PHASE II DRAINAGE REPORT
FOR
GRAND PARK – WEST MOUNTAIN -
PLANNING AREAS 8Wb, 9W.1, 9W.2, 10W.1, 10W.2, 11W &
Portions of 23W

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DECEMBER 2025

Engineer's Statement:

This report was prepared by me, or under my direct supervision, in accordance per the Town of Fraser Storm Drainage Design and Technical Criteria which references the Grand County Storm Drainage Design and Technical Criteria Manual, dated August 1st, 2006, and it was designed to comply with the provisions thereof. I understand that Town of Fraser does not and will not assume liability for drainage facilities designed by others.

____
Martin Metsker, P.E.
Colorado Professional Engineer
License #41743

Owner/Developer's Statement:

I Grand Park Development Company hereby certify that the drainage facilities for planning areas 8Wb, 9W.1, 9W.2, 10W.1, 10W.2, 11W & portions of 23W, shall be constructed according to the design presented in this report. I understand that the Town of Fraser does not and will not assume liability for drainage facilities designed or reviewed by my engineer. I also understand that the Town of Fraser relies on the representations of others to establish that drainage facilities are designed and built in compliance with applicable guidelines, standards and specifications. Review by the Town of Fraser can therefore in no way limit or diminish any liability which I or any other party may have with respect to the design or construction of such facilities.

____
Grand Park Development Company

____
Printed Name

TABLE OF CONTENTS

I. GENERAL LOCATION AND DESCRIPTION 4

- A. SITE LOCATION 4
- B. DESCRIPTION OF SITE 4

II. DRAINAGE BASINS AND SUB-BASINS 5

- A. MAJOR DRAINAGE BASINS 5
- B. SUB-BASIN DESCRIPTION 5

III. DRAINAGE DESIGN CRITERIA 6

- A. REGULATIONS 6
- B. DEVELOPMENT OF BASIC DATA AND CONSTRAINTS 6
- C. HYDROLOGICAL CRITERIA 6
- D. HYDRAULIC CRITERIA 7
- E. STORMWATER QUALITY CRITERIA 8
- F. VARIANCES FROM CRITERIA 8

IV. DRAINAGE FACILITY DESIGN 8

- A. GENERAL CONCEPTS 8
- B. SPECIFIC DETAILS 8

V. CONCLUSIONS 12

- A. COMPLIANCE WITH STANDARDS 12
- B. DRAINAGE CONCEPT 12

VI. REFERENCES 13

APPENDICES

Appendix A – General Maps

Appendix B – Hydrologic Calculations

Appendix C – Detention Basin/Water Quality Enhancement BMP's

Appendix D – References

Appendix E – Drainage Maps

I. GENERAL LOCATION AND DESCRIPTION

A. Site Location

This Phase II Drainage Report provides recommendations for changes in the drainage patterns resulting from the future construction of the major infrastructure components for Grand Park – West Mountain – Planning Areas 8Wb, 9W.1, 9W.2, 10W.1, 10W.2, 11W, and portions of 23W in Fraser, CO, from here on known as the "Site". The Site is currently undeveloped and future development will include multi-family, commercial, hospitality, open space, associated roadway and utility infrastructure. The intent of the report and the Site is to establish parameters for future development which will include 184 residential units, 248 lodging units, and about 123,584 square feet of commercial space.

The Site is approximately 189.3 acres and the inspected drainage area is 276.43 acres. The Site is bound to the west by Spring Meadow drainageway and open space, to the north and east by the Union Pacific Railroad, and to the south by Grand Park Drive. The Site is a part of the northwest quarter of Section 29 and northwest quarter of Section 32, Township 1 South, Range 75 West of the 6th Principal Meridian, Town of Fraser, County of Grand, State of Colorado. A vicinity map for the site can be found in Appendix A.

B. Description of Site

The Site is currently undeveloped with existing native vegetation, and the land uses according to the approved PD are residential, clubhouse and open space containing approximately 189.3 acres. The Site has naturally occurring slopes ranging from 1 to 45 percent, generally slopes from the south to the north towards Spring Meadow Drainage Basin. The soils within the Site include Cowdrey loam, Cumulic Cryaquolls, and Frisco-Peeler gravelly sandy loams, and the soil primarily consist of hydrologic soil groups B and C. A soils map has been provided and can be found in Appendix A.

The Site primarily lies in the Spring Meadow basin. The Site is adjacent to an existing floodplain, and lies within Zone X, "Areas determined to be outside the 0.2% annual chance floodplain," as depicted on the FEMA Flood Insurance Rates Map 08049C0991C Effective January 2, 2008, found in Appendix A. The Site does lie near Leland Creek which is a major drainageway. The Site will not propose modifications or improvements to the floodplain. The Site drainage will not adversely impact the surrounding existing drainage infrastructure.

Historically, discharge from the Site sheet flows northeast to the existing culvert that conveyed runoff generated within Spring Meadow basin across the railroad. Ultimately all runoff generated within the Site will be conveyed to the northeast, across US40 and into the Fraser River.

The intent of this project is to construct the necessary roadways and utility infrastructure to begin development of planning areas 8Wb, 9W.1, 9W.2, 10W.1, 10W.2, and 11W. This report details the general drainage patterns that the planning areas will follow in the final developed conditions. Subsequent reports will be required detaining the final design of the individual planning areas.

II. DRAINAGE BASINS AND SUB-BASINS

A. Major Drainage Basins

The Site lies within Spring Meadow drainage basin. Runoff generated within the Site will generally follow historic drainage pattern. Runoff will generally be conveyed to the northeast to each basin's respective pond before being discharged towards an existing culvert that will convey the runoff across the railroad. The flows will then be conveyed into various existing ponds located in the meadow to the northwest. Flows then continue under US-40 and confluence into the Fraser River that will ultimately discharge into the Colorado River. Please see the Proposed Drainage Map found in Appendix E of this report for basins flow information.

The Site falls within Zone X, as shown on the Federal Emergency Management Agency Flood Insurance Rate Map (FIRM) panel 08049C0991C. The development will have no effect on the Zone X designation where there are "Areas determined to be outside the 0.2% annual chance floodplain." The development will not have an effect on the Zone X designation and will remain the same. If improvements for the development require entering the floodplain, further evaluation of improvements taking place and disturbance of the floodplain will be described in subsequent reports. A FIRM map can be found in Appendix A.

There are no previous drainage studies associated with the Site; however, the "Storm Drainage Master Plan for Grand Park" by High country Engineering, dated February 2006 analyzed the runoff generated to the southwest of the railroad and the culvert capacities of all railroad crossings within West Mountain. This drainage report has been written as a standalone report that will conform to the culvert capacities established in this previously approved drainage report.

B. Sub-basin Description

Minor Drainage Basins for the Site have been delineated using the proposed site layout and grading. Grading within the planning areas represents general drainage patterns; however, final grading will take place at a later date and will be described in subsequent reports during the future development of the planning areas. Overall, the proposed drainage patterns for the sub-basins will generally follow the historic patterns prior to development. For sub-basins within the Site, runoff will drain towards low points in the future roadways and other design points. The developed minor basin will include overland flow and storm sewer collection systems which will direct stormwater to the detention basins (DBs) or to off-site facilities that can account for developed runoff from the Site.

Basin A in its fully developed conditions will consist of roadways, single-family housing, multi-family housing, commercial area, a golf course and a detention pond. Runoff generated within the basin will be captured by proposed storm infrastructure, then conveyed into the proposed DB pond to the north of the Site. This pond will outfall to the existing 48-inch storm infrastructure located under the Union Pacific Railroad and the discharged runoff will eventually be conveyed through Cozens Meadow.

Basin B in its fully developed conditions will include roadways, single and multi-family housing areas, a detention pond, and open space. All runoff generated within B basins will drain to the east to the proposed DB pond to the east of the Site. This DB outfalls to the north, where the runoff will be conveyed across the Union Pacific Railroad via a 24-inch existing culvert, and the flows will eventually be conveyed through Cozens Meadow.

Basin C includes roadways, single family housing areas, and open space. All runoff generated within the C basins will drain to the south to temporary sediment basin Pond C. In the fully developed conditions of West Mountain, this temporary sediment basin will be modified to be a detention pond that treats a much larger watershed area. Pond C will remain a temporary sediment basin until 15 acres or more of development drains to it. This temporary sediment basin was sized according to Table SB-1 in the Sediment Basin Section of the Mile High Flood District (MHFD) Storm Drainage Criteria Manual volume 3 (Ref. E). An exhibit has been included in Appendix C showing the methodology used to size this temporary sediment basin. Hydraulic calculations have been included for the stage-storage discharge relationship for the temporary sediment basin and these calculations can be found in Appendix C.

All D, E, and OS basins will drain to their respective design points and leave the site undetained. These basins will not receive treatment or be detained because DB ponds are not feasible within these basins due to existing site constraints.

III. DRAINAGE DESIGN CRITERIA

A. Regulations

The Town of Fraser has adopted Grand County Strom Drainage Design and Technical Criteria Manual (Ref. A).

