELATIONSHIPS

Section 8 provides charts which show the stage-area, stage-volume, and stage-discharge relationships for both the user inputs and the City DCM recommended inputs. These charts are generated from the stage-area-volume-discharge tables located within the SF worksheet, hidden below and to the right of the preliminary design form.

## CHAPTER 7

### PRELIMINARY DESIGN FORM – EXTENDED DETENTION BASIN (EDB)

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An Extended Detention Basin (EDB) is a sedimentation basin designed to capture and detain storm runoff for an extended period (typically 40 hours) to allow pollutants to settle out before being slowly released downstream. EDBs consists dry basin with a surcharge zone designed to capture the WQCV (and optionally EURV). The EDB has the most complicated design of the various PCMs and typically includes a forebay, trickle channel, and an outlet structure with a micropool, orifice plate, and trash rack. The design of an EDB may also provide detention for events exceeding the WQCV and EURV. In this Workbook, the EDB can be linked to the FSD Routing worksheet to provide flood routing for larger runoff events. Instructions for Extended Detention Basins are organized to be consistent with the section numbering seen on the EDB worksheet. Refer to the figures in the worksheet, located to the right of the preliminary design form, for guidance and explanation of the various terms used here.

## 1. BASIN STORAGE VOLUME

1.A) Tributary Watershed Area – Enter the tributary watershed area (acres) including the extended detention basin area.

1.B) Effective Imperviousness of Tributary Area – Enter the effective imperviousness (percent) of the total tributary area including the extended detention basin area. Use 100% imperviousness for the EDB area when calculating the composite imperviousness for the total tributary area since there is no surface runoff from it.

1.C) Drain Time (DT) needed to completely empty WQCV – Enter the drain time (hours) needed to completely empty the WQCV. The City DCM requires a minimum drain time of 40 hours to provide sufficient residence time for removal of pollutants and to mitigate downstream impacts due to hydrologic changes of the catchment on the geomorphology of the downstream receiving waters. If a drain time less than 40 hours is used the input will be flagged.

1.D) Design Concept – Select whether the basin will provide “WQCV Only” storage or if it will provide “EURV and WQCV” storage. If “WQCV Only” is selected, Sections 1.F through 1.H will be greyed out since they only apply to the EURV.

1.E) Water Quality Capture Volume (WQCV) – Enter the design WQCV for the tributary area (watershed inches). The program will show the required WQCV specified by the DCM for comparison and will flag your entry if it is less than the DCM value.

1.F) NRCS Hydrologic Soil Groups of Tributary Watershed – The NRCS Hydrologic Soil Group percentages are only required when “EURV and WQCV” is selected in Section 1.D. The EURV is dependent on the percentage of each soil type in the tributary watershed. The total percentage of all three soil type entries needs to equal 100%.

*1.F.i) Percentage of Watershed consisting of Type A Soils* – Enter the percentage of the tributary catchment area that has Type A soils.

*1.F.ii) Percentage of Watershed consisting of Type B Soils* – Enter the percentage of the tributary catchment area that has Type B soils.

*1.F.iii) Percentage of Watershed consisting of Type C/D Soils* – Enter the percentage of the tributary catchment area that has Type C/D soils.

1.G) Excess Urban Runoff Volume (EURV) – The EURV is only required when “EURV and WQCV” is selected in Section 1.D. Enter the design EURV for the tributary area (watershed inches). The program will show the required EURV specified by the DCM for comparison and will flag your entry if it is less than the DCM value. It should be noted that the EURV is inclusive of the WQCV.

1.H) Drain Time to completely empty EURV (includes WQCV) – The EURV drain time is only required when “EURV and WQCV” is selected in Section 1.D. Enter the drain time (hours) needed to completely empty the EURV. The workbook defaults to a drain time of 68 hours for the DCM recommendation, however the user can provide a shorter or longer drain time. A maximum of 72 hours is recommended to avoid complications with water rights regulations.

## 2. BASIN GEOMETRY

This section is used to develop a preliminary design for the EDB geometry.

2.A) Maximum Depth of WQCV (or EURV) – This input depends on whether the design concept is “WQCV Only” or “EURV and WQCV” in Section 1.D. If “WQCV Only” is selected, enter the maximum ponding depth for the WQCV measured from the surface of the micropool near the outlet structure. The City DCM recommends a maximum depth of 5 feet for the WQCV in an attempt to keep the outlet plate orifice openings from getting too small. If the user enters a depth greater than 5 feet the input will be flagged. If “EURV and WQCV” is selected, enter the maximum ponding depth for the EURV measured from the surface of the micropool. The City DCM recommends a maximum depth of 8 feet for the EURV. If the user enters a depth greater than 8 feet the input will be flagged.

2.B) Average Side Slopes above Filter Surface – Enter the average of all side-slopes (Horizontal/Vertical) of the EDB basin from the bottom to the WQCV (or EURV) maximum depth. The City DCM recommends that no side slope be steeper than 4H:1V, but allows slopes as steep as 3:H:1V. Enter "0" if vertical walls will be used.

2.C) Basin Bottom Length and Width Dimensions – This section allows the user to choose how to define the EDB bottom dimensions for purposes of preliminary design. Only one option can be used.

2.C.i) *Bottom Width* – This option allows the user to specify the bottom width of the EDB bottom and the program will then determine the resulting bottom length necessary to provide the WQCV (or EURV).

2.C.ii) *Length to Width Ratio* – This option allows the user to specify the Length to Width Ratio for the EDB bottom and the program will determine the width and length necessary to provide the WQCV (or EURV). The City DCM recommends the L:W Ratio be greater than 2:1 to maximize the flow distance between the inlet and outlet to minimize short circuiting and improve pollutant removal.

### 3. MICROPPOOL AND INITIAL SURCHARGE VOLUME

3.A) Depth of Micropool (small permanent pool) – Enter the depth of the micropool (permanent pool). It is required that it be no less than 2.5 feet to mitigate mosquito breeding potential.

3.B) Initial Surcharge Depth above Micropool to the invert of Trickle Channel – Enter the depth between the water surface of the micropool and the invert of the trickle channel. The City DCM requires a minimum of 4 inches to keep water from backing up into the main part of the EDB and to facilitate maintenance operations. A maximum of 12 inches is recommended. If a depth is entered outside of this range, it will be flagged.

3.C) Surface Area of Micropool based on Tributary Impervious Area – The program automatically calculates the surface area of the micropool based on City guidance. The surface area is constrained between a minimum of 10 square feet and a maximum of 400 square feet per the City DCM. The calculated Initial Surcharge Volume (ISV) is then calculated based on the initial surcharge depth (3.B) and the micropool surface area.

### 4. BASIN BOTTOM AND TRICKLE CHANNEL

4.A) Type of Trickle Channel – Select whether a trickle channel is used, and if it is, whether it is concrete lined or has some other type of bottom. Describe any specific characteristics of the trickle channel or why one is not needed. If “None” is selected, the depth of the trickle channel (4.B) is greyed out.

4.B) Depth of Trickle Channel – Enter the depth of the trickle channel in inches. For concrete-lined trickle channels a depth of 6 inches is required. Explain any differences from the requirements (e.g. very small tributary catchment, trickle channel sized to carry peak flow from forebay outlet, etc.)

4.C) Longitudinal Slope of Trickle Channel or Basin Bottom – If the user selects “None” for a trickle channel in 4.A, enter the longitudinal slope (vertical distance / horizontal distance) of the basin bottom from the inlet to the outlet. Enter '0' if flat bottom is used (not recommended). If the user selects “Concrete” or “Other”, enter the longitudinal slope (V:H) of the trickle channel. The DCM requires a minimum longitudinal slope of 0.005 ft/ft for concrete trickle channels.



4.D) Cross-Slope of Bottom toward Trickle Channel – Enter the slope of the basin bottom from the sides toward the trickle channel (vertical distance / horizontal distance). Enter '0' if flat bottom is used (not recommended). The preliminary design assumes that the Trickle Channel is centered in basin bottom. The City DCM recommends a minimum cross-slope of 0.02 ft/ft, flatter slopes will be flagged.

## 5. CALCULATED BASIN DIMENSIONS

Once all inputs above have been entered, the user can click on the “*Calculate Extended Detention Basin Geometry*” button and the program will calculate the preliminary basin geometry results as outlined below.

5.A) Surface Area of Micropool and ISV – This value is copied directly from Section (3.C).

5.B) Length of Micropool and ISV (square micropool assumed) – Calculated as the square root of 5.A.

5.C) Width of Micropool and ISV (square micropool assumed) – Calculated as the square root of 5.A.

5.D) Depth between Micropool Surface and Top of Trickle Channel – Calculated as the sum of the Initial Surcharge Depth (3.B) and the trickle channel depth (4.B).

5.E) Length of Basin at Bottom (as flat projection of bottom) – The bottom of the basin is referenced to the top of the trickle channel where it intersects the Initial Surcharge Volume (Micropool). The length of the basin at the bottom is a projection of the bottom length at this elevation as shown on the schematic perspective figure in the EDB worksheet to the right of the preliminary design form. The bottom length is calculated through an iterative process within the program where the length and width dimensions are changed until the total storage volume of the basin matches the target WQCV (or EURV). This length is only used to assist in calculating the basin length at the slope transition where the bottom slope intersects the side slope.

5.F) Width of Basin at Bottom (as flat projection of bottom) – The width of the basin at the bottom is similar to the description provided in 5.E above and is calculated using the same iterative routine.

5.G) Area of Basin at Bottom (as flat projection of bottom) – Calculated as the product of 5.E and 5.F.

5.H) Depth between Top of Trickle Channel and Slope Transition – The depth between the top of the trickle channel (at micropool) and the slope transition (where bottom slope intersects side slope) is calculated as a function of the trickle channel slope (4.C) and the cross-slope of the basin bottom (4.D). This dimension can be seen in the schematic perspective figure in the EDB worksheet to the right of the preliminary design form.

5.I) Length at Slope Transition (where bottom slope meets side slope) – The basin length at the slope transition is calculated based on the Length of Basin at Bottom (5.E), the average basin side slope (2.B), and the depth between the Trickle Channel and Slope Transition (5.H).

5.J) Width at Slope Transition (where bottom slope meets side slope) – The basin width at the slope transition is calculated in the same manner as the Length of the Slope Transition (5.I) above.

5.K) Area of Slope Transition (where bottom slope meets side slope) – Calculated as the product of 5.I and 5.J.

5.L) Volume of Basin between Top of Trickle Channel and Slope Transition – The slice of volume stored between the top of the Trickle Channel and the Slope Transition is calculated using the conic volume method. The surface area of the Micropool and ISV (5.A) and the Area at the Slope Transition (5.K) are the areas used in the conic volume equation. This calculation provides the volume within the sloping bottom of the EDB.

5.M) Depth between Slope Transition and Basin Top (freeboard not included) – The depth between the Slope Transition and the Basin Top is calculated by subtracting the depth ( $H_{\text{Bottom}}$ ) between the micropool surface and the trickle channel top (5.D) and the depth ( $H_{\text{Transition}}$ ) between the Trickle Channel and Slope Transition (5.H) from the maximum depth of the WQCV (or EURV) in Section 2.A.

5.N) Length of Basin at Top (does not account for freeboard) – The length of the basin at the Top (maximum WQCV or EURV depth) is calculated based on the Length at Slope Transition (5.I), the average basin side slope (2.B), and the depth between the Slope Transition and Top (5.M).

5.O) Width of Basin at Top (does not account for freeboard) – The width of the basin at the top is calculated in the same manner as the Basin Top Length (5.N) above.

5.P) Area of Basin at Top (does not account for freeboard) – Calculated as the product of 5.N and 5.O.

5.Q) Volume of Basin between Slope Transition and Top – The slice of volume stored between the Slope Transition and the Basin Top is calculated using the conic volume method. The Area at Slope Transition (5.K) and the Basin Top Area (5.P) are the areas used in the conic volume equation.

5.R) Total Calculated Basin Volume – The total basin volume is calculated by adding the Volume at Slope Transition (5.L) and the Top Volume (5.Q) together. It should be noted that the minor volume between the micropool surface and the top of the trickle channel is not accounted for in the total volume.

## 6. INLET ENERGY DISSIPATION (REQUIRED)

6.A) Select the Type of Energy Dissipation at Inlet – From the dropdown menu, select the type of energy dissipation provided at concentrated inflow locations. Energy dissipation needs to occur upstream of the forebay area. Provide a brief explanation for your selection and describe any specific characteristics.

## 7. FOREBAY

7.A) Forebay Volume based on percent of WQCV – Enter the forebay volume as a percentage of the WQCV. The City DCM requires a minimum of 1% of the WQCV used to size the forebay. If the forebay volume does not meet the DCM requirements it will be flagged.

7.B) Forebay Depth based on Tributary Impervious Area – Enter the depth of the forebay. A recommended range in depth will be shown in the description to the left of the input cell. This range is based on the tributary impervious area. The user may enter a different forebay depth, but a flag will appear if it is outside of this range.

7.C) Forebay Area – The forebay area is calculated by dividing the forebay volume (7.A) by the forebay depth (7.B).

7.D) Forebay Drain Time – Enter the drain time needed to fully empty the brim-full forebay (minutes). The recommended drain time is 5 minutes, which should provide sufficient resident time for larger particles to settle out.

7.E) Calculated Forebay Outlet Rectangular Notch Width – The program calculates the rectangular notch width necessary to drain the forebay volume in the specified drain time using an integrated form of the weir equation.

## 8. OUTLET ORIFICE PLATE

8.A) Orifice Discharge Coefficient – Enter the discharge coefficient for the outlet orifice plate. The City DCM defaults to 0.60 for a sharp crested orifice. Use appropriate value if a different orifice is used.

8.B) Minimum Allowable Orifice Diameter – Enter the minimum allowable orifice diameter to be used when the program attempts to size the orifice plate in Section 9. The City DCM recommends a minimum orifice diameter of 1/4 inches to limit clogging potential, anything less will be flagged.

8.C) Vertical Spacing between WQCV Orifice Rows – Enter the vertical spacing between outlet orifices in the orifice plate used to control the release rate of the WQCV (or EURV). The City DCM recommends a minimum spacing of 4 inches to avoid compromising the structural integrity of the plate, anything less will be flagged. Larger spacing between orifice rows will result in few orifice openings with larger diameters, thereby limiting the potential for clogging.

## 9. CALCULATED OUTLET ORIFICE PLATE DIMENSIONS

Once all inputs above have been entered, the user can click on the “*Size Orifice Area to Match Drain Time*” button and the program will calculate the preliminary outlet orifice plate results as outlined below. The iterative sizing routine may take some time to complete depending on the complexity of the design and whether the EURV is included. It should also be noted that when sizing both the WQCV and EURV, if both drain times can't be matched simultaneously, the EURV drain time will be selected as the more conservative approach.

### **WQCV Orifice Openings**

9.A) Number of WQCV Orifice Rows – The number of WQCV orifice rows is calculated by dividing the WQCV ponding depth (determined from hidden Stage-Volume table) by the vertical spacing between WQCV orifice rows (8.C). The workbook can handle up to 25 separate orifice rows.

9.B) WQCV Orifice Area (Ao) per Row – The WQCV orifice area per row is calculated using the iterative sizing routine to find the appropriate orifice size necessary to match the WQCV drain time. It should be noted that when sizing the orifice plate to match both the WQCV drain time and EURV drain time, it is likely that the WQCV orifice size will need to be smaller in order to match the EURV drain time. This may result in a WQCV drain time that is longer than intended (improved water quality treatment). When this situation occurs a message box will inform the user that the EURV drain time is controlling the orifice sizing routine. The user also has the option of overriding the program calculated value but a flag will appear to highlight that the calculated value has been overridden.

9.C) WQCV Circular Orifice Diameter – Based on the WQCV Orifice Area (9.B), the program will determine the corresponding orifice diameter. If the resulting orifice diameter is greater than 2 inches the program will return “N/A” and use a rectangular orifice instead in Section 9.D below.

9.D) WQCV Rectangular Orifice Width – Based on the WQCV Orifice Area (9.B), the program will determine the corresponding rectangular orifice width assuming a 2-inch height. The rectangular orifice is only used when the circular orifice diameter (9.C) would be greater than 2 inches.

9.E) Calculated WQCV Drain Time – The WQCV drain time is calculated using the Modified Puls Routing Method to determine how long it takes to drain 99% of the WQCV through the outlet orifice plate. The stage-area-volume-discharge and Modified Puls Routing tables are located within the EDB worksheet hidden below and to the right of the preliminary design form. If the calculated result does not match the target drain time (1.C) it will be flagged.

9.F) Maximum Stage of WQCV – The maximum stage of the WQCV is determined from the Stage-Area-Volume table (hidden below and to the right of the preliminary design form) based on the target WQCV (1.E) and includes the Initial Surcharge Depth (3.B) and the Trickle Channel Depth (4.B).

9.G) Surface Area at WQCV Maximum Stage – The surface area at the WQCV maximum stage is determined from the Stage-Area-Volume table (hidden below and to the right of the preliminary design form).

9.H) Volume at WQCV Maximum Stage – The stored volume at the WQCV maximum stage is determined from the Stage-Area-Volume table (hidden below and to the right of the preliminary design form). This should match the target WQCV in Section 1.E.

### **EURV Orifice Opening**

9.I) Single EURV Orifice Row at Top of WQCV – If the EURV is included in the design, this row will default to a single row.

9.J) EURV Orifice Area (Ao) in Row – The EURV orifice is calculated using an iterative sizing routine to find the appropriate orifice size necessary to match the EURV drain time (same routine used by WQCV). It should be noted that when sizing the orifice plate to match both the WQCV drain time and EURV drain time, it is likely that the WQCV orifice size will need to be smaller in order to match the EURV drain time. The user also has the option of overriding the program calculated value but a flag will appear to highlight that the calculated value has been overridden.

9.K) EURV Circular Orifice Diameter – Based on the EURV Orifice Area (9.J), the program will determine the corresponding orifice diameter. If the resulting orifice diameter is greater than 2 inches the program will return “N/A” and use a rectangular orifice instead in Section 9.L below.

9.L) EURV Rectangular Orifice Width – Based on the EURV Orifice Area (9.J), the program will determine the corresponding rectangular orifice width assuming a 2-inch height. The rectangular orifice is only used when the circular orifice diameter (9.K) would be greater than 2 inches.

9.M) Calculated EURV Drain Time – The EURV drain time is calculated using the Modified Puls Routing Method to determine how long it takes to drain 99% of the EURV through the outlet orifice plate. The stage-area-volume-discharge and Modified Puls Routing tables are located within the EDB worksheet hidden below and to the right of the preliminary design form. If the calculated result does not match the target drain time (1.H) it will be flagged.

9.N) Maximum Stage of EURV – The maximum stage of the EURV is determined from the Stage-Area-Volume table (hidden below and to the right of the preliminary design form) based on the target EURV (1.G) and includes the Initial Surcharge Depth (3.B) and the Trickle Channel Depth (4.B).

9.O) Surface Area at EURV Maximum Stage – The surface area at the EURV maximum stage is determined from the Stage-Area-Volume table (hidden below and to the right of the preliminary design form).

9.P) Volume at EURV Maximum Stage – The stored volume at the EURV maximum stage is determined from the Stage-Area-Volume table (hidden below and to the right of the preliminary design form). This should match the target EURV in Section 1.G.

### **Combined Orifice Plate**

9.Q) Total Outlet Area of All Orifices – The total outlet area is calculated as the summing the total WQCV Orifice area (9.A \* 9.B) and the EURV Orifice Area (9.J). This total area is used in sizing the required trash rack dimensions in Section 10.

9.R) Minimum Width of Opening in Concrete Wall to mount Orifice Plate – The orifice plate will be mounted to a concrete outlet structure. The outlet structure will include a vertical opening in the concrete face so that the orifice openings can discharge freely into the outlet structure. The minimum width of the vertical opening must be at least 12 inches, but may be larger depending on the size of the orifice openings (particularly wide rectangular openings).

9.S) Minimum Width of Orifice Plate to permit mounting to Concrete Wall – The orifice plate must be at a minimum 8 inches wider than the opening in the concrete wall (9.R).

## **10. TRASH RACK**

10.A) Type of Trash Rack – Select “recommended materials” if using the City recommended trash rack materials. If specifying an alternative to the recommended materials, choose "Other" and provide a description of the specified material. Also make sure that the width of the largest opening in the trash rack is smaller than the smallest orifice dimension in the orifice plate). A trash rack is an essential component of a WQCV/EURV outlet structure and keeps the outlet operational and prevents the small orifice openings from clogging. The trash rack needs to be submerged into the micro-pool to minimize the complete clogging of the rack itself, thereby accumulation the floating trash at the water’s surface level and having cleaner water passing through the rack below the water surface. Regardless, the rack will tend to eventually clog and needs to be inspected after a storm has occurred. If the recommended track rack design is used, simple vertical raking will fully restore its capacity.

10.B) Minimum Trash Rack Open Area – Calculated value based on the total outlet area of all orifices in orifice plate (9.Q) using the equation provided. This ensures that the orifice plate controls the discharge rate and not the trash rack.

10.C) Open Area / Gross Area Ratio of Trash Rack – This is the ratio of the trash rack open area to the total trash rack area. DCM recommends a minimum ratio of 0.6 for circular orifices and 0.71 for rectangular orifices. These are recommended minimums and larger ratios can reduce the chances of complete clogging of the trash rack with debris and prolong the periods between cleanings.

10.D) Minimum Total Gross Trash Rack Area – Calculated value provides the minimum trash rack area (length x width) required to satisfy the minimum trash rack open area calculated in 10.B.

10.E) Minimum Height of the Trash Rack – Enter the total height of the trash rack. It is required that it be extended at least 2 feet below the permanent water surface of the micropool. The program will flag the height if it is not greater than or equal to the WQCV (or EURV) depth plus 2 feet.

10.F) Width of Opening in Concrete Wall for Mounting Trash Rack – Enter the width of opening in concrete wall for mounting trash rack, in inches. A minimum of 12 inches is recommended for a maintainable installation. The program will flag the width if less than the orifice plate width or if when multiplied by the height of the trash rack (10.E) the total area is less than the minimum total gross trash rack area (10.D).

## 11. EMBANKMENT DESIGN AND PROTECTION

In addition to the following three inputs, the design engineer is required to file all appropriate paperwork with the Dam Safety Engineer whenever the embankment or the basin design falls within the filing requirements of the State.

11.A) Describe Embankment Protection – Select whether there is an emergency spillway or some other type of embankment protection. Describe embankment protection design and level of protection it provides, such as the 100-year or larger flood event.

11.B) Select Type of Material used for spillway or embankment hardening – From the dropdown menu, select whether the spillway or embankment hardening will use concrete lining, heavy riprap, heavy soil riprap, buried and vegetated turf reinforcement mats, geocell mats, or other type of erosion protection. For other, explain the type being used and the engineering behind its use.

11.C) Downstream Slope of Embankment – Enter the downstream slope of the embankment. DCM recommends no steeper than 4 feet horizontal for each 1 foot vertical

## 12. VEGETATION TYPE, SOURCES, AND INSTALLATION PROTOCOLS

Select whether the design uses irrigation or is non-irrigated vegetation. Briefly describe the vegetation type, sources, and installation protocols. Recommend use of crimped straw mulching or erosion blankets when using native seed applications.

### 13. MAINTENANCE ACCESS

13.A) Describe Routine & Restorative Maintenance Access – Check each box that applies for providing maintenance access to each of the elements of the EDB. Applicable options include Basin Bottom, Inlet/Forebay, Trickle Channel, and Outlet Works. Describe how this access is being provided (e.g. use adjacent public street to access outlet).

### 14. STAGE-AREA-VOLUME-DISCHARGE RELATIONSHIPS

Section 14 provides charts which show the stage-area, stage-volume, and stage-discharge relationships for both the user inputs and the City DCM recommended inputs. These charts are generated from the stage-area-volume-discharge tables located within the EDB worksheet, hidden below and to the right of the preliminary design form.