This Phase II Report is in accordance with Grand County's Storm Drainage Design and Technical Criteria Manual (Ref. A) and the Mile High Flood District (MHFD) Storm Drainage Criteria Manual (Ref. C, D and E). These manuals were used as a basis of design for the Site. The report will analyze the minor (5-year) and major (100-year) storm events. The 5-year storm was used for the minor storm event because there will be curb and gutter throughout the Site which is the criteria for the minor storm to be considered the 5-year storm event per Grand County's Storm Drainage Design and Technical Criteria Manual (Ref. A). All applicable figures, tables, and graphs from these manuals have been included in the Appendices.

The drainage design of the Site adheres to the requirements of Section 404 of the Clean Water Act, Section 106 of the National Historic Preservation Act of 1966 and the Endangered Species Act. Additionally, the drainage design conforms to all applicable local, state, and federal requirements for drainage design and stormwater discharge.

B. Development of Basic Data and Constraints

There are no previous drainage studies associated with the Site. The proposed drainage conditions discussed herein will have no adverse impact to surrounding developments or properties.

C. Hydrological Criteria

Some proposed minor drainage basins within the Site are greater than 90 acres; therefore, a routed hydrograph procedure is recommended to determine the flow rates for basin within the Site. Since HEC-HMS has historically been used to perform hydrologic calculations for the Site, this software was used to generate and route storm hydrographs for all basins within the Site. The sub-basins were delineated based on the existing and proposed topography developed for the pad sites. A proposed drainage map for the Site can be found in Appendix E.

The intensity-frequency curves used in the hydrologic calculations were taken from Grand County's Storm Drainage Design and Technical Criteria Manual (Ref. A) and storm events that were not provided by Grand County's drainage manual were supplemented by NOAA ATLAS 14 Point Precipitation Frequency Estimates, which can be found in Appendix A. All drainage infrastructure was analyzed and designed for both the minor (5-year) and major (100-year) storm events. The 5-year storm was used for the minor storm event because there will be curb and gutter throughout the Site which is the criteria for the minor storm to be considered the 5-year storm event per Grand County's Storm Drainage Design and Technical Criteria Manual (Ref. A). All applicable figures, tables, and graphs from these manuals have been included in the Appendices.

Within the HEC-HMS software, the SCS Curve Number Loss method was used, and the use of this method is well documented in the HEC-HMS Technical Reference Manual published by the USACE (Ref. I). The calculation of the curve number and initial abstraction were adjusted because the SCS Curve Number Loss Method assumes the soil will infiltrate to 20% of the maximum potential retention. It is well documented that this assumption decreases the models accuracy when applied to steep slopes, forested regions, or mountainous areas because the SCS Curve Number Loss Method was developed for relatively flat agricultural areas which allow significantly more infiltration. In order to adjust the Curve Number and Initial Abstraction, we used equations 1, 2, and 3 provided by Ajmal, et. al. (2020) (Ref. J), where lambda was equal to 0.05, or in other words 5% of the maximum potential retention will be used for infiltration before the excess precipitation produces runoff. All curve number and lag time calculations, HEC-HMS inputs, and HEC-HMS outputs can be found in Appendix B. A picture from the HEC-HMS basin model as well as a map showing all elements in the HEC-HMS model and their existing and proposed flow rates have been included in Appendix E.

The proposed detention ponds within basins A and B have been provided for water quality treatment and stormwater detention as defined in Grand County's Storm Drainage Design and Technical Criteria Manual (Ref. A). Because the HEC-HMS software was used for hydrologic calculations instead of the rational method, the modified FAA procedure was used to size the detention ponds, following section 10.2.2 of the Grand County Storm Drainage Design and Technical Criteria Manual (Ref. A). When sizing the required detention volume for the DBs, the 10-year storm event was used for the minor storm because section 10.2 of Grand County's Storm Drainage Design and Technical Criteria Manual specifies "For detention purposes, the minor storm event shall be the 10-year recurrence interval, and the major storm event shall be the 100-year recurrence interval." Results for the detention pond sizing can be found in Appendix C. The detention ponds will also restore developed stormwater flows to their historic conditions before releasing flows to the existing downstream storm infrastructure. Because flows will be restored to their historic conditions before release, no floodplain limits will be adversely impacted by the development of the Site, and downstream properties will not be negatively impacted by the developed stormwater.

D. Hydraulic Criteria

Hydraulic calculations for detention pond sizing were based on the modified FAA method. After calculating the required detention volume for the minor and major storms, the MHFD design spreadsheets were used to design each pond's outlet structure. Within this spreadsheet, zone 1 was the WQCV (calculated within the MHFD detention spreadsheet), zone 2 was the minor detention volume minus the WQCV, and zone 3 was the major detention volume. The total detention volume in the MHFD spreadsheet was user defined to equal the combined minor and major detention volumes from the modified FAA method. The modified FAA spreadsheets and associated MHFD detention spreadsheets for Ponds A and B can be found in Appendix C. A temporary sediment basin will be used to treat the runoff generated within the C basins before being discharged into Leland Creek. An exhibit as well as stage storage discharge tables for this temporary sediment basin can be found in Appendix C. The final detention pond outlet control design will be provided in ensuing reports.

Street and inlet capacity designs will be provided in subsequent reports and will be based on Grand County's Storm Drainage Design and Technical Criteria Manual (Ref. A), and design spreadsheets provided by the MHFD.

Swale velocity and capacity will be analyzed in a subsequent Phase III Drainage report using Hydraflow Express. Hydraflow Express uses the Manning's equation to compute flow at a known depth or a depth at a known flow.

E. Stormwater Quality Criteria

Water quality measures will be provided in subsequent reports that will include the designs of the proposed DB, forebay, and outlet structure for proposed detention Ponds A and B. The DB will have been designed to incorporate a structure that releases flows for the water quality capture volume (WQCV), minor (10-year) storm event, and the major (100-year) storm event. Please see the Proposed Drainage Map found in Appendix E of this report for basin flow information.

F. Variances from Criteria

No variances are being requested at this time.

IV. DRAINAGE FACILITY DESIGN

A. General Concepts

Low Impact Development (LID) practices and strategies have been applied to the comprehensive land planning and engineering design approach to managing stormwater runoff. The primary objective of these concepts is the preservation of the natural features of the property by arranging the development to minimize Site grading, impacts to existing vegetation and wetlands, as well as providing open space areas. The drainage design will generally maintain the historic drainage patterns and release rates for the Site. The detention ponds on Site have been located to minimize subsurface systems and control the developed discharge prior to entering the established waterways thus reducing the impact to the surrounding tributaries.

In the final developed condition, runoff will be designed to drain to sump locations, be captured by inlets, or sheet flow into grass lined swales that will be detailed in future reports. The runoff will then be conveyed via a subsurface system or via swales toward proposed or existing detention ponds that will have a final design in subsequent reports. These ponds will discharge via a pipe from an outlet structure *(to be designed and detailed in subsequent reports)* or overflow weirs to an existing culvert that will convey flows across the Union Pacific railroad.

B. Specific Details

Sub-basin A

Sub-basin A is 165.82 acres and in its final developed condition will be comprised of open space, paved area, single and multi-family lots, commercial area, a permanent pond and golf course areas. Runoff generated within the basin will drain north to a proposed detention pond located at Design Point A. After being detained, the pond will discharge flows to the north where flows will be captured by an existing forty-eight (48") inch flared end section and conveyed across the Union Pacific railroad to the north to Grand Park meadow.

Pond A will be used as a permanent feature pond; however, the top 5 feet of the pond will be utilized as a DB. The portion of the pond being used as a DB has been designed to store 10.081 acre-feet, which is equal to the combined minor and major required detention volumes per the modified FAA method. The 100-year storm predeveloped peak flow is 183 cfs per the HEC-HMS hydrologic model, and the pond outlet structure will be designed in subsequent reports to release at 90% or less of the predeveloped peak flow. The detention basin design workbook (MHFD-Detention, Version 4.07, June 2025) was used for the preliminary design of detention Pond A. The modified FAA and MHFD detention spreadsheet output files for detention Pond A have been included in Appendix C. These are preliminary calculations and the final design of this pond and its outlet structure will be provided in a subsequent Phase III drainage report.

Sub-basin A1

Sub-basin A1 is 23.59 acres comprised of paved area, multi-family lots, commercial area, golf course, and open space. Runoff generated within the basin will drain northwest to Design Point A1 and sheet flow into the existing drainage channel leading to DB Pond A. After being detained, the pond will discharge flows to the north where flows will be captured by an existing forty-eight (48”) inch flared end section and conveyed across the Union Pacific railroad to the north to Grand Park meadow.

Sub-basin A2

Sub-basin A2 is 11.06 acres comprised of paved area, multi-family lots, commercial area and open space. Runoff generated within the basin will drain north to a sump type R inlet at Design Point A2. After being captured, the runoff will be conveyed to the west via proposed subsurface infrastructure, through a tract, until it is discharged into a swale at design point A2/3. This swale will convey the flows to DB Pond A. After being detained, the pond will discharge flows to the north where flows will be captured by an existing forty-eight (48”) inch flared end section and conveyed across the Union Pacific railroad to the north to Grand Park meadow.

Sub-basin A3

Sub-basin A3 is 5.95 acres comprised of paved area, multi-family lots, and open space. Runoff generated within the basin will drain north to a sump type R inlet at Design Point A3. After being captured, the runoff will be conveyed to the north via proposed subsurface infrastructure, through a tract, until it is discharged into a swale at design point A2/3. This swale will convey the flows to DB Pond A. After being detained, the pond will discharge flows to the north where flows will be captured by an existing forty-eight (48”) inch flared end section and conveyed across the Union Pacific railroad to the north to Grand Park meadow.

Sub-basin A4

Sub-basin A4 is 2.73 acres comprised of paved area, future single-family lots, and open space. Runoff generated within the basin will drain north to a set of on-grade type R inlet at Design Point A4. After being captured, the runoff will be conveyed to the north via proposed subsurface infrastructure, through a tract, until it is discharged into the existing channel within Basin A. This channel will convey the flows to DB Pond A. After being detained, the pond will discharge flows to the north where flows will be captured by an existing forty-eight (48”) inch flared end section and conveyed across the Union Pacific railroad to the north to Grand Park meadow.

Sub-basin B

Sub-basin B is 8.62 acres comprised of single and multi-family lots, and open space. The runoff generated in basin B will sheet flow into the drainage channel leading to DB Pond B at design point B. After being detained in DB Pond B, the runoff will be discharged to the north to design point OS3, where the runoff will be captured by an existing twenty-four (24”) inch culvert that will convey the runoff across the Union Pacific railroad to Cozen’s Meadow.

Pond B has been designed to store 2.295 acre-feet with a maximum depth of 9 feet which is equal to the combined minor and major required detention volumes per the modified FAA method. The 100-year storm predeveloped peak flow is 29.9 cfs per the HEC-HMS hydrologic model, and the pond outlet structure will be designed in subsequent reports to release at 90% or less of the predeveloped peak flow. The detention basin design workbook (MHFD-Detention, Version 4.07, June 2025) was used for the preliminary design of detention Pond B. The modified FAA and MHFD detention spreadsheet output files for detention Pond B have been included in Appendix C. These are preliminary calculations and the final design of this pond and its outlet structure will be provided in a subsequent Phase III drainage report.

Sub-basin B1

Sub-basin B1 is 10.33 acres comprised of roadways, single family lots, and open space. Runoff generated within the basin will drain northeast to a sump type R inlet at Design Point B1. After being captured, the runoff will be conveyed to the northeast to DB Pond B at design point B via proposed subsurface infrastructure and swales. After being detained in DB Pond B, the runoff will be discharged to the north to design point OS3, where the runoff will be captured by an existing twenty-four (24”) inch culvert that will convey the runoff across the Union Pacific railroad to Cozen’s Meadow.

Sub-basin B2

Sub-basin B2 is 8.97 acres comprised of roadways, single family lots, and open space. Runoff generated within the basin will drain northeast to a sump type R inlet at Design Point B2. After being captured, the runoff will be conveyed to the northeast to DB Pond B at design point B via proposed subsurface infrastructure and swales. After being detained in DB Pond B, the runoff will be discharged to the north to design point OS3, where the runoff will be captured by an existing twenty-four (24”) inch culvert that will convey the runoff across the Union Pacific railroad to Cozen’s Meadow.

Sub-basin B3

Sub-basin B3 is 8.47 acres comprised of roadways, multi-family lots, and open space. Runoff generated within the basin will drain northeast to a sump type R inlet at Design Point B3. After being captured, the runoff will be conveyed to the east to DB Pond B at design point B via proposed subsurface infrastructure and swales. After being detained in DB Pond B, the runoff will be discharged to the north to design point OS3, where the runoff will be captured by an existing twenty-four (24”) inch culvert that will convey the runoff across the Union Pacific railroad to Cozen’s Meadow.

Sub-basin B4

Sub-basin B4 is 1.05 acres comprised of roadways. Runoff generated within the basin will drain north to a sump type R inlet at Design Point B4. After being captured, the runoff will be conveyed to the north to DB Pond B at design point B via proposed subsurface infrastructure. After being detained in DB Pond B, the runoff will be discharged to the north to design point OS3, where the runoff will be captured by an existing twenty-four (24”) inch culvert that will convey the runoff across the Union Pacific railroad to Cozen’s Meadow.

Sub-basin C

Sub-basin C is 1.71 acres comprised of a temporary sediment basin and open space. Runoff generated within the basin will drain into the temporary sediment basin at Design Point C. After being held in temporary sediment basin Pond C, the runoff will be discharged to the east into Leland Creek. The runoff will be conveyed to the northeast via Leland Creek and existing storm infrastructure that will convey the runoff across the Union Pacific railroad to Cozen’s Meadow. This temporary sediment basin was sized according to Table SB-1 in the Sediment Basin Section of the Mile High Flood District (MHFD) Storm Drainage Criteria Manual volume 3 (Ref. E). An exhibit has been included in Appendix C showing the methodology used to size this temporary sediment basin. Hydraulic calculations have been included for the stage-storage discharge relationship for the temporary sediment basin and these calculations can be found in Appendix C.

In the fully developed conditions of West Mountain, temporary sediment basin Pond C will be modified to be a detention pond that treats a much larger watershed area. Pond C will remain a temporary sediment basin until 15 acres or more of development drains to it.

Sub-basin C1

Sub-basin C1 is 2.92 acres comprised of roadways, single family lots, and open space. Runoff generated within the basin will drain southeast to a curbcut at Design Point C1. After being captured, the runoff will be conveyed to the south to temporary sediment basin Pond C at design point C via proposed subsurface infrastructure and swales. After being held in temporary sediment basin Pond C, the runoff will be discharged to the east into Leland Creek. The runoff will be conveyed to the northeast via Leland Creek and existing storm infrastructure that will convey the runoff across the Union Pacific railroad to Cozen's Meadow.

Sub-basin C2
Sub-basin C2 is 7.57 acres comprised of roadways, single family lots, and open space. Runoff generated within the basin will drain southeast to a set of on-grade type R inlets at Design Point C2. After being captured, the runoff will be conveyed to the south to temporary sediment basin Pond C at design point C via proposed subsurface infrastructure and swales. After being held in temporary sediment basin Pond C, the runoff will be discharged to the east into Leland Creek. The runoff will be conveyed to the northeast via Leland Creek and existing storm infrastructure that will convey the runoff across the Union Pacific railroad to Cozen's Meadow.

Sub-basin D1
Sub-basin D1 is 6.77 acres comprised of roadways, single family lots, and open space. Runoff generated within the basin will drain east to a set of on-grade type R inlets at Design Point D1. After being captured, the runoff will be conveyed to the south to Leland Creek via proposed subsurface infrastructure. The runoff will be conveyed to the northeast via Leland Creek and existing storm infrastructure that will convey the runoff across the Union Pacific railroad to Cozen's Meadow.

Sub-basin D2
Sub-basin D2 is 0.32 acres comprised of roadways. Runoff generated within the basin will drain east to an on-grade type R inlet at Design Point D2. After being captured, the runoff will be conveyed to the south to Leland Creek via proposed subsurface infrastructure. The runoff will be conveyed to the northeast via Leland Creek and existing storm infrastructure that will convey the runoff across the Union Pacific railroad to Cozen's Meadow.

Sub-basin E1
Sub-basin E1 is 3.05 acres comprised of roadways, single-family lots, and open space. Runoff generated within the basin will drain south to a set of on-grade type R inlets at Design Point E1. After being captured, the runoff will be conveyed to the south to Leland Creek via proposed subsurface infrastructure. The runoff will be conveyed to the northeast via Leland Creek and existing storm infrastructure that will convey the runoff across the Union Pacific railroad to Cozen's Meadow.

Sub-basin OS1
Sub-basin OS1 is 0.93 acres comprised of single-family lots and open space. Runoff generated within the basin will drain south to an proposed 30-inch culvert at Design Point OS1. After being captured, the runoff will be conveyed to the south to Leland Creek via proposed subsurface infrastructure. The runoff will be conveyed to the northeast via Leland Creek and existing storm infrastructure that will convey the runoff across the Union Pacific railroad to Cozen's Meadow.

Sub-basin OS2
Sub-basin OS2 is 2.42 acres comprised of single-family lots. Runoff generated within the basin will drain southeast to the back of lots where it will follow historic drainage patterns.

Sub-basin OS3
Sub-basin OS3 is 3.76 acres comprised of multi-family lots and open space. Runoff generated within the basin will drain north to design point OS3, where the runoff will be captured by an existing twenty-four (24") inch culvert that will convey the runoff across the Union Pacific railroad to Cozen's Meadow.

V. CONCLUSIONS

A. Compliance with Standards

The drainage design for the Site conforms to Grand County's Storm Drainage Design and Technical Criteria Manual (Ref. A) and the Mile High Flood District (MHFD) Storm Drainage Criteria Manual where applicable. The report outlines the required design and construction of offline water quality basins within each applicable sub-basin.

B. Drainage Concept

The HEC-HMS software was used to create and routed hydrograph method through the Site to determine the historic and developed runoff values for the minor drainage basins throughout the Site. These basins were delineated based on the natural Site topography and the developed Site plan. The proposed detention ponds will be designed in subsequent reports. Preliminary sizing calculations for the DBs have been added to Appendix C. The storm sewer system will be designed to capture the minor (5-year) and major (100-year) storm events. This report has been written as a standalone report.