## CHAPTER 8

### PRELIMINARY DESIGN FORM – RETENTION POND (RP)

1.	<b>Baseflow</b> .....	1
2.	<b>Pond Surge Volume</b> .....	1
3.	<b>Pond Surge Geometry</b> .....	2
4.	<b>Permanent Pool Geometry</b> .....	3
5.	<b>Calculated Pond Dimensions</b> .....	4
6.	<b>Inlet Energy Dissipation and Floatable Containment</b> .....	6
7.	<b>Forebay</b> .....	6
8.	<b>Outlet Orifice</b> .....	6
9.	<b>Caclulated Outlet Orifice Dimensions</b> .....	6
10.	<b>Trash Rack</b> .....	8
11.	<b>Embankment Design and Protection</b> .....	9
12.	<b>Vegetation Type, Sources, and Installation Protocols</b> .....	9
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A Retention Pond (RP) has a permanent pool of water with an available surcharge volume above the permanent pool to capture and slowly release the WQCV (and optionally EURV). During a storm runoff event, incoming flow mixes with and displaces the permanent pool water allowing for a reduced residence time (typically 12 hours) relative to an EDB. Retention Ponds can be very effective in removing pollutants through sedimentation, as well as removing soluble pollutants through biological processes. The design of a RP may also provide detention for events exceeding the WQCV and EURV. In this Workbook, the RP can be linked to the FSD Routing worksheet to provide flood routing for larger runoff events. Instructions for Retention Ponds are organized to be consistent with the section numbering seen on the RP worksheet. Refer to the figures in the worksheet, located to the right of the preliminary design form, for guidance and explanation of the various terms used here.

## 1. BASEFLOW

1.A) Is there sufficient baseflow to support the permanent pool – Determine whether there is sufficient baseflow to sustain the permanent pool or if the pool can be sustained by groundwater. Urban runoff alone may not be sufficient to meet that purpose during protracted dry periods. Briefly describe the reason for your conclusion and reference any supporting documentation.

## 2. POND SURCHARGE VOLUME

2.A) Tributary Watershed Area – Enter the tributary watershed area (acres) including the retention pond area.

2.B) Effective Imperviousness of Tributary Area – Enter the effective imperviousness (percent) of the total tributary area including the retention pond area. Use 100% imperviousness for the RP area when calculating the composite imperviousness for the total tributary area since there is no surface runoff from it.

2.C) Drain Time (DT) needed to completely empty WQCV – Enter the drain time (hours) needed to completely empty the WQCV. The City DCM requires a minimum drain time of 12 hours to provide sufficient residence time for removal of pollutants and to mitigate downstream impacts due to hydrologic changes of the catchment on the geomorphology of the downstream receiving waters. If a drain time less than 12 hours is used the input will be flagged.

2.D) Design Concept – Select whether the pond will provide “WQCV Only” storage or if it will provide “EURV and WQCV” storage. If “WQCV Only” is selected, Sections 2.F through 2.H will be greyed out since they only apply to the EURV.

2.E) Water Quality Capture Volume (WQCV) – Enter the design WQCV for the tributary area (watershed inches). The program will show the required WQCV specified by the DCM for comparison and will flag your entry if it is less than the DCM value.

2.F) NRCS Hydrologic Soil Groups of Tributary Watershed – The NRCS Hydrologic Soil Group percentages are only required when “EURV and WQCV” is selected in Section 2.D. The EURV is dependent on the percentage of each soil type in the tributary watershed. The total percentage of all three soil type entries needs to equal 100%.

*2.F.i) Percentage of Watershed consisting of Type A Soils* – Enter the percentage of the tributary catchment area that has Type A soils.

*2.F.ii) Percentage of Watershed consisting of Type B Soils* – Enter the percentage of the tributary catchment area that has Type B soils.

*2.F.iii) Percentage of Watershed consisting of Type C/D Soils* – Enter the percentage of the tributary catchment area that has Type C/D soils.

2.G) Excess Urban Runoff Volume (EURV) – The EURV is only required when “EURV and WQCV” is selected in Section 2.D. Enter the design EURV for the tributary area (watershed inches). The program will show the required EURV specified by the DCM for comparison and will flag your entry if it is less than the DCM value. It should be noted that the EURV is inclusive of the WQCV.

2.H) Drain Time to completely empty EURV (includes WQCV) – The EURV drain time is only required when “EURV and WQCV” is selected in Section 2.D. Enter the drain time (hours) needed to completely empty the EURV. The workbook defaults to a drain time of 68 hours for the DCM recommendation, however the user can provide a shorter or longer drain time. A maximum of 72 hours is recommended to avoid complications with water rights regulations.

### 3. POND SURCHARGE GEOMETRY

This section is used to develop a preliminary design for the RP surcharge geometry.

3.A) Maximum Surcharge Depth of WQCV (or EURV) – This input depends on whether the design concept is “WQCV Only” or “EURV and WQCV” in Section 2.D. If “WQCV Only” is selected, enter the maximum ponding depth for the WQCV measured from the top of the permanent pool surface. If “EURV and WQCV” is selected, enter the maximum ponding depth for the EURV measured from the top of the permanent pool surface. The City DCM recommends a maximum depth of 5 feet for the WQCV (or EURV) in an attempt to keep the outlet plate orifice openings from getting too small. If the user enters a depth greater than 5 feet the input will be flagged.

3.B) Average Side Slopes above Filter Surface – Enter the average of all side-slopes (Horizontal/Vertical) of the retention pond from the permanent pool surface to the WQCV (or EURV) maximum depth. The City DCM recommends that no side slope be steeper than 4H:1V. Enter “0” if vertical walls will be used.

3.C) Basin Bottom Length and Width Dimensions – This section allows the user to choose how to define the RP bottom dimensions for purposes of preliminary design. Only one option can be used.

*3.C.i) Bottom Width* – This option allows the user to specify the bottom width of the RP bottom at the permanent pool surface and the program will then determine the resulting bottom length necessary to provide the WQCV (or EURV).

*3.C.ii) Length to Width Ratio* – This option allows the user to specify the Length to Width Ratio for the RP bottom at the permanent pool surface and the program will determine the width and length necessary to provide the WQCV (or EURV). The City DCM recommends the L:W Ratio be between 2:1 and 3:1 to maximize the flow distance between the inlet and outlet to minimize short circuiting and improve pollutant removal.

## 4. PERMANENT POOL GEOMETRY

4.A) Desired Permanent Pool Volume based on percent of WQCV – Enter the permanent pool volume as a percentage of the WQCV. The City DCM requires a minimum of 120% of the WQCV based on early findings in other parts of United States that this volume will minimize eutrophication effects (algal growth) of the permanent pool. Also, based on the International BMP Database team's findings, this percentage will also produce higher water quality for the RP's effluent. If the permanent pool volume does not meet the DCM requirements it will be flagged.

4.B) Width of Wetland Safety Bench (Littoral Zone) – Enter the width of wetland safety bench, in feet. It is recommended that it be no less than 4 feet at all edges of the permanent pool. This is an important feature for public safety purposes intended to minimize children and adults from falling into the deep part of the pool. This bench also serves as a littoral zone (i.e., emergent wetland vegetation) that helps reduce eutrophication of the pool.

4.C) Maximum Depth of Wetland Safety Bench (Littoral Zone) at Inner Edge – Enter the maximum depth of wetland safety bench at the innermost edge, in feet. It is recommended that it be between 0.5 and 1.0 feet to facilitate emergent wetland growth.

4.D) Maximum Depth of Pond – Enter the maximum depth of pond, namely the depth between the permanent pool's surface and the bottom of the pond. It is recommended that this be between 6 and 12 feet to enhance mixing of the water column by wind action and to minimize chances for stratification and development of anaerobic conditions near the bottom.

4.E) Average Pond Side Slopes below Safety Bench – Enter the average of all side slopes of the pond below the safety bench (center of pond). For slope stability purposes of saturated soils, it is recommended this slope be no steeper than 3H:1V.

## 5. CALCULATED POND DIMENSIONS

Once all inputs above have been entered, the user can click on the “*Calculate Retention Pond Geometry*” button and the program will calculate the preliminary pond geometry results as outlined below. The program first solves for the surcharge volume dimensions above the permanent pool necessary to store the WQCV (or EURV) using an iterative process. Once the surcharge volume dimensions are known, the program can then calculate the permanent pool dimensions based on the user specified widths, depths, and slopes provided in section 4. It is possible that the surcharge volume dimensions can result in negative lengths or widths at the bottom of the permanent pool. If this situation arises, the user will be notified with flagged errors. In order to address this issue, it is recommended that the pond surcharge geometry inputs in Section 3 be modified to use a shallower surcharge depth and/or larger length and width dimensions.

5.A) Length of Pond at Bottom of Permanent Pool – Once the program iteratively solves for the surcharge volume dimensions necessary to store the WQCV (or EURV), the length of the pond bottom is calculated based on the permanent pool geometry inputs in Section 4.

5.B) Width of Pond at Bottom of Permanent Pool – Once the program iteratively solves for the surcharge volume dimensions necessary to store the WQCV (or EURV), the width of the pond bottom is calculated based on the permanent pool geometry inputs in Section 4.

5.C) Area of Pond at Bottom of Permanent Pool – Calculated as the product of 5.A and 5.B.

5.D) Depth between Pond Bottom and Inner/Lower Edge of Safety Bench – Calculated as the difference between the maximum depth of the pond (4.D) and the maximum depth of the wetland safety bench (4.C).

5.E) Length of Pond where Bottom transitions to Safety Bench – Once the program iteratively solves for the surcharge volume dimensions necessary to store the WQCV (or EURV), the length of the pond at the inner edge of the safety bench is calculated based on the permanent pool geometry inputs in Section 4.

5.F) Width of Pond where Bottom transitions to Safety Bench – Once the program iteratively solves for the surcharge volume dimensions necessary to store the WQCV (or EURV), the width of the pond at the inner edge of the safety bench is calculated based on the permanent pool geometry inputs in Section 4.

5.G) Area of Pond where Bottom transitions to Safety Bench – Calculated as the product of 5.E and 5.F.

5.H) Volume of Pond Bottom below Safety Bench – The slice of volume stored below the safety bench is calculated using the conic volume method. The area at the bottom of the permanent pool (5.C) and the area where the bottom transitions to the Safety Bench (5.G) are the areas used in the conic volume equation.

5.I) Depth at Inside of Safety Bench below Permanent Pool Surface – This is simply the depth entered in Section 4.C.

5.J) Length of Permanent Pool Surface – The program iteratively solves for the length of the permanent pool surface necessary to store the WQCV or EURV (2.E or 2.G) based on the pond surcharge geometry inputs provided in Section 3.

5.K) Width of Permanent Pool Surface – The program iteratively solves for the width of the permanent pool surface necessary to store the WQCV or EURV (2.E or 2.G) based on the pond surcharge geometry inputs provided in Section 3.

5.L) Area of Permanent Pool Surface – Calculated as the product of 5.J and 5.K.

5.M) Volume of Pond between Safety Bench and Permanent Pool Surface – The slice of volume stored between the safety bench and the permanent pool surface is calculated using the conic volume method. The area where the bottom transitions to the Safety Bench (5.G) and the area of the permanent pool surface (5.L) are the areas used in the conic volume equation.

5.N) Total Volume of Permanent Pool (above and below Safety Bench) – This is simply calculated by summing the volumes of the permanent pool above (5.M) and below (5.H) the safety bench.

5.O) Ratio of Permanent Pool Volume to WQCV – The ratio of permanent pool volume (5.N) to the WQCV (2.E) is a simple check to ensure the City DCM minimum of 120% is satisfied.

5.P) Depth of Surcharge above Permanent Pool (freeboard not included) – This is simply the maximum surcharge depth specified by the user in Section 3.A.

5.Q) Length of Pond at Top of Surcharge – The program iteratively solves for the length of the permanent pool surface (5.J) necessary to store the WQCV or EURV (2.E or 2.G). This calculated length along with the user specified pond surcharge geometry inputs in Section 3 are used to calculate the top length.

5.R) Width of Pond at Top of Surcharge – The program iteratively solves for the width of the permanent pool surface (5.K) necessary to store the WQCV or EURV (2.E or 2.G). This calculated width along with the user specified pond surcharge geometry inputs in Section 3 are used to calculate the top width.

5.S) Area of Pond at Top of Surcharge – Calculated as the product of 5.Q and 5.R.

5.T) Volume of WQCV (or EURV) Surcharge above Permanent Pool – The surcharge volume stored above the permanent pool surface is calculated using the conic volume method. The permanent pool area (5.L) and the area at the top of the surcharge volume (5.S) are the areas used in the conic volume equation.

## 6. INLET ENERGY DISSIPATION AND FLOATABLE CONTAINMENT

6.A) Select the Type of Energy Dissipation at Inlet – From the dropdown menu, select the type of energy dissipation provided at concentrated inflow locations. Energy dissipation needs to occur upstream of the forebay area. Provide a brief explanation for your selection and describe any specific characteristics.

6.B) Is a flexible floating trash boom provided to trap floatables – Indicate if a floating trash boom is provided and provide specific details of the type and location. Explain reasoning if a boom is not provided.

## 7. FOREBAY

7.A) Forebay Volume based on percent of WQCV – Enter the forebay volume as a percentage of the WQCV. A forebay in a retention pond is part of the total permanent pool, typically separated by an underwater berm from the main body of the pond. Because of this a larger forebay is recommended than is used for an EDB and a minimum of 3% of the WQCV is required. A concrete-lined bottom is also recommended to facilitate maintenance. If the forebay volume does not meet the DCM requirements it will be flagged.

## 8. OUTLET ORIFICE

8.A) Orifice Discharge Coefficient – Enter the discharge coefficient for the outlet orifice. The City DCM defaults to 0.60 for a sharp crested orifice. Use appropriate value if a different orifice is used.

8.B) Minimum Allowable Orifice Diameter – Enter the minimum allowable orifice diameter to be used when the program attempts to size the orifice place in Section 9. The City DCM recommends a minimum orifice diameter of 1/4 inches to limit clogging potential, anything less will be flagged.

## 9. CALCULATED OUTLET ORIFICE DIMENSIONS

Once all inputs above have been entered, the user can click on the *"Size Orifice Area to Match Drain Time"* button and the program will calculate the preliminary outlet orifice results as outlined below. The iterative sizing routine may take some time to complete depending on the complexity of the design and whether the EURV is included. It should also be noted that when sizing both the WQCV and EURV, the EURV drain time will be selected as the more conservative approach in sizing the outlet orifice.

9.A) Orifice Area (Ao) – The orifice area is calculated using the iterative sizing routine to find the appropriate orifice size necessary to match the WQCV (or EURV) drain time. It should be noted that when sizing the orifice area to match both the WQCV drain time and EURV drain time, it is likely that the WQCV orifice size will need to be smaller in order to match the EURV drain time. This may result in a WQCV drain time that is longer than

intended (improved water quality treatment). The user also has the option of overriding the program calculated value but a flag will appear to highlight that the calculated value has been overridden.

9.B) Circular Orifice Diameter – Based on the Orifice Area (9.A), the program will determine the corresponding orifice diameter. If the resulting orifice diameter is greater than 2 inches the program will return “N/A” and use a rectangular orifice instead in Section 9.C below.

9.C) Rectangular Orifice Width – Based on the Orifice Area (9.A), the program will determine the corresponding rectangular orifice width assuming a 2-inch height. The rectangular orifice is only used when the circular orifice diameter (9.B) would be greater than 2 inches.

### **WQCV Results**

9.D) Calculated WQCV Drain Time – The WQCV drain time is calculated using the Modified Puls Routing Method to determine how long it takes to drain 99% of the WQCV through the outlet orifice. The stage-area-volume-discharge and Modified Puls Routing tables are located within the RP worksheet hidden below and to the right of the preliminary design form. If the calculated result does not match the target drain time (2.C) it will be flagged.

9.E) Maximum Stage of WQCV – The maximum stage of the WQCV is determined from the Stage-Area-Volume table (hidden below and to the right of the preliminary design form) based on the target WQCV (2.E).

9.F) Surface Area at WQCV Maximum Stage – The surface area at the WQCV maximum stage is determined from the Stage-Area-Volume table (hidden below and to the right of the preliminary design form).

9.G) Surcharge Volume at WQCV Maximum Stage – The stored volume at the WQCV maximum stage is determined from the Stage-Area-Volume table (hidden below and to the right of the preliminary design form). This should match the target WQCV in Section 2.E.

### **EURV Results**

9.H) Calculated EURV Drain Time – The EURV drain time is calculated using the Modified Puls Routing Method to determine how long it takes to drain 99% of the EURV through the outlet orifice. The stage-area-volume-discharge and Modified Puls Routing tables are located within the RP worksheet hidden below and to the right of the preliminary design form. If the calculated result does not match the target drain time (2.H) it will be flagged.

9.I) Maximum Stage of EURV – The maximum stage of the EURV is determined from the Stage-Area-Volume table (hidden below and to the right of the preliminary design form) based on the target EURV (2.G).



9.J) Surface Area at EURV Maximum Stage – The surface area at the EURV maximum stage is determined from the Stage-Area-Volume table (hidden below and to the right of the preliminary design form).

9.K) Surcharge Volume at EURV Maximum Stage – The stored volume at the EURV maximum stage is determined from the Stage-Area-Volume table (hidden below and to the right of the preliminary design form). This should match the target EURV in Section 2.G.

### **Orifice Plate and Concrete Opening**

9.L) Minimum Width of Opening in Concrete Wall to mount Orifice Plate – The orifice plate will be mounted to a concrete outlet structure. The outlet structure will include a vertical opening in the concrete face so that the orifice openings can discharge freely into the outlet structure. The minimum width of the vertical opening must be at least 12 inches, but may be larger depending on the size of the orifice openings (particularly wide rectangular openings).

9.M) Minimum Width of Orifice Plate to permit mounting to Concrete Wall – The orifice plate must be at a minimum 8 inches wider than the opening in the concrete wall (9.R).

## **10. TRASH RACK**

10.A) Type of Trash Rack – Select “recommended materials” if using the City recommended trash rack materials. If specifying an alternative to the recommended materials, choose “Other” and provide a description of the specified material. Also make sure that the width of the largest opening in the trash rack is smaller than the smallest orifice dimension in the orifice plate). A trash rack is an essential component of a WQCV/EURV outlet structure and keeps the outlet operational and prevents the small orifice openings from clogging. The trash rack needs to be submerged into the permanent pool to minimize the complete clogging of the rack itself, thereby accumulation the floating trash at the water’s surface level and having cleaner water passing through the rack below the water surface. Regardless, the rack will tend to eventually clog and needs to be inspected after a storm has occurred. If the recommended track rack design is used, simple vertical raking will fully restore its capacity.

10.B) Minimum Trash Rack Open Area – Calculated value based on the total outlet orifice area (9.A) using the equation provided. This ensures that the orifice plate controls the discharge rate and not the trash rack.

10.C) Open Area / Gross Area Ratio of Trash Rack – This is the ratio of the trash rack open area to the total trash rack area. DCM recommends a minimum ratio of 0.6 for circular orifices and 0.71 for rectangular orifices. These are recommended minimums and larger ratios can reduce the chances of complete clogging of the trash rack with debris and prolong the periods between cleanings.

10.D) Minimum Total Gross Trash Rack Area – Calculated value provides the minimum trash rack area (length x width) required to satisfy the minimum trash rack open area calculated in 10.B.

10.E) Minimum Height of the Trash Rack – Enter the total height of the trash rack. It is required that it be extended at least 2 feet below the permanent water surface. The program will flag the height if it is not greater than or equal to the WQCV (or EURV) depth plus 2 feet.

10.F) Width of Opening in Concrete Wall for Mounting Trash Rack – Enter the width of opening in concrete wall for mounting trash rack, in inches. A minimum of 12 inches is recommended for a maintainable installation. The program will flag the width if less than the orifice plate width or if when multiplied by the height of the trash rack (10.E) the total area is less than the minimum total gross trash rack area (10.D).

## 11. EMBANKMENT DESIGN AND PROTECTION

In addition to the following three inputs, the design engineer is required to file all appropriate paperwork with the Dam Safety Engineer whenever the embankment or the basin design falls within the filing requirements of the State.

11.A) Describe Embankment Protection – Select whether there is an emergency spillway or some other type of embankment protection. Describe embankment protection design and level of protection it provides, such as the 100-year or larger flood event.

11.B) Select Type of Material used for spillway or embankment hardening – From the dropdown menu, select whether the spillway or embankment hardening will use concrete lining, heavy riprap, heavy soil riprap, buried and vegetated turf reinforcement mats, geocell mats, or other type of erosion protection. For other, explain the type being used and the engineering behind its use.

11.C) Downstream Slope of Embankment – Enter the downstream slope of the embankment. DCM recommends no steeper than 4 feet horizontal for each 1 foot vertical.

## 12. VEGETATION TYPE, SOURCES, AND INSTALLATION PROTOCOLS

Select whether the design uses irrigation or is non-irrigated vegetation. Briefly describe the vegetation type, sources, and installation protocols. Recommend use of crimped straw mulching or erosion blankets when using native seed applications.

### 13. MAINTENANCE ACCESS

13.A) Describe Routine & Restorative Maintenance Access – Check each box that applies for providing maintenance access to each of the elements of the RP. Applicable options include Permanent Pool, Safety Bench, Inlet/Forebay, and Outlet Works. Describe how this access is being provided (e.g. use adjacent public street to access outlet).

### 14. STAGE-AREA-VOLUME-DISCHARGE RELATIONSHIPS

Section 14 provides charts which show the stage-area, stage-volume, and stage-discharge relationships for both the user inputs and the City DCM recommended inputs. These charts are generated from the stage-area-volume-discharge tables located within the RP worksheet, hidden below and to the right of the preliminary design form.

## CHAPTER 9

### PRELIMINARY DESIGN FORM – WETLAND BASIN (WB)

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A Wetland Basin (WB) has a permanent pool of water with an available surcharge volume above the permanent pool to capture and slowly release the WQCV (and optionally EURV). A Wetland Basin is essentially a shallow retention pond designed to permit the growth of wetland plants. Wetland Basins slow runoff and allow time for sedimentation, filtration, and biological uptake. During a storm runoff event, incoming flow mixes with and displaces the permanent pool water allowing for a reduced residence time (typically 24 hours) relative to an EDB. The design of a WB may also provide detention for events exceeding the WQCV and EURV. In this Workbook, the WB can be linked to the FSD Routing worksheet to provide flood routing for larger runoff events. Instructions for Wetland Basins are organized to be consistent with the section numbering seen on the WB worksheet. Refer to the figures in the worksheet, located to the right of the preliminary design form, for guidance and explanation of the various terms used here.

## 1. BASEFLOW

1.A) Is there sufficient baseflow to support the permanent pool – Determine whether there is sufficient baseflow to sustain the permanent pool or if the pool can be sustained by groundwater. Urban runoff alone may not be sufficient to meet that purpose during protracted dry periods. Briefly describe the reason for your conclusion and reference any supporting documentation.

## 2. WETLAND BASIN SURCHARGE VOLUME

2.A) Tributary Watershed Area – Enter the tributary watershed area (acres) including the wetland basin area.

2.B) Effective Imperviousness of Tributary Area – Enter the effective imperviousness (percent) of the total tributary area including the wetland basin area. Use 100% imperviousness for the WB area when calculating the composite imperviousness for the total tributary area since there is no surface runoff from it.

2.C) Drain Time (DT) needed to completely empty WQCV – Enter the drain time (hours) needed to completely empty the WQCV. The City DCM requires a minimum drain time of 24 hours to provide sufficient residence time for removal of pollutants and to mitigate downstream impacts due to hydrologic changes of the catchment on the geomorphology of the downstream receiving waters. If a drain time less than 24 hours is used the input will be flagged.

2.D) Design Concept – Select whether the wetland basin will provide “WQCV Only” storage or if it will provide “EURV and WQCV” storage. If “WQCV Only” is selected, Sections 2.F through 2.H will be greyed out since they only apply to the EURV.

2.E) Water Quality Capture Volume (WQCV) – Enter the design WQCV for the tributary area (watershed inches). The program will show the required WQCV specified by the DCM for comparison and will flag your entry if it is less than the DCM value.

2.F) NRCS Hydrologic Soil Groups of Tributary Watershed – The NRCS Hydrologic Soil Group percentages are only required when “EURV and WQCV” is selected in Section 2.D. The EURV is dependent on the percentage of each soil type in the tributary watershed. The total percentage of all three soil type entries needs to equal 100%.

*2.F.i) Percentage of Watershed consisting of Type A Soils* – Enter the percentage of the tributary catchment area that has Type A soils.

*2.F.ii) Percentage of Watershed consisting of Type B Soils* – Enter the percentage of the tributary catchment area that has Type B soils.

*2.F.iii) Percentage of Watershed consisting of Type C/D Soils* – Enter the percentage of the tributary catchment area that has Type C/D soils.