VI. REFERENCES

A) Grand County Storm Drainage Design and Technical Criteria Manual, August 1st, 2006

B) Fraser Municipal Code, Chapter 14: Town of Fraser Design and Construction Standards, 2007, revised 2024.

C) MHFD (Mile High Flood District). 1969. Urban Storm Drainage Criteria Manual. Volume 1: Management, Hydrology and Hydraulics. Revised March 2024. https://mhfd.org/resources/criteria-manual.

D) MHFD. 1969. Urban Storm Drainage Criteria Manual. Volume 2: Structures, Storage and Recreation. Revised January 2016. https://mhfd.org/resources/criteria-manual.

E) MHFD. 1992. Urban Storm Drainage Criteria Manual. Volume 3: Stormwater Best Management Practices. Revised March 2024. https://mhfd.org/resources/criteria-manual.

F) National Flood Hazard Layer FIRMette Map – 08049C0991C Effective Date January 2, 2008

G) USDA NRCS Soil Maps – Updated May 7, 2025

H) Storm Drainage Master Plan For Grand Park, High Country Engineering, February 17, 2006

I) HEC-HMS Technical Reference Manual. U.S. Army Corps of Engineers, Hydrologic Engineering Center. 2025.

J) A Pragmatic Slope-Adjusted Curve Number Model to Reduce Uncertainty in Predicting Flood Runoff from Steep Watersheds. Ajmal, M. Wassem, M., Kim, D., & Kim, T. 2020.

K) Computer Programs:

AutoCAD Civil3D Hydraflow Express Extension by Autodesk Inc. April 2010.

Detention Basin Design Workbook by MHFD, V.7, July 2022

Detention Volume by the Modified FAA Method by Urban Drainage and Flood Control District, v2.35, January 2015

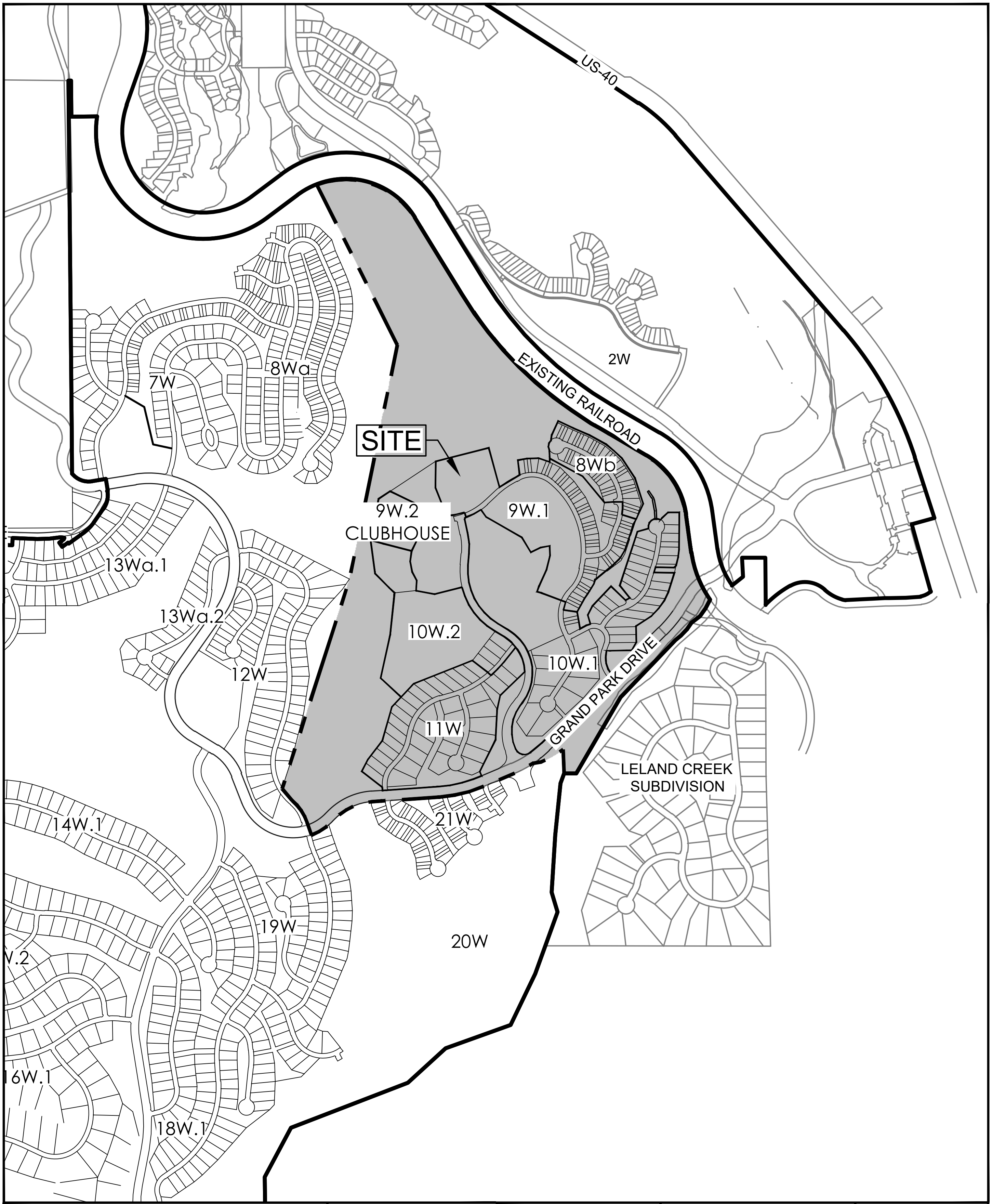
Hydrologic Engineering Center – Hydrologic Modeling System by USACE, v.4.13, July 2025.

APPENDIX A

GENERAL MAPS

Vicinity Map
Soil Map
Firm Map
Precipitation Data

12/15/2025 1:36 PM ; X:\GRAND PARK\DOCUMENTS\REPORTS\DRAINAGE\16.1 - FILING 1 - 8WB, 9W, 10W, 11W\PHASE 2\A1 - MAPS (VIC-FEMA-SOILS)\VICINITY MAP - WM 8WB, 9W, 10W, & 11W.DWG;



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WEST MOUTAIN 8Wb, 9W, 10W, & 11W
VICINITY MAP

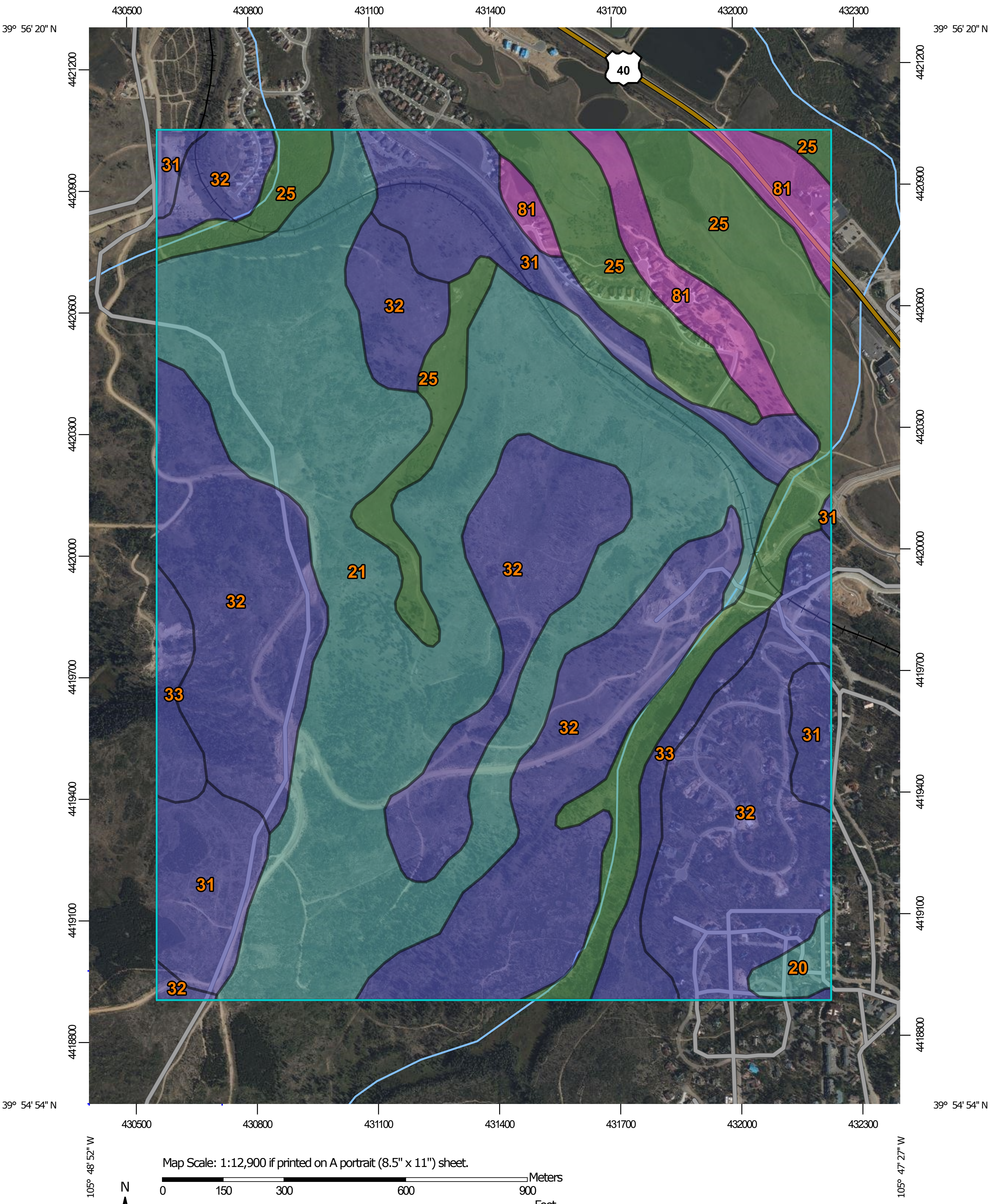
TOWN OF FRASER, CO DATE: 12/15/2025

0 1000'

1" = 1000'

N

Hydrologic Soil Group—Grand County Area, Colorado



Map Scale: 1:12,900 if printed on A portrait (8.5" x 11") sheet.