2.G) Excess Urban Runoff Volume (EURV) – The EURV is only required when “EURV and WQCV” is selected in Section 2.D. Enter the design EURV for the tributary area (watershed inches). The program will show the required EURV specified by the DCM for comparison and will flag your entry if it is less than the DCM value. It should be noted that the EURV is inclusive of the WQCV.

2.H) Drain Time to completely empty EURV (includes WQCV) – The EURV drain time is only required when “EURV and WQCV” is selected in Section 2.D. Enter the drain time (hours) needed to completely empty the EURV. The workbook defaults to a drain time of 68 hours for the DCM recommendation, however the user can provide a shorter or longer drain time. A maximum of 72 hours is recommended to avoid complications with water rights regulations.

### 3. WETLAND BASIN SURCHARGE GEOMETRY

This section is used to develop a preliminary design for the WB surcharge geometry.

3.A) Maximum Surcharge Depth of WQCV (or EURV) – This input depends on whether the design concept is “WQCV Only” or “EURV and WQCV” in Section 2.D. If “WQCV Only” is selected, enter the maximum ponding depth for the WQCV measured from the permanent pool surface. The City DCM recommends a maximum depth of 2 feet for the WQCV in order to maintain healthy wetland growth. If the user enters a depth greater than 2 feet the input will be flagged. If “EURV and WQCV” is selected, enter the maximum ponding depth for the EURV measured from the permanent pool surface. The City DCM recommends a maximum depth of 5 feet for the EURV. If the user enters a depth greater than 5 feet the input will be flagged.

3.B) Average Side Slopes above Filter Surface – Enter the average of all side-slopes (Horizontal/Vertical) of the wetland basin from the permanent pool surface to the WQCV (or EURV) maximum depth. The City DCM recommends that no side slope be steeper than 4H:1V. Enter “0” if vertical walls will be used.

3.C) Basin Bottom Length and Width Dimensions – This section allows the user to choose how to define the WB bottom dimensions for purposes of preliminary design. Only one option can be used.

*3.C.i) Bottom Width* – This option allows the user to specify the bottom width of the WB bottom at the permanent pool surface and the program will then determine the resulting bottom length necessary to provide the WQCV (or EURV).

*3.C.ii) Length to Width Ratio* – This option allows the user to specify the Length to Width Ratio for the WB bottom at the permanent pool surface and the program will determine the width and length necessary to provide the WQCV (or EURV). The City DCM recommends the L:W Ratio be between 2:1 and 4:1 to maximize the flow distance between the inlet and outlet to minimize short circuiting and improve pollutant removal.

## 4. PERMANENT POOL AND LITTORAL ZONE GEOMETRY

4.A) Desired Permanent Pool Volume based on percent of WQCV – Enter the permanent pool volume as a percentage of the WQCV. The City DCM requires a minimum of 75% of the WQCV to minimize eutrophication, increase nutrient reduction, and to provide biodiversity. If the permanent pool volume does not meet the DCM requirements it will be flagged.

4.B) Littoral Zone Area as a Percent of Permanent Pool Area – Enter the approximate littoral zone area as a percentage of total permanent pool surface area. It is recommended that the littoral zone occupy 50% to 70% of the wetland basin's surface area to provide contact with wetland vegetation as the water flows through the pool.

4.C) Width of Littoral Zone Safety Bench around perimeter – Enter the width of the littoral zone safety bench located around the entire perimeter of the basin. It is recommended that it be no less than 4 feet wide. This is an important feature for public safety purposes intended to minimize children and adults from falling into the deep part of the pool. This bench also serves as a littoral zone (i.e., emergent wetland vegetation) that helps reduce eutrophication of the pool.

4.D) Average Depth of Littoral Zone – Enter the average depth of the littoral zone. It is recommended that it be between 0.5 and 1.0 feet to promote wetland vegetation growth.

4.E) Number of Open Water Areas in Permanent Pool – Enter the total number of open water areas in the permanent pool. It is recommended that there be at least 3, including the forebay and the outlet area to provide diverse habitat for predator species (i.e., species that mitigate mosquito problems).

4.F) Maximum Depth of Open Water Areas – Enter the maximum depth of all open water areas. It is recommended that the maximum depth in a wetland basin be between 2 and 4 feet.

4.G) Average Side Slopes for Open Water Areas (below Littoral Zone) – Enter the average of all side slopes of the open water areas below the littoral zone. For slope stability purposes of saturated soils, it is recommended this slope be no steeper than 3H:1V.

## 5. CALCULATED WETLAND BASIN DIMENSIONS

Once all inputs above have been entered, the user can click on the “Calculate Wetland Basin Geometry” button and the program will calculate the preliminary wetland basin geometry results as outlined below. The program first solves for the surcharge volume dimensions above the permanent pool necessary to store the WQCV (or EURV) using an iterative process. Once the surcharge volume dimensions are known, the program can then calculate the permanent pool and littoral zone dimensions based on the user specified widths, depths, and slopes provided in section 4. It is possible that the surcharge volume dimensions can result in negative lengths or widths at the bottom of the permanent pool. If this situation arises, the user will be notified with flagged errors. In order to address this issue, it is recommended that the wetland basin surcharge geometry inputs in Section 3 be modified to use a shallower surcharge depth and/or larger length and width dimensions. The figures located in the WB worksheet to the right of the preliminary design form are helpful in visualizing the default wetland basin layout.

5.A) Average Length at Bottom of each Open Water Area – Once the program iteratively solves for the surcharge volume dimensions necessary to store the WQCV (or EURV), the average length of the open water area bottoms is calculated based on the permanent pool and littoral zone geometry inputs in Section 4.

5.B) Average Width at Bottom of each Open Water Area – Once the program iteratively solves for the surcharge volume dimensions necessary to store the WQCV (or EURV), the average width of the open water area bottoms is calculated based on the permanent pool and littoral zone geometry inputs in Section 4.

5.C) Total Combined Area at Bottom of Open Water Area – The area for each Open Water Area bottom is calculated as the product of 5.A and 5.B. This is then multiplied by the number of open water areas (4.E) to determine the total combined area.

5.D) Depth between Basin Bottom and Lower Edge of Littoral Zone – Calculated as the difference between the maximum depth of open water areas (4.F) and the average depth of littoral zone (4.D).

5.E) Average Length at Top of each Open Water Area – Once the program iteratively solves for the surcharge volume dimensions necessary to store the WQCV (or EURV), the average length of the open water areas where the littoral zone safety bench starts is calculated based on the permanent pool and littoral zone geometry inputs in Section 4.

5.F) Average Width at Top of each Open Water Area – Once the program iteratively solves for the surcharge volume dimensions necessary to store the WQCV (or EURV), the average width of the open water areas where



the littoral zone safety bench starts is calculated based on the permanent pool and littoral zone geometry inputs in Section 4.

5.G) Total Open Water Surface Area – Once the program iteratively solves for the surcharge volume dimensions necessary to store the WQCV (or EURV), the total permanent pool surface area (5.N) is known. This area is then multiplied by the open water surface area percentage (100% - littoral zone percentage, 4.B).

5.H) Total Volume of Open Water Area – The slice of volume stored within the open water areas is calculated using the conic volume method. The total combined area at the bottom of the open water areas (5.C) and the total open water surface area (5.G) are the areas used in the conic volume equation.

5.I) Average Depth of Littoral Zone below Permanent Pool Surface – This is simply the average depth entered in Section 4.D.

5.J) Average Top Length of Each Littoral Zone Cross Berm – Once the program iteratively solves for the surcharge volume dimensions necessary to store the WQCV (or EURV), the average top length of each littoral zone cross berm is calculated based on the permanent pool and littoral zone geometry inputs in Section 4.

5.K) Total Area of Littoral Zone – Once the program iteratively solves for the surcharge volume dimensions necessary to store the WQCV (or EURV), the total permanent pool surface area (5.N) is known. This area is then multiplied by the littoral zone surface area percentage (4.B) to determine the total littoral zone area including perimeter safety bench and cross berms.

5.L) Volume of Littoral Zone – Calculated as the product of 5.I and 5.K.

5.M) Length of Permanent Pool Surface – The program iteratively solves for the length of the permanent pool surface necessary to store the WQCV or EURV (2.E or 2.G) based on the wetland basin surcharge geometry inputs provided in Section 3.

5.N) Width of Permanent Pool Surface – The program iteratively solves for the width of the permanent pool surface necessary to store the WQCV or EURV (2.E or 2.G) based on the wetland basin surcharge geometry inputs provided in Section 3.

5.O) Area of Permanent Pool Surface – Calculated as the product of 5.M and 5.N.

5.P) Total Volume of Permanent Pool – Calculated as the sum of the Volume of Open Water (5.H) and the Volume of Littoral Zone (5.L).

5.Q) Ratio of Permanent Pool Volume to WQCV – The ratio of permanent pool volume (5.P) to the WQCV (2.E) is a simple check to ensure the City DCM minimum of 75% is satisfied.

5.R) Depth of Surcharge above Permanent Pool (freeboard not included) – This is simply the maximum surcharge depth specified by the user in Section 3.A.

5.S) Length of Pond at Top of Surcharge – The program iteratively solves for the length of the permanent pool surface (5.M) necessary to store the WQCV or EURV (2.E or 2.G). This calculated length along with the user specified pond surcharge geometry inputs in Section 3 are used to calculate the top length.

5.T) Width of Pond at Top of Surcharge – The program iteratively solves for the width of the permanent pool surface (5.N) necessary to store the WQCV or EURV (2.E or 2.G). This calculated width along with the user specified pond surcharge geometry inputs in Section 3 are used to calculate the top width.

5.U) Area of Pond at Top of Surcharge – Calculated as the product of 5.S and 5.T.

5.V) Volume of Surcharge above Permanent Pool – The surcharge volume stored above the permanent pool surface is calculated using the conic volume method. The permanent pool area (5.O) and the area at the top of the surcharge volume (5.U) are the areas used in the conic volume equation.

## 6. INLET ENERGY DISSIPATION AND FLOATABLE CONTAINMENT

6.A) Select the Type of Energy Dissipation at Inlet – From the dropdown menu, select the type of energy dissipation provided at concentrated inflow locations. Energy dissipation needs to occur upstream of the forebay area. Provide a brief explanation for your selection and describe any specific characteristics.

6.B) Is a flexible floating trash boom provided to trap floatables – Indicate if a floating trash boom is provided and provide specific details of the type and location. Explain reasoning if a boom is not provided.

## 7. FOREBAY

7.A) Forebay Volume based on percent of WQCV – Enter the forebay volume as a percentage of the WQCV. A forebay in a wetland basin is part of the total permanent pool, typically separated by a littoral zone/berm between it and the main body of the wetland. Because of this a larger forebay is recommended than is used for an EDB and a minimum of 3% of the WQCV is required. A concrete-lined bottom is also recommended to facilitate maintenance. If the forebay volume does not meet the DCM requirements it will be flagged.

## 8. OUTLET ORIFICE

8.A) Orifice Discharge Coefficient – Enter the discharge coefficient for the outlet orifice. The City DCM defaults to 0.60 for a sharp crested orifice. Use appropriate value if a different orifice is used.

8.B) Minimum Allowable Orifice Diameter – Enter the minimum allowable orifice diameter to be used when the program attempts to size the orifice place in Section 9. The City DCM recommends a minimum orifice diameter of 1/4 inches to limit clogging potential, anything less will be flagged.

## 9. CALCULATED OUTLET ORIFICE DIMENSIONS

Once all inputs above have been entered, the user can click on the “*Size Orifice Area to Match Drain Time*” button and the program will calculate the preliminary outlet orifice results as outlined below. The iterative sizing routine may take some time to complete depending on the complexity of the design and whether the EURV is included. It should also be noted that when sizing both the WQCV and EURV, the EURV drain time will be selected as the more conservative approach in sizing the outlet orifice.

9.A) Orifice Area (Ao) – The orifice area is calculated using the iterative sizing routine to find the appropriate orifice size necessary to match the WQCV (or EURV) drain time. It should be noted that when sizing the orifice area to match both the WQCV drain time and EURV drain time, it is likely that the WQCV orifice size will need to be smaller in order to match the EURV drain time. This may result in a WQCV drain time that is longer than intended (improved water quality treatment). The user also has the option of overriding the program calculated value but a flag will appear to highlight that the calculated value has been overridden.

9.B) Circular Orifice Diameter – Based on the Orifice Area (9.A), the program will determine the corresponding orifice diameter. If the resulting orifice diameter is greater than 2 inches the program will return “N/A” and use a rectangular orifice instead in Section 9.C below.

9.C) Rectangular Orifice Width – Based on the Orifice Area (9.A), the program will determine the corresponding rectangular orifice width assuming a 2-inch height. The rectangular orifice is only used when the circular orifice diameter (9.B) would be greater than 2 inches.

### **WQCV Results**

9.D) Calculated WQCV Drain Time – The WQCV drain time is calculated using the Modified Puls Routing Method to determine how long it takes to drain 99% of the WQCV through the outlet orifice. The stage-area-volume-discharge and Modified Puls Routing tables are located within the WB worksheet hidden below and to the right of the preliminary design form. If the calculated result does not match the target drain time (2.C) it will be flagged.

9.E) Maximum Stage of WQCV – The maximum stage of the WQCV is determined from the Stage-Area-Volume table (hidden below and to the right of the preliminary design form) based on the target WQCV (2.E).

9.F) Surface Area at WQCV Maximum Stage – The surface area at the WQCV maximum stage is determined from the Stage-Area-Volume table (hidden below and to the right of the preliminary design form).

9.G) Surcharge Volume at WQCV Maximum Stage – The stored volume at the WQCV maximum stage is determined from the Stage-Area-Volume table (hidden below and to the right of the preliminary design form). This should match the target WQCV in Section 2.E.

### **EURV Results**

9.H) Calculated EURV Drain Time – The EURV drain time is calculated using the Modified Puls Routing Method to determine how long it takes to drain 99% of the EURV through the outlet orifice. The stage-area-volume-discharge and Modified Puls Routing tables are located within the WB worksheet hidden below and to the right of the preliminary design form. If the calculated result does not match the target drain time (2.H) it will be flagged.

9.I) Maximum Stage of EURV – The maximum stage of the EURV is determined from the Stage-Area-Volume table (hidden below and to the right of the preliminary design form) based on the target EURV (2.G).

9.J) Surface Area at EURV Maximum Stage – The surface area at the EURV maximum stage is determined from the Stage-Area-Volume table (hidden below and to the right of the preliminary design form).

9.K) Surcharge Volume at EURV Maximum Stage – The stored volume at the EURV maximum stage is determined from the Stage-Area-Volume table (hidden below and to the right of the preliminary design form). This should match the target EURV in Section 2.G.

### **Orifice Plate and Concrete Opening**

9.L) Minimum Width of Opening in Concrete Wall to mount Orifice Plate – The orifice plate will be mounted to a concrete outlet structure. The outlet structure will include a vertical opening in the concrete face so that the orifice openings can discharge freely into the outlet structure. The minimum width of the vertical opening must be at least 12 inches, but may be larger depending on the size of the orifice openings (particularly wide rectangular openings).

9.M) Minimum Width of Orifice Plate to permit mounting to Concrete Wall – The orifice plate must be at a minimum 8 inches wider than the opening in the concrete wall (9.R).

## **10. TRASH RACK**

10.A) Type of Trash Rack – Select “recommended materials” if using the City recommended trash rack materials. If specifying an alternative to the recommended materials, choose “Other” and provide a description of the specified material. Also make sure that the width of the largest opening in the trash rack is smaller than the smallest orifice dimension in the orifice plate). A trash rack is an essential component of a WQCV/EURV outlet structure and keeps the outlet operational and prevents the small orifice openings from clogging. The trash

rack needs to be submerged into the permanent pool to minimize the complete clogging of the rack itself, thereby accumulation the floating trash at the water's surface level and having cleaner water passing through the rack below the water surface. Regardless, the rack will tend to eventually clog and needs to be inspected after a storm has occurred. If the recommended track rack design is used, simple vertical raking will fully restore its capacity.

10.B Minimum Trash Rack Open Area – Calculated value based on the total outlet orifice area (9.A) using the equation provided. This ensures that the orifice plate controls the discharge rate and not the trash rack.

10.C) Open Area / Gross Area Ratio of Trash Rack – This is the ratio of the trash rack open area to the total trash rack area. DCM recommends a minimum ratio of 0.6 for circular orifices and 0.71 for rectangular orifices. These are recommended minimums and larger ratios can reduce the chances of complete clogging of the trash rack with debris and prolong the periods between cleanings.

10.D) Minimum Total Gross Trash Rack Area – Calculated value provides the minimum trash rack area (length x width) required to satisfy the minimum trash rack open area calculated in 10.B.

10.E) Minimum Height of the Trash Rack – Enter the total height of the trash rack. It is required that it be extended at least 2 feet below the permanent water surface. The program will flag the height if it is not greater than or equal to the WQCV (or EURV) depth plus 2 feet.

10.F) Width of Opening in Concrete Wall for Mounting Trash Rack – Enter the width of opening in concrete wall for mounting trash rack, in inches. A minimum of 12 inches is recommended for a maintainable installation. The program will flag the width if less than the orifice plate width or if when multiplied by the height of the trash rack (10.E) the total area is less than the minimum total gross trash rack area (10.D).

## 11. EMBANKMENT DESIGN AND PROTECTION

In addition to the following three inputs, the design engineer is required to file all appropriate paperwork with the Dam Safety Engineer whenever the embankment or the basin design falls within the filing requirements of the State.

11.A) Describe Embankment Protection – Select whether there is an emergency spillway or some other type of embankment protection. Describe embankment protection design and level of protection it provides, such as the 100-year or larger flood event.

11.B) Select Type of Material used for spillway or embankment hardening – From the dropdown menu, select whether the spillway or embankment hardening will use concrete lining, heavy riprap, heavy soil riprap, buried and vegetated turf reinforcement mats, geocell mats, or other type of erosion protection. For other, explain the type being used and the engineering behind its use.

11.C) Downstream Slope of Embankment – Enter the downstream slope of the embankment. DCM recommends no steeper than 4 feet horizontal for each 1 foot vertical.

## 12. VEGETATION TYPE, SOURCES, AND INSTALLATION PROTOCOLS

Select whether the design uses irrigation or is non-irrigated vegetation. Briefly describe the vegetation type, sources, and installation protocols. Recommend use of crimped straw mulching or erosion blankets when using native seed applications.

## 13. MAINTENANCE ACCESS

13.A) Describe Routine & Restorative Maintenance Access – Check each box that applies for providing maintenance access to each of the elements of the WB. Applicable options include Permanent Pool, Safety Bench, Inlet/Forebay, and Outlet Works. Describe how this access is being provided (e.g. use adjacent public street to access outlet).

## 14. STAGE-AREA-VOLUME-DISCHARGE RELATIONSHIPS

Section 14 provides charts which show the stage-area, stage-volume, and stage-discharge relationships for both the user inputs and the City DCM recommended inputs. These charts are generated from the stage-area-volume-discharge tables located within the WB worksheet, hidden below and to the right of the preliminary design form.

## CHAPTER 10

# PRELIMINARY DESIGN FORM – FULL SPECTRUM DETENTION (FSD) ROUTING

1.	<b>Select WQCV/EURV PCM Type .....</b>	<b>1</b>
2.	<b>WQCV/EURV Outlet Details .....</b>	<b>1</b>
3.	<b>Flood Control Surchage Basin Geometry .....</b>	<b>3</b>
4.	<b>Tributary Watershed Hydrology .....</b>	<b>4</b>
5.	<b>Flood Control Outlet Structure Type .....</b>	<b>5</b>
6.	<b>Overflow Weir (Dropbox) and Grate (Flat or Sloped) .....</b>	<b>6</b>
7.	<b>Outlet Pipe with Flow Restriction Plate .....</b>	<b>7</b>
8.	<b>Emergency Spillway (Rectangular or Trapezoidal) .....</b>	<b>9</b>
9.	<b>Routed Hydrograph Results .....</b>	<b>11</b>

The Full Spectrum Detention (FSD) Routing worksheet has the ability to import preliminary PCM designs for WQCV/EURV storage from the RG, SF, EDB, RP, and WB worksheets (GB, GS, and PPS worksheets are not linked). The FSD Routing worksheet then allows the user to develop a preliminary design for flood control routing above the WQCV/EURV storage. This is accomplished by letting the user extend the WQCV/EURV basin geometry upwards to provide additional storage and then incorporating an outlet structure to control the release rate of larger flood events. The required user inputs and descriptions vary with the type of PCM being used and inputs that are not applicable to the selected PCM type will be greyed out to avoid confusion. The figures located to the right of the respective PCM preliminary design form and the figures to the right of the FSD Routing preliminary design form provide guidance and explanation of various terms.

## 1. SELECT WQCV/EURV PCM TYPE

The first step in developing a preliminary design for Full Spectrum Detention is to select the type of Permanent Control Measure (PCM) being used to capture and treat the WQCV and EURV. The pulldown list includes options for Rain Garden (RG), Sand Filter (SF), Extended Detention Basin (EDB), Retention Pond (RP), and Wetland Basin (WB). In order to select a PCM Type, the corresponding PCM worksheet must be completed first or message will notify the user the import can't be completed. When a PCM Type is selected, the program will import the stage-area-volume-discharge information from the corresponding worksheet. The stage-area-volume relationship is copied to the hidden table located below and to the right of the preliminary design form. The WQCV/EURV outlet structure details (e.g. underdrain orifice or orifice plate depending on PCM Type) will be copied into Section 2 of this worksheet. The required user inputs and descriptions vary with the type of PCM being used and inputs that are not applicable to the selected PCM type will be greyed out to avoid confusion.

## 2. WQCV/EURV OUTLET DETAILS

Depending on the PCM Type selection in Section 1 above, the relevant preliminary design information for the WQCV/EURV outlet will be imported into this section. Rows that are not applicable will show "N/A" and will be greyed out.

2.A) Average Infiltration Rate of WQCV – Average Infiltration Rate only applies to rain gardens and sand filters. The average infiltration rate is copied from Section 2.G of the RG or SF worksheet.

2.B) Depth to Centroid of Underdrain Outlet Orifice from filter media surface – This depth only applies to rain gardens and sand filters and only if underdrains were included in the preliminary design. The depth to the centroid of the underdrain outlet measured from the filter media surface is copied from Section 4.C.i of the RG or SF worksheet.



2.C) Underdrain Outlet Orifice Area – The underdrain outlet orifice area only applies to rain gardens and sand filters and only if underdrains were included in the preliminary design. The orifice area is copied from Section 4.C.iii of the RG or SF worksheet. In the case of the RG worksheet, the orifice diameter is converted to the orifice area.

2.D) Number of WQCV Orifice Rows – The number of WQCV orifice rows only applies to extended detention basins, retention ponds, and wetland basins. The value is always one row for a RP or WB. For an EDB, the number of rows is copied from Section 9.A of the EDB worksheet.

2.E) Vertical Spacing between WQCV Orifice Rows – The vertical spacing between WQCV orifice rows only applies for extended detention basins. The vertical spacing distance is copied from Section 8.C of the EDB worksheet.

2.F) WQCV Orifice Area (Ao) per row – The WQCV orifice area only applies to extended detention basins, retention ponds, and wetland basins. For an EDB, the WQCV orifice area is copied from Section 9.B of the EDB worksheet. For a RP or WB, the WQCV orifice area is copied from Section 9.A of the respective worksheet.

2.G) Maximum Stage of WQCV – The WQCV maximum stage applies for all PCM Types. For a RG or SF, the WQCV maximum stage is copied from Section 2.F.vii of the respective worksheet. For an EDB, the WQCV maximum stage is copied from Section 9.F of the EDB worksheet. For a RP or WB, the WQCV maximum stage is copied from Section 9.E of the respective worksheet.

2.H) EURV Orifice Area (Ao) in Single Row – The EURV orifice area only applies to extended detention basins, retention ponds, and wetland basins. For an EDB, the EURV orifice area is copied from Section 9.J of the EDB worksheet. For a RP or WB, the EURV orifice area is the same as the WQCV orifice area and is copied from Section 9.A of the respective worksheet.

2.I) Maximum Stage of EURV – The EURV maximum stage applies for all PCM Types except rain gardens. For a SF, the EURV maximum stage is copied from Section 2.F.viii of the SF worksheet. For an EDB, the EURV maximum stage is copied from Section 9.N of the EDB worksheet. For a RP or WB, the EURV maximum stage is copied from Section 9.I of the respective worksheet.