Meters
0 150 300 600 900

N

Feet
0 500 1000 2000 3000

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 13N WGS84

MAP LEGEND

Area of Interest (AOI)

▭ Area of Interest (AOI)

Soils

Soil Rating Polygons

▭ A

▭ A/D

▭ B

▭ B/D

▭ C

▭ C/D

▭ D

▭ Not rated or not available

Soil Rating Lines

〰 A

〰 A/D

〰 B

〰 B/D

〰 C

〰 C/D

〰 D

〰 Not rated or not available

Soil Rating Points

■ A

■ A/D

■ B

■ B/D

■ C

■ C/D

■ D

□ Not rated or not available

Water Features

〰 Streams and Canals

Transportation

┼┼┼ Rails

〰 Interstate Highways

〰 US Routes

〰 Major Roads

〰 Local Roads

Background

▨ Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Grand County Area, Colorado
Survey Area Data: Version 18, Aug 29, 2024

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Aug 25, 2021—Sep 5, 2021

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
20	Cowdrey loam, 6 to 15 percent slopes	C	6.1	0.7%
21	Cowdrey loam, 15 to 45 percent slopes	C	288.8	32.4%
25	Cumulic Cryaquolls, nearly level	A/D	137.1	15.4%
31	Frisco-Peeler gravelly sandy loams, 2 to 6 percent slopes	B	81.8	9.2%
32	Frisco-Peeler gravelly sandy loams, 6 to 25 percent slopes	B	310.8	34.9%
33	Frisco-Peeler gravelly sandy loams, 25 to 65 percent slopes	B	28.9	3.2%
81	Tine gravelly sandy loam, 0 to 3 percent slopes	A	36.5	4.1%
Totals for Area of Interest			**890.1**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

12/2/2025 2:50 PM ; X:\GRAND PARK\DOCUMENTS\REPORTS\DRAINAGE\16.1 - FILING 1 - 8WB, 9W, 10W, 11W\PHASE 2\A1 - MAPS (VIC-FEMA-SOILS)\SITE SOIL MAP.DWG;

terracina
design
10200 E. Girard Ave, A-314
Denver, CO 80231
ph: 303.632.8867

GRAND PARK - WEST MOUNTAIN -
8Wb, 9W, 10W, 11W

OVERALL BASIN SOILS MAP

DATE: 12/02/2025

CREATED BY:
JNS

SHEET
1

NOTES TO USERS

use in administering the National Flood Insurance Program. It arily identify all areas subject to flooding, particularly from local ; of small size. The **community map repository** should be ssible updated or additional flood hazard information.

detailed information in areas where **Base Flood Elevations** **oodways** have been determined, users are encouraged to consult es and Floodway Data and/or Summary of Stillwater Elevations within the Flood Insurance Study (FIS) report that accompanies rs should be aware that BFEs shown on the FIRM represent foot elevations. These BFEs are intended for flood insurance only and should not be used as the sole source of flood ation. Accordingly, flood elevation data presented in the FIS be utilized in conjunction with the FIRM for purposes of or floodplain management.

Flood Elevations shown on this map apply only landward American Vertical Datum of 1988 (NAVD 88). Users of this aware that coastal flood elevations are also provided in the illwater Elevations table in the Flood Insurance Study report on. Elevations shown in the Summary of Stillwater Elevations used for construction and/or floodplain management purposes higher than the elevations shown on this FIRM.

floodways were computed at cross sections and interpolated ections. The floodways were based on hydraulic considerations equirements of the National Flood Insurance Program. Floodway er pertinent floodway data are provided in the Flood Insurance this jurisdiction.

t in Special Flood Hazard Areas may be protected by **flood res.** Refer to Section 2.4 "Flood Protection Measures" of ance Study report for information on flood control structures on.

used in the preparation of this map was Universal Transverse zone 13. The **horizontal datum** was NAD83, GRS1980 nces in datum, spheroid, projection or UTM zones used in f FIRMs for adjacent jurisdictions may result in slight positional nap features across jurisdiction boundaries. These differences accuracy of this FIRM.

on this map are referenced to the North American Vertical . These flood elevations must be compared to structure and ns referenced to the same **vertical datum.** For information rsion between the National Geodetic Vertical Datum of 1929 American Vertical Datum of 1988, visit the National Geodetic at http://www.ngs.noaa.gov/ or contact the National Geodetic llowing address:

Services

Survey

Highway
20910-3282

elevation, description, and/or location information for **bench marks** map, please contact the Information Services Branch of the tic Survey at **(301) 713-3242,** or visit its website at aa.gov/.

ation shown on this FIRM was provided in digital format by the partment of Agriculture/ Service Center Agencies; produced from Quadrangles at a scale of 1:12,000, dated 2005 or later as a part of ultural Imagery Program.

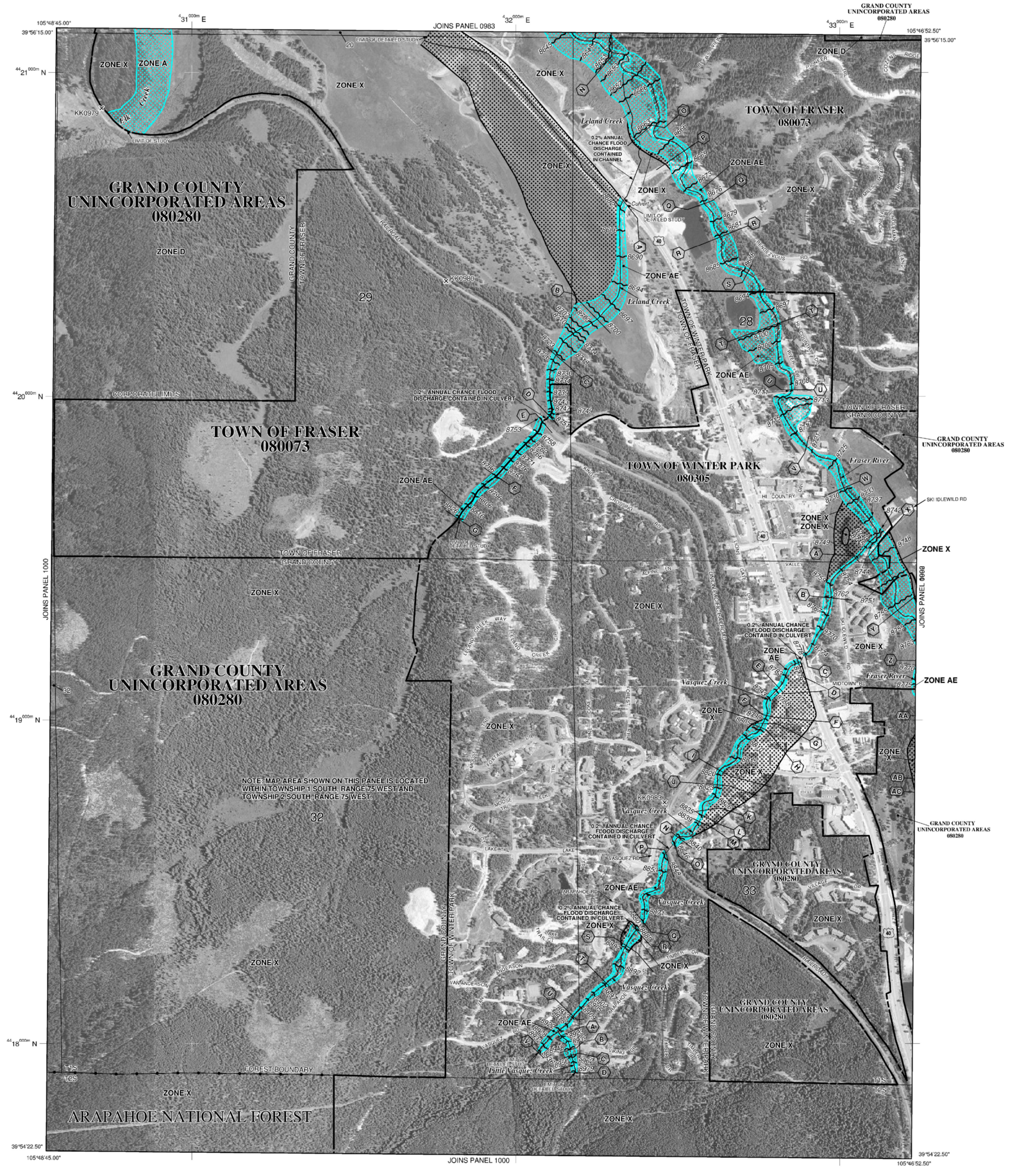
more detailed and up-to-date **stream channel configurations** n on the previous FIRM for this jurisdiction. The floodplains hat were transferred from the previous FIRM may have been nform to these new stream channel configurations. As a d Profiles and Floodway Data tables *in the Flood Insurance hich contains authoritative hydraulic data*) may reflect stream s that differ from what is shown on this map.

s shown on this map are based on the best data available blication. Because changes due to annexations or de-annexations rred after this map was published, map users should contact nunity officials to verify current corporate limit locations.

he separately printed **Map Index** for an overview map of the the layout of map panels; community map repository addresses; Communities table containing National Flood Insurance Program community as well as a listing of the panels on which each ated.

MA Map Service Center at 1-800-358-9616 for information on ts associated with this FIRM. Available products may include d Letters of Map Change, *a Flood Insurance Study report,* sions of this map. The FEMA Map Service Center may also be at 1-800-358-9620 and its website at http://www.msc.fema.gov/.

estions about this map or questions concerning the National Program in general, please call **1-877-FEMA MAP** (1-877-336-2627) A website at http://www.fema.gov/.



LEGEND

▨ SPECIAL FLOOD HAZARD AREAS (SFHAs) SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

ZONE A	No Base Flood Elevations determined.
ZONE AE	Base Flood Elevations determined.
ZONE AH	Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
ZONE AO	Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
ZONE AR	Special Flood Hazard Area formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
ZONE A99	Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.
ZONE V	Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
ZONE VE	Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

▨ FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

▨ OTHER FLOOD AREAS

ZONE X	Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

☐ OTHER AREAS

ZONE X	Areas determined to be outside the 0.2% annual chance floodplain.
ZONE D	Areas in which flood hazards are undetermined, but possible.

▨ COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

▨ OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

———	1% annual chance floodplain boundary
———	0.2% annual chance floodplain boundary
— — —	Floodway boundary
- —— —— -	Zone D boundary
●●●●●●●●	CBRS and OPA boundary
▨	Boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.
~~ 513 ~~~~	Base Flood Elevation line and value; elevation in feet*
(EL 987)	Base Flood Elevation value where uniform within zone; elevation in feet*

* Referenced to the North American Vertical Datum of 1988 (NAVD 88)

(A)———(A)	Cross section line
(23)- - - - -(23)	Transect line
97°07'30", 32°22'30"	Geographic coordinates referenced to the North American Datum of 1983 (NAD 83)
$^{42}75^{000m}$N	1000-meter Universal Transverse Mercator grid ticks, zone 13
6000000 M	5000-foot grid ticks: New York State Plane coordinate system, east zone (FIPSZONE 3101), Transverse Mercator
DX5510 ×	Bench mark (see explanation in Notes to Users section of this FIRM panel)
• M1.5	River Mile

MAP REPOSITORIES
Refer to Map Repositories list on Map Index

EFFECTIVE DATE OF COUNTYWIDE
FLOOD INSURANCE RATE MAP
January 2, 2008
EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL

For community map revision history prior to countywide mapping, refer to the Community Map History table located in the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in this community, contact your insurance agent or call the National Flood Insurance Program at 1-800-638-6620.

N

MAP SCALE 1" = 500'

250 0 500 1000 FEET

150 0 150 300 METERS

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0991C

FIRM
FLOOD INSURANCE RATE MAP
GRAND COUNTY,
COLORADO
AND INCORPORATED AREAS

PANEL 991 OF 1200
(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
GRAND COUNTY	080280	0991	C
FRASER, TOWN OF	080073	0991	C
WINTER PARK, TOWN OF	080305	0991	C

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
08049C0991C

EFFECTIVE DATE
JANUARY 2, 2008

Federal Emergency Management Agency

NOAA Atlas 14, Volume 8, Version 2
Location name: Fraser, Colorado, USA*
Latitude: 39.9249°, Longitude: -105.8001°
Elevation: 8873.92 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Deborah Martin, Sandra Pavlovic, Ishani Roy, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Michael Yekta, Geoffery Bonnin

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.169** (0.130-0.219)	**0.202** (0.156-0.263)	**0.262** (0.201-0.342)	**0.317** (0.242-0.416)	**0.401** (0.300-0.559)	**0.472** (0.344-0.668)	**0.548** (0.387-0.800)	**0.632** (0.428-0.953)	**0.751** (0.490-1.17)	**0.848** (0.537-1.34)
10-min	**0.247** (0.191-0.321)	**0.296** (0.228-0.385)	**0.383** (0.294-0.500)	**0.464** (0.354-0.609)	**0.587** (0.439-0.819)	**0.691** (0.504-0.977)	**0.803** (0.566-1.17)	**0.925** (0.627-1.40)	**1.10** (0.717-1.72)	**1.24** (0.786-1.96)
15-min	**0.301** (0.233-0.392)	**0.360** (0.278-0.469)	**0.467** (0.359-0.610)	**0.566** (0.432-0.743)	**0.715** (0.536-0.999)	**0.842** (0.614-1.19)	**0.979** (0.690-1.43)	**1.13** (0.764-1.70)	**1.34** (0.875-2.09)	**1.51** (0.958-2.39)
30-min	**0.385** (0.297-0.500)	**0.460** (0.354-0.598)	**0.595** (0.457-0.778)	**0.720** (0.550-0.946)	**0.910** (0.681-1.27)	**1.07** (0.780-1.52)	**1.24** (0.877-1.81)	**1.43** (0.970-2.16)	**1.70** (1.11-2.65)	**1.92** (1.21-3.02)
60-min	**0.476** (0.367-0.618)	**0.559** (0.430-0.727)	**0.711** (0.546-0.929)	**0.855** (0.653-1.12)	**1.08** (0.807-1.50)	**1.26** (0.924-1.79)	**1.47** (1.04-2.15)	**1.70** (1.15-2.57)	**2.02** (1.32-3.16)	**2.29** (1.45-3.61)
2-hr	**0.567** (0.443-0.728)	**0.658** (0.513-0.846)	**0.827** (0.643-1.07)	**0.989** (0.764-1.28)	**1.24** (0.944-1.72)	**1.46** (1.08-2.05)	**1.70** (1.21-2.46)	**1.96** (1.35-2.94)	**2.35** (1.55-3.63)	**2.66** (1.70-4.15)
3-hr	**0.640** (0.503-0.817)	**0.728** (0.572-0.930)	**0.900** (0.704-1.15)	**1.07** (0.832-1.38)	**1.34** (1.03-1.85)	**1.58** (1.18-2.21)	**1.84** (1.33-2.66)	**2.14** (1.48-3.19)	**2.57** (1.71-3.96)	**2.93** (1.89-4.55)
6-hr	**0.805** (0.641-1.01)	**0.889** (0.707-1.12)	**1.07** (0.847-1.35)	**1.26** (0.991-1.60)	**1.58** (1.23-2.17)	**1.87** (1.42-2.61)	**2.21** (1.61-3.17)	**2.59** (1.82-3.84)	**3.16** (2.13-4.83)	**3.64** (2.36-5.59)
12-hr	**1.02** (0.825-1.27)	**1.11** (0.895-1.39)	**1.32** (1.06-1.65)	**1.55** (1.24-1.95)	**1.96** (1.56-2.69)	**2.34** (1.80-3.24)	**2.79** (2.07-3.98)	**3.31** (2.35-4.87)	**4.08** (2.79-6.20)	**4.75** (3.12-7.21)
24-hr	**1.25** (1.02-1.54)	**1.38** (1.12-1.70)	**1.66** (1.35-2.05)	**1.98** (1.60-2.46)	**2.52** (2.03-3.42)	**3.03** (2.36-4.14)	**3.62** (2.71-5.10)	**4.30** (3.09-6.26)	**5.32** (3.67-7.99)	**6.18** (4.10-9.29)
2-day	**1.46** (1.21-1.78)	**1.66** (1.37-2.02)	**2.07** (1.70-2.53)	**2.50** (2.04-3.07)	**3.21** (2.61-4.28)	**3.86** (3.03-5.20)	**4.60** (3.48-6.38)	**5.43** (3.94-7.80)	**6.68** (4.64-9.90)	**7.72** (5.18-11.5)
3-day	**1.62** (1.35-1.95)	**1.84** (1.53-2.22)	**2.29** (1.90-2.78)	**2.76** (2.28-3.37)	**3.55** (2.90-4.69)	**4.26** (3.37-5.69)	**5.06** (3.86-6.98)	**5.97** (4.36-8.52)	**7.32** (5.13-10.8)	**8.46** (5.71-12.5)
4-day	**1.76** (1.47-2.11)	**1.99** (1.66-2.38)	**2.46** (2.05-2.96)	**2.94** (2.44-3.57)	**3.75** (3.08-4.94)	**4.49** (3.57-5.97)	**5.33** (4.08-7.31)	**6.28** (4.60-8.90)	**7.68** (5.41-11.3)	**8.87** (6.01-13.1)
7-day	**2.14** (1.81-2.54)	**2.37** (2.00-2.82)	**2.85** (2.40-3.40)	**3.34** (2.80-4.01)	**4.17** (3.45-5.41)	**4.92** (3.95-6.46)	**5.77** (4.46-7.83)	**6.74** (4.99-9.47)	**8.18** (5.80-11.9)	**9.38** (6.42-13.7)
10-day	**2.47** (2.11-2.92)	**2.72** (2.31-3.21)	**3.21** (2.72-3.80)	**3.71** (3.13-4.42)	**4.53** (3.77-5.81)	**5.27** (4.25-6.86)	**6.11** (4.75-8.21)	**7.05** (5.24-9.82)	**8.45** (6.03-12.2)	**9.61** (6.62-14.0)
20-day	**3.39** (2.93-3.94)	**3.72** (3.21-4.34)	**4.33** (3.72-5.07)	**4.89** (4.18-5.76)	**5.75** (4.79-7.16)	**6.47** (5.25-8.21)	**7.26** (5.67-9.52)	**8.11** (6.07-11.1)	**9.32** (6.70-13.2)	**10.3** (7.18-14.8)
30-day	**4.15** (3.61-4.79)	**4.59** (3.99-5.31)	**5.34** (4.63-6.21)	**6.00** (5.16-7.01)	**6.94** (5.79-8.50)	**7.70** (6.27-9.63)	**8.49** (6.67-11.0)	**9.33** (7.01-12.6)	**10.5** (7.56-14.7)	**11.4** (7.97-16.2)
45-day	**5.13** (4.50-5.88)	**5.72** (5.01-6.56)	**6.69** (5.84-7.70)	**7.49** (6.50-8.69)	**8.61** (7.22-10.4)	**9.48** (7.76-11.7)	**10.4** (8.17-13.3)	**11.3** (8.49-15.0)	**12.4** (9.02-17.2)	**13.4** (9.41-18.9)
60-day	**5.98** (5.27-6.81)	**6.70** (5.90-7.64)	**7.87** (6.91-9.02)	**8.83** (7.71-10.2)	**10.1** (8.54-12.2)	**11.2** (9.16-13.7)	**12.2** (9.63-15.5)	**13.2** (9.98-17.4)	**14.5** (10.5-19.9)	**15.5** (11.0-21.8)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