2.J) Discharge Coefficient for all WQCV/EURV Outlet Orifice(s) – The discharge coefficient applies for all PCM Types. For a RG or SF, the underdrain orifice discharge coefficient is copied from Section 2.C.ii of the respective worksheet. For an EDB, RP or WB, the outlet orifice discharge coefficient is copied from Section 8.A of the respective worksheet.

### 3. FLOOD CONTROL SURCHARGE BASIN GEOMETRY

Once the PCM Type has been selected and the associated stage-area-volume-discharge information has been imported from the respective PCM worksheet, the user needs to define the flood control surcharge basin geometry above the WQCV/EURV storage. The figures to the right of the FSD Routing preliminary design form help to illustrate how the WQCV/EURV storage transitions into the flood control storage above. The program will default to a linear extension of the WQCV/EURV basin geometry where the PCM side slopes extend up to the top of the flood control storage. However, the user has the ability to override the default geometry to create a transition bench between the WQCV/EURV geometry and the flood control volume. The override option is useful when the linear extension of the WQCV/EURV geometry results in a very deep flood control volume. If that is the case, the user may reduce the overall depth by modifying the bottom length, bottom width, and/or side slopes of the flood control basin.

3.A) Length of Basin at Top of WQCV (or EURV) – For rain gardens, the top length is measured at the WQCV surface since the EURV is not incorporated. For all other PCMs, the top length is measured at the EURV surface. This length is determined by looking up the WQCV (or EURV) maximum stage (2.G or 2.I) in the imported stage-area-volume table hidden down and to the right of the preliminary design form and returning the corresponding length. This length can only be changed by modifying the PCM preliminary design on the corresponding worksheet.

3.B) Width of Basin at Top of WQCV (or EURV) – For rain gardens, the top width is measured at the WQCV surface since the EURV is not incorporated. For all other PCMs, the top width is measured at the EURV surface. This width is determined by looking up the WQCV (or EURV) maximum stage (2.G or 2.I) in the imported stage-area-volume table hidden down and to the right of the preliminary design form and returning the corresponding width. This width can only be changed by modifying the PCM preliminary design on the corresponding worksheet.

3.C) Stage at Top of Transition Bench (Bottom of Flood Control Surcharge) – The stage at the top of the transition bench indicates the depth of the transition bench separating the WQCV/EURV basin geometry and the flood control surcharge geometry. The default stage is 1/10<sup>th</sup> of a foot above the maximum WQCV (or EURV) stage and the corresponding default length and width dimensions at the top of the transition bench (3.D and 3.E) assume that the transition bench side slopes are the same as the PCM side slopes. In other words, the default condition assumes that there is no transition bench and that the flood control basin geometry is a linear extension of the WQCV/EURV basin geometry.

The user has the ability to override this default stage and create a transition bench between the WQCV/EURV basin geometry and the overlying flood control basin geometry. The figures to the right of the FSD Routing preliminary design form help to illustrate how the transition bench can be used to change the flood control basin geometry. The user can enter a new stage for the top of the transition bench (0.1 ft increments) but the

new stage must be equal to or larger than the default stage. If the user wants to create the transition bench at a lower stage, the PCM preliminary design must be modified to decrease the maximum WQCV (or EURV) stage.

3.D) Length at Top of Transition Bench (Bottom of Flood Control Surcharge) – The length at the top of the transition bench starts with a default value based on a linear extension of the WQCV/EURV basin geometry at a depth 1/10<sup>th</sup> of a foot higher than the maximum WQCV (or EURV) stage. As a result, the transition bench has a default slope equal to the PCM side slope as shown in the message to the right of the input cell. The user has the ability to override this default length to create a longer flood control basin. The new length must be greater than or equal to the default length provided. Based on the override length, the message to the right of the input cell will show the resulting transition bench slope in the length direction.

3.E) Width at Top of Transition Bench (Bottom of Flood Control Surcharge) – The width at the top of the transition bench starts with a default value based on a linear extension of the WQCV/EURV basin geometry at a depth 1/10<sup>th</sup> of a foot higher than the maximum WQCV (or EURV) stage. As a result, the transition bench has a default slope equal to the PCM side slope as shown in the message to the right of the input cell. The user has the ability to override this default width to create a wider flood control basin. The new width must be greater than or equal to the default width provided. Based on the override width, the message to the right of the input cell will show the resulting transition bench slope in the width direction.

3.F) Average Side Slopes of Flood Control Surcharge above Transition Bench – The average side slope of the flood control surcharge starts with a default value equal to the PCM side slope. The user has the ability to override this slope. The City DCM recommends a side slope no steeper than 4H:1V, however a slope of 3:1 can be used or enter "0" for vertical walls.

The new width must be greater than or equal to the default width provided. Based on the override width, the message to the right of the input cell will show the resulting transition bench slope in the width direction.

## 4. TRIBUTARY WATERSHED HYDROLOGY

In this section the user must provide tributary watershed hydrology including pre-development peak flows, post-development storm inflow hydrographs and the associated hydrograph time interval.

### 4.A) Input Hydrology Data (copy/paste) from Model Runs

**Pre-Development Peak Flows** – The user may enter the pre-development peak flows (cfs) in the blue input cells for the return periods to be routed through the storage facility. These peak flows are needed to show how close the post-developed peak flows match the pre-developed condition and how well the preliminary design mitigates downstream flooding. The blue input cells provide options for the 2-, 5-, 10-, 25-, 50-, 100- and 500-year pre-development peak flows. The City requires that, at a minimum, you provide the 5- and 100-year values in order to evaluate the 5-year with respect to Colorado Statutes regarding drain times under 72

hours and the 100-year for flood hazard purposes. Providing other return period values is optional but provides a good way to evaluate if the preliminary design is meeting the intent of the full-spectrum detention concept by limiting peak flows for intermediate storms (5-yr through 50-yr) to pre-development conditions and to ensure that the 500-year volume and peak flow can pass through the emergency spillway without overtopping the embankment. Keep in mind that this analysis only shows the comparison just downstream of the detention facility and that further downstream the combined outflow from multiple detention facilities may exceed pre-development conditions. Detailed analysis of larger urban catchments has shown that matching the peak 100-year pre-developed flow at each site results in increased flooding along major waterways downstream. Therefore, it is a good idea to slightly over detain the 100-year runoff volume and release it at 90% of the pre-development peak flow to account for the downstream effects of multiple facilities. Despite the fact that only 90% of the pre-developed peak is targeted, the actual volume of the detention basin, in most cases, is not significantly larger when compared to the releases of 100% of the peak rate.

**Post-Development Inflow Hydrographs** – Enter the post-development storm inflow hydrographs for each of the return periods that you entered for pre-developed peak flows. The City requires that, at a minimum, you provide the 5-year and 100-year hydrograph values for the reasons discussed above. The hydrographs can be copied and pasted from another Excel worksheet to speed up and simplify data entry.

4.B) Adjust “Time Interval” to Match Hydrograph Data – Enter the time interval that your post-development storm inflow hydrographs are based on. Up to 72 rows may be filled out, sufficient for 2-, 3- and 6-hour storms at 5-minute increments. If you need to use a 12-hour storm, change the “Time Interval” from 5-minutes to 10-minutes and use appropriate hydrograph values.

## 5. FLOOD CONTROL OUTLET STRUCTURE TYPE

Section 5 provides a pulldown list which allows the user to select the type of outlet structure being used to detain and release flood events. The user is given two options in the pulldown list.

The first option is the traditional FSD outlet structure consisting of an overflow weir (dropdown) and grate that is drained by an outlet pipe with a flow restriction plate (horizontal plate over top half of pipe, circular orifice plate, or rectangular orifice plate). An emergency spillway is also included with this option. This design assumes that the flow restriction plate on the entrance to the outlet pipe controls the release rate of the 100-year design storm. The overflow weir is set at an elevation above the WQCV/EURV water surface elevation so that it is only utilized when the WQCV or EURV is exceeded (typically larger flood events greater than 5-year design storm). The overflow grate serves as a trash rack to screen trash that may plug the outlet pipe’s entrance and to provide a safety barrier to keep people out of the structure. The emergency spillway is designed to allow larger design storms (e.g. 500-year) to pass through the detention facility or to provide an overflow path if the outlet structure gets clogged. If this option is selected, Sections 6, 7, and 8 will need to be filled out in order to route the design storms.

The second option is to only provide an emergency spillway above the WQCV/EURV outlet structure and not have an overflow weir or outlet pipe. This option may be common in smaller PCM installations where flood control will be handled in downstream regional facilities. If this option is selected, Sections 6 and 7 will be locked and greyed out and the user only needs to provide inputs for the emergency spillway in Section 8.

Cautionary note: If the “Emergency Spillway Only” option is selected and a long spillway crest is used, the flow routing can sometimes become unstable and the results in the comparison tables for the events other than WQCV or EURV may not be valid. Check the charts at the end of this worksheet to determine if the flows oscillate, and if they do ignore the comparisons. Decreasing the spillway crest length of the emergency spillway may help to stabilize it.

## 6. OVERFLOW WEIR (DROPBOX) AND GRATE (FLAT OR SLOPED)

In this section, enter the parameters for the preliminary design configuration of the outlet control box when the “Overflow Weir/Grate, etc.” option is selected in Section 5 above. These are the overflow dropbox sizing parameters used to preliminarily size the overflow weir dimensions, grate slope, grate open area, and clogging potential. The user needs to fill out the first six blue-colored input cells and the software will then calculate the next four rows.

6.A) Overflow Weir Front Edge Height – Enter the height above Stage Zero (feet) that represents the top front edge of the overflow box. The program assumes that the top of the trash control grate is flush with the top of the overflow outlet box (no gap between the concrete overflow box and the grate). The default overflow weir front edge height is set equal the maximum EURV stage (or maximum WQCV stage for rain gardens). Any stage less than the default will be flagged.

6.B) Overflow Weir Front Edge Length (inside edge of dropbox) – Enter the overflow Weir Front Edge Length as measured on the inside edge of overflow box. This is set equal to the horizontal distance between the inside walls of the dropbox behind the front wall or the distance between the inside edges of the grate frame, whichever is smaller. The minimum recommended length is four feet to allow access to the structure for maintenance purposes and to accommodate the size of the outlet pipe (Section 7). A length less than 4 will be flagged. The program may override this length input when the routine to size the outlet structure is running after clicking the sizing button in Section 7. The program will ask the user if they would like to override this length.

6.C) Overflow Weir Grate Slope (H:V, enter zero for flat grate) – This entry defines if you have a flat or sloping grate. If the grate is flat across the top of the dropbox, enter “zero”. If the grate is sloping up from front to back, enter the slope as horizontal vs. vertical (H:V). The slope must be greater than or equal to 3:1.

6.D) Horizontal Length of Weir Sides (inside edge of dropbox) – Enter the horizontal distance (feet), between the front inside-wall and the back-inside wall of the dropbox, or the horizontal distance between the front and

back inside edges of the grate frame, whichever is smaller. The minimum recommended length is four feet to allow access to the structure for maintenance purposes, anything less will be flagged. If the user enters a length of zero, the program assumes that the dropbox is simply an overflow weir without sides as opposed to a drop box.

6.E) Overflow Grate Open Area % (grate open area / total grate area) – Enter, in percent, the total area of the grate that is actually open, namely not blocked by trash rack bars or the grate frame.

6.F) Debris Clogging % – Based on engineer’s best professional judgement, enter the percent of the grate that may be blocked by floating debris during larger storm events. Depending on the size of the tributary area and the size of the grate openings, the debris clogging for small catchments (e.g., 3 to 8 impervious acres) could be as little as 25%. For large catchments (e.g., 50 impervious acres) it could be 50% or more. This also depends on land uses and waterway type upstream. Natural channels with woody debris are likely to deliver larger quantities of floating debris during large events.

6.G) Height of Grate Upper Edge (at back side of dropbox) – The calculated height at the top of a sloping grate based on the horizontal length of the weir sides (6.D) divided by the grate slope (6.C). For flat grates (zero slope), the height will be the same as the weir front edge height entered in 6.A.

6.H) Overflow Grate Slope Length (inside edge of dropbox) – The calculated length of the sloping grate along the grate surface determined using the Pythagorean theorem with the horizontal length of the weir sides (6.D) and the grate slope (6.C). For flat grates (zero slope), the slope length will be the same as the horizontal length entered in 6.D.