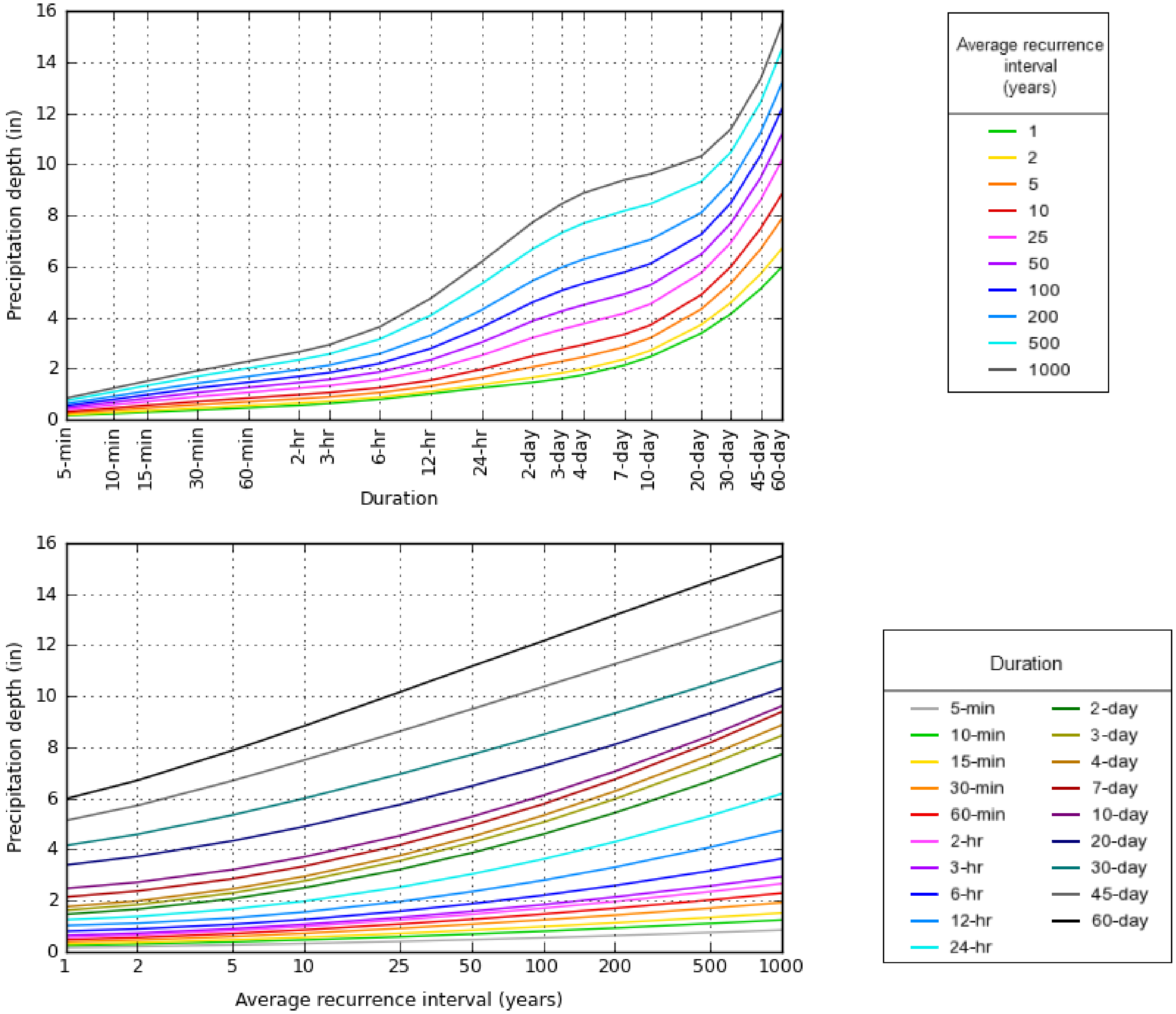
Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

Back to Top

PF graphical

PDS-based depth-duration-frequency (DDF) curves
Latitude: 39.9249°, Longitude: -105.8001°