6.I) Overflow Grate Open Area (without debris) – The calculated open area of the grate based on the grate dimensions (6.B. and 6.H.) and the percent open area (6.E.).

6.J) Overflow Grate Open Area (with debris) – The calculated open area of the grate determined by adjusting the grate open area without debris (6.I) by the percent debris clogging entered in 6.F.

## 7. OUTLET PIPE WITH FLOW RESTRICTION PLATE

In this section the user enters the preliminary design parameters for the outlet pipe and flow restriction plate used to control the release rate of the 100-year design storm when detaining flood events. The required input parameters will depend on the type of outlet restriction selected in 7.A.

7.A) Select Type of Outlet Restriction – The pulldown list includes three flow restriction plate options. The figure shown to the right of the FSD Routing Preliminary Design Form worksheet inputs provides images depicting each outlet configuration. Once an option is selected from the pulldown list, the appropriate input

cells descriptions below will be updated to reflect the required inputs for that outlet configuration. The three options include:

Circular Outlet Pipe w/ Restrictor Plate which consists of a circular pipe with a horizontal restrictor plate covering up the top portion of the outlet pipe. The restrictor plate height above the invert of the outlet pipe controls the discharge rate into the outlet pipe during the 100-year event.

Circular Orifice Plate which consists of a circular or rectangular outlet pipe with a restrictor plate fully covering the entrance. The restrictor plate has a circular orifice cutout which is smaller than the outlet pipe dimensions and controls the discharge rate into the outlet pipe during the 100-year event.

Rectangular Orifice Plate which consists of a circular or rectangular outlet pipe with a restrictor plate fully covering the entrance. The restrictor plate has a rectangular orifice cutout which is smaller than the outlet pipe dimensions and controls the discharge rate into the outlet pipe during the 100-year event.

7.B) Depth to Invert of Outlet Pipe (or Outlet Orifice) – This input cell description depends on the selection of the Outlet Restriction Type selected in 7.A. If “Circular Outlet Pipe w/ Restrictor Plate” was selected, the user will be asked to provide the depth to invert of outlet pipe relative to Stage Zero. Otherwise, the user will be asked to provide the depth to the invert of outlet orifice relative to Stage Zero. This value should be a positive number and is the distance below the media filter, micropool, or permanent pool.

7.C) Outlet Pipe Diameter, Circular Orifice Diameter or Rectangular Orifice Width – Depending on the Outlet Restriction Type selected in 7.A, the user must provide either the outlet pipe diameter, circular orifice diameter, or width of rectangular orifice (all in inches). If the user knows the pipe or orifice size that they would like to use, they can enter it here directly. However, if they would like the program to automatically determine the pipe or orifice size necessary to control the 100-year release rate to pre-development levels, they can click the sizing button to the right. The sizing routine is described in more detail below.

7.D) Restrictor Plate Height above Pipe Invert or Rectangular Orifice Height – If the user selected “Circular Outlet Pipe with Restrictor Plate” in Section 7.A, the height from the outlet pipe invert to the bottom edge of the restrictor plate (inches) must be provided. If the user selected “Circular Orifice Plate” in Section 7.A, this input cell is not needed and the cell will be grayed out. If the user selected “Rectangular Orifice Plate” in Section 7.A, the height of the rectangular orifice cutout (inches) must be provided. If the user knows the restrictor plate height or rectangular orifice height that they would like to use, they can enter it here directly. However, if they would like the program to automatically determine the dimension necessary to control the 100-year release rate to pre-development levels, they can click the sizing button to the right. The sizing routine is described in more detail below.

**The user has the option of providing input parameters for Sections 7.C and 7.D and the program will calculate the results for Sections 7.E through 7.H based on those inputs. Alternatively, the user can click**



on the button titled **“Size Outlet Pipe and Flow Restrictor Plate to Release 100-yr Post-Development Peak Flow at Pre-Development Peak Flow Levels”** to automatically calculate the required inputs for Sections 7.C and 7.D that control the 100-year release rate. This sizing routine first determines the outlet pipe and restrictor plate or orifice plate configuration necessary to control the 100-year release rate. The routine then goes back and checks to ensure that the overflow weir (dropdown) and grate configuration in Section 6 is not constricting the 100-year release rate more than the outlet pipe/orifice. If the dropdown is controlling, the program will automatically increase the overflow weir front edge length (6.B) until the outlet pipe/orifice controls the 100-year release rate. As a last step, the sizing routine will then automatically determine the emergency spillway parameters (Section 8) necessary to pass the un-detained 100-year peak flows (post-development peak flow rate) in case the outlet structure becomes fully clogged. It should be noted that any and all of the parameters calculated using the automated sizing routine can be later overridden by the user.

7.E) Half Central Angle of Restrictor Plate on Pipe – This calculation is only performed when “Circular Pipe with Restrictor Plate” is selected in Section 7.A. The calculation is necessary to determine the orifice area and orifice centroid for the portion of the outlet pipe below the restrictor plate. If circular or rectangular orifice plates are selected this row is greyed out because the calculation is not necessary.

7.F) Outlet Orifice Area – This is the calculated orifice area based on the user inputs in 7.A through 7.D.

7.G) Height of Outlet Orifice Centroid above Outlet Pipe Invert (or Orifice Invert) – This is the calculated orifice centroid relative to the outlet pipe invert or orifice invert depending on the Outlet Restriction Type selected in 7.A.

7.H) Ratio of Grate Open Area / 100-yr Orifice Area – This is the calculated open area ratio of the Overflow Grate Open Area (6.I.) divided by the Outlet Orifice Area (7.F). It is recommended that this value be greater than or equal to 4 to ensure that the Outlet Restriction Plate is the controlling element of the outlet structure and that the grate is not controlling the actual release rate of the 100-year design storm. If the ratio is less than 4, the value will be flagged.

## 8. EMERGENCY SPILLWAY (RECTANGULAR OR TRAPEZOIDAL)

In this section the user enters the geometry of the emergency spillway and the desired freeboard in order to check the adequacy of the emergency spillway/overflow capacity and depth.

8.A) Spillway Invert Stage – Enter the stage (relative to stage zero) of the spillway crest. The minimum stage entered depends on the outlet structure type selected in Section 5. When the dropdown with grate and outlet pipe are being utilized, the spillway stage should be above the 100-year ponding depth to ensure it does not interfere with the controlled release rate of the 100-year design storm through the outlet pipe restriction plate. For designs where only the emergency spillway is being used (no dropdown or outlet pipe), the stage should be



above the WQCV (or EURV) ponding depth to ensure it does not interfere with the controlled release rate of the WQCV and EURV through the filter media and underdrain or orifice plate.

8.B) Spillway Crest Length – Enter the length of the broad-crested spillway weir perpendicular to the flow direction. If you are not using a spillway and are using a reinforced embankment, enter the total length of the embankment crest. The user should be aware that mathematical instabilities can occur for large weir lengths since the discharge rate can increase very rapidly with depth, thus causing the Modified Puls Routing method to produce oscillating results in flow and depth. Should that happen, providing a shorter spillway crest length may stabilize the outflow, but may somewhat underestimate the actual flow rates overtopping the basin.

8.C) Spillway End Slopes (H:V) – Enter the average of the side slopes at the ends of the spillway (horizontal vs. vertical). Estimate these using either the formed slopes or the terrain slopes at the ends of the spillway. Enter "0" if the ends are vertical walls.

8.D) Freeboard above Maximum Water Surface – Enter the freeboard above the emergency spillway overflow water surface stage. Typically, 1.0 foot of freeboard is recommended, but for large installations the user may consider providing more freeboard and for very small installations less freeboard. The State Engineer may require the spillway be designed to pass the modified or full probable maximum flood when the detention storage and embankment height exceed specified minimums set by the State.

**The user has the option of providing input parameters for Sections 8.A through 8.D and the program will calculate the results for Sections 8.E through 8.G based on those inputs. Alternatively, the user can click on the button titled "Size Emergency Spillway to Pass Post-Development 100-year Peak Runoff Rate" to automatically calculate the required inputs for Sections 8.A through 8.D. The sizing routine will then automatically determine the emergency spillway parameters necessary to pass the un-detained 100-year peak flows (post-development peak flow rate) in case the outlet structure becomes fully clogged. It should be noted that any and all of the parameters calculated using the automated sizing routine can be later overridden by the user. This sizing routine is identical to the emergency spillway sizing that occurs as part of the Outlet Pipe/Orifice sizing routine button in Section 7.**

8.E) Spillway Design Flow Depth – This is the calculated flow depth through the emergency spillway based on the un-detained post-development peak flow rate for the 100-year design storm entered in Section 4.

8.F) Stage at Top of Freeboard – This is the calculated stage at the freeboard level (100-year overflow water surface plus freeboard depth).

8.G) Basin Area at Top of Freeboard – This is the calculated surface area of the detention facility at the stage corresponding to the stage at top of freeboard (8.F.). This provides the user with the surface area footprint of the detention facility assuming the outlet structure is clogged and the entire 100-year design storm inflow passes through the emergency spillway.

## 9. ROUTED HYDROGRAPH RESULTS

Once all of the required inputs have been entered in Sections 1 through 8, the program will automatically route the hydrographs through the detention facility and summarize the results in this section. Only results for the return periods containing hydrology data in Section 4 will be populated. Results that are outside of City required or recommended ranges will be highlighted in pink for further evaluation and possible changes in the preliminary design. The summary results include:

Inflow hydrograph volume calculated based on the user input post-development storm inflow hydrographs. It is a good idea to double check the calculated volumes against the source of the inflow hydrographs to make sure the data was entered correctly.

Predevelopment Peak Flows are simply a copy of the user entered values in Section 4.

Peak Inflow is the largest value in the post-development storm inflow hydrographs entered by the user in Section 4.

Peak Outflow is calculated using the Puls Routing Method to route the storm inflow hydrographs through the user defined storage facility and outlet structure.

Ratio (Outflow/Predevelopment) is simply the ratio of the peak outflow from the detention facility divided by the user entered pre-development peak flow. This provides a quick comparison of the release rates against the pre-development condition to determine if the preliminary design is functioning as intended.

Structure Controlling Flow identifies which component of the overall outlet configuration is controlling the release rate at that return periods maximum water surface elevation. For example, in an EDB, a good FSD design would result in the orifice plate controlling the WQCV, EURV, 2-yr and possibly 5-yr release rates. The overflow weir (dropbox) and grate would likely control the 10-year through 50-year storms. The outlet pipe restrictor plate would control the 100-year release rate (ideally to 90% of the pre-development peak flow), and the emergency spillway would be functioning during the 500-year storm.

Maximum Velocity through Grate represents the velocity through the grate open area at the maximum water surface elevation of each return period. Research has shown that the maximum velocity should not exceed 2 feet per second due to safety concerns regarding a person getting pinned to the rack during a large storm event. At velocities below 2 fps the average child should be strong enough to pull themselves safely off of the outlet structure. If no overflow weir (dropbox) with grate is provided this row is not applicable.

Time to Drain 97% of Volume shows the duration in hours it takes to drain a design storm from when the inflow hydrograph begins until only 3% of the design storm volume remains in the detention facility. The value of 97% is based on the Colorado Statute that 97% of the 5-year storm drain within 72 hours to avoid impacts on senior water rights.

Time to Drain 99% of Volume shows the duration in hours it takes to drain a design storm from when the inflow hydrograph begins until only 1% of the design storm volume remains in the detention facility. These results are used to determine the drain time of the WQCV (e.g. 40 hours for an EDB) and also to ensure that all design storms drain within 120 hours per the Colorado Statute. The value of 99% is used because the math used to calculate drain times results in a disproportionately long time to drain the last 1% due to the very small head on the outlet structure.

Maximum Ponding Depth is the calculated maximum depth of each return period based on the Modified Puls Routing Method.

Area at Maximum Ponding Depth is the corresponding surface area at the maximum ponding depth based on the Stage-Area relationship.

Maximum Volume Stored is the corresponding storage volume at the maximum ponding depth based on the Stage-Volume relationship.

In addition to the summary results table, three charts are provided showing inflow vs. outflow hydrographs, ponding depth over time, and the stage-area-volume-discharge relationships for the preliminary design. If unexpected oscillations show up in the outflow hydrographs, the cause is most likely due to routing instabilities being caused by a large jump in flow rate at a weir crest (overflow dropbox or emergency spillway).