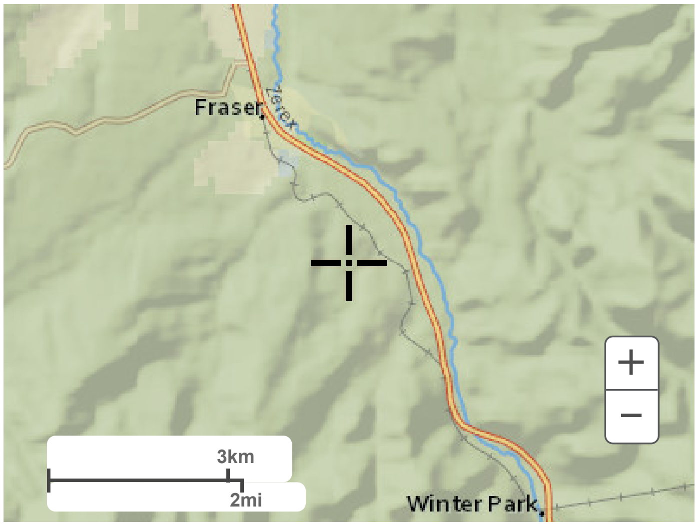
NOAA Atlas 14, Volume 8, Version 2

Created (GMT): Tue Jun 28 20:11:21 2022

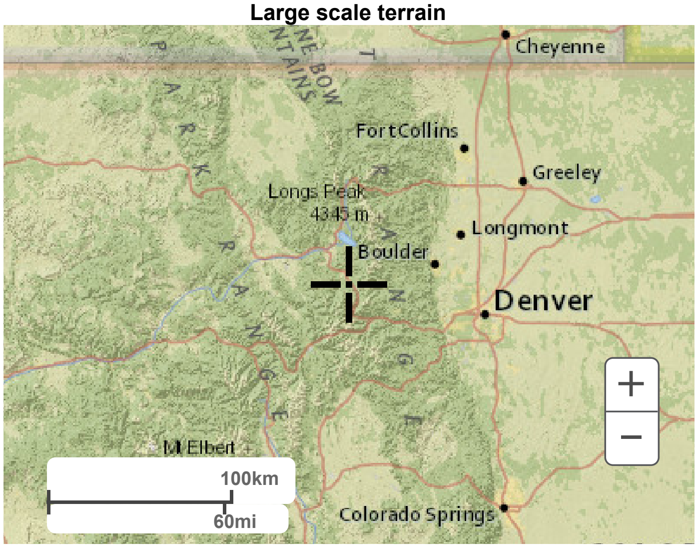
Back to Top

Maps & aerials

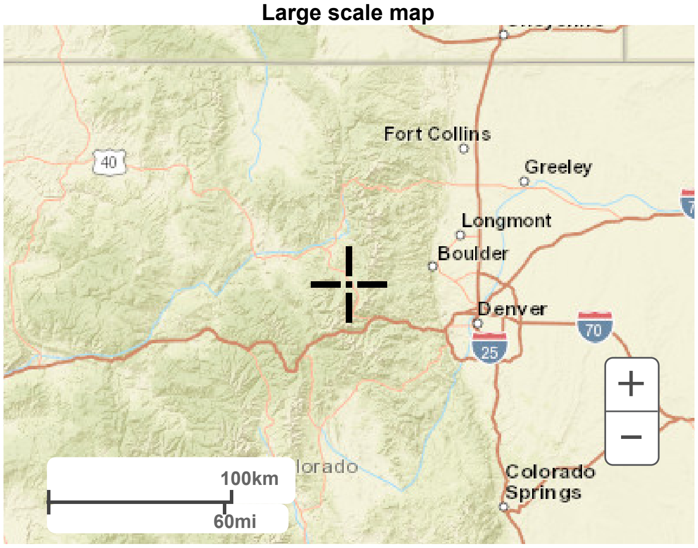
Small scale terrain



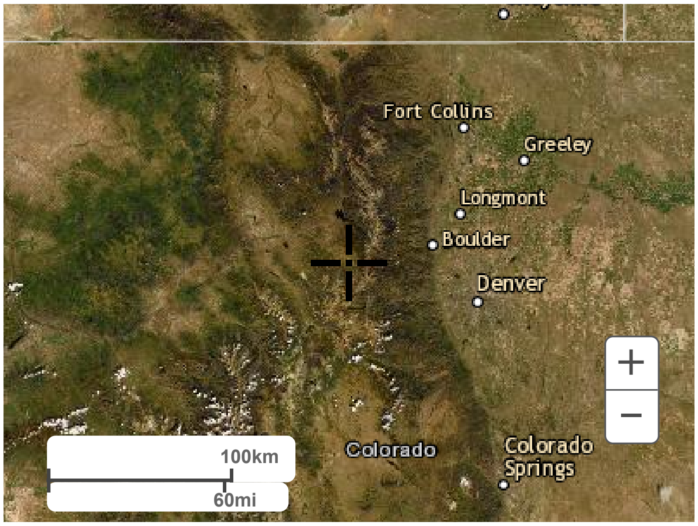
Large scale terrain



Large scale map



Large scale aerial



Back to Top

US Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service
National Water Center
1325 East West Highway
Silver Spring, MD 20910
Questions?: HDSC.Questions@noaa.gov

Disclaimer

APPENDIX B
HYDROLOGIC CALCULATIONS

Existing Curve Number Calculation
Existing Curve Number Adjustment Calculations
Existing Lag Time Calculations
Existing Reach Time of Concentration Calculations

Proposed Curve Number Calculation
Proposed Curve Number Adjustment Calculations
Proposed Lag Time Calculations
Proposed Reach Time of Concentration Calculations
Proposed Pond Stage Storage Discharge Tables

HEC-HMS Flow Results
Pond A HEC-HMS Inflow Results
Pond B HEC-HMS Inflow Results

Project Name: West Mountain - Filing 1 - Existing
Prepared By: JNS

Curve Number Calculations

Curve Number calculations based on the CN Tables provided in the USACE HEC-HMS Technical Reference Manual and the section of this manual dedicated to the SCS Curve Number Loss Model

Land Use CN Values						
	Land Use					
HSG	Historic (Good Brush)	Paved Area	Gravel	Commercial	SFH - Rural/Medium Density (1/4 acre lots)	MFH/SFH - High Density
A	30	98	76	89	61	77
B	48	98	85	92	75	85
C	65	98	89	94	83	90
D	73	98	91	95	87	92
C/D	69	98	90	94.5	85	91

Basin Id	**Soil Type by Percent of Basin**			**Land Use by Percent of Basin**						**(Land Use CN Value)*(Soil Type by Percent of Basin)*(Land Use by Percent of Basin)**							**Sum of CN Values by Soil Number**		**Composite CN Value**
	A	**B**	**C/D**	**Historic**	**Paved Area**	**Gravel**	**Commercial**	**SFH - Rural/Medium Density**	**MFH/SFH - High Density**	**Soil Type**	**Historic**	**Paved Area**	**Gravel**	**Commercial**	**SFH - Rural/Medium Density**	**MFH/SFH - High Density**			
A	0.0%	16.3%	83.7%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	65.57
										B	7.83	0.00	0.00	0.00	0.00	0.00	B	7.83	
										C/D	57.74	0.00	0.00	0.00	0.00	0.00	C/D	57.74	
A1	0.00%	54.76%	45.24%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	57.50
										B	26.29	0.00	0.00	0.00	0.00	0.00	B	26.29	
										C/D	31.21	0.00	0.00	0.00	0.00	0.00	C/D	31.21	
A2	0.00%	100.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	48.00
										B	48.00	0.00	0.00	0.00	0.00	0.00	B	48.00	
										C/D	0.00	0.00	0.00	0.00	0.00	0.00	C/D	0.00	
A3	0.00%	33.27%	66.73%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	62.01
										B	15.97	0.00	0.00	0.00	0.00	0.00	B	15.97	
										C/D	46.04	0.00	0.00	0.00	0.00	0.00	C/D	46.04	
A4	0.00%	79.83%	20.17%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	52.24
										B	38.32	0.00	0.00	0.00	0.00	0.00	B	38.32	
										C/D	13.92	0.00	0.00	0.00	0.00	0.00	C/D	13.92	
B	0.00%	42.73%	57.27%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	60.03
										B	20.51	0.00	0.00	0.00	0.00	0.00	B	20.51	
										C/D	39.52	0.00	0.00	0.00	0.00	0.00	C/D	39.52	
B1	0.00%	46.47%	53.53%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	59.24
										B	22.31	0.00	0.00	0.00	0.00	0.00	B	22.31	
										C/D	36.94	0.00	0.00	0.00	0.00	0.00	C/D	36.94	
B2	0.00%	58.82%	41.18%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	56.65
										B	28.23	0.00	0.00	0.00	0.00	0.00	B	28.23	
										C/D	28.42	0.00	0.00	0.00	0.00	0.00	C/D	28.42	
B3	0.00%	46.27%	53.73%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	59.28
										B	22.21	0.00	0.00	0.00	0.00	0.00	B	22.21	
										C/D	37.08	0.00	0.00	0.00	0.00	0.00	C/D	37.08	
B4	0.00%	73.73%	26.27%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	53.52
										B	35.39	0.00	0.00	0.00	0.00	0.00	B	35.39	
										C/D	18.13	0.00	0.00	0.00	0.00	0.00	C/D	18.13	

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Curve Number Calculations

Curve Number calculations based on the CN Tables provided in the USACE HEC-HMS Technical Reference Manual and the section of this manual dedicated to the SCS Curve Number Loss Model

Land Use CN Values

HSG	Land Use					
	Historic (Good Brush)	Paved Area	Gravel	Commercial	SFH - Rural/Medium Density (1/4 acre lots)	MFH/SFH - High Density
A	30	98	76	89	61	77
B	48	98	85	92	75	85
C	65	98	89	94	83	90
D	73	98	91	95	87	92
C/D	69	98	90	94.5	85	91

Basin Id	Soil Type by Percent of Basin			Land Use by Percent of Basin						(Land Use CN Value)*(Soil Type by Percent of Basin)*(Land Use by Percent of Basin)							Sum of CN Values by Soil Number		Composite CN Value
	A	B	C/D	Historic	Paved Area	Gravel	Commercial	SFH - Rural/Medium Density	MFH/SFH - High Density	Soil Type	Historic	Paved Area	Gravel	Commercial	SFH - Rural/Medium Density	MFH/SFH - High Density			
C	0.00%	100.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	48.00
										B	48.00	0.00	0.00	0.00	0.00	0.00	B	48.00	
										C/D	0.00	0.00	0.00	0.00	0.00	0.00	C/D	0.00	
C1	0.00%	38.51%	61.49%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	60.91
										B	18.48	0.00	0.00	0.00	0.00	0.00	B	18.48	
										C/D	42.43	0.00	0.00	0.00	0.00	0.00	C/D	42.43	
C2	0.00%	66.77%	33.23%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	54.98
										B	32.05	0.00	0.00	0.00	0.00	0.00	B	32.05	
										C/D	22.93	0.00	0.00	0.00	0.00	0.00	C/D	22.93	
D1	0.00%	100.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	48.00
										B	48.00	0.00	0.00	0.00	0.00	0.00	B	48.00	
										C/D	0.00	0.00	0.00	0.00	0.00	0.00	C/D	0.00	
D2	0.00%	100.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	48.00
										B	48.00	0.00	0.00	0.00	0.00	0.00	B	48.00	
										C/D	0.00	0.00	0.00	0.00	0.00	0.00	C/D	0.00	
E1	0.00%	100.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	48.00
										B	48.00	0.00	0.00	0.00	0.00	0.00	B	48.00	
										C/D	0.00	0.00	0.00	0.00	0.00	0.00	C/D	0.00	
OS1	0.00%	100.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	48.00
										B	48.00	0.00	0.00	0.00	0.00	0.00	B	48.00	
										C/D	0.00	0.00	0.00	0.00	0.00	0.00	C/D	0.00	
OS2	0.00%	83.20%	16.80%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	51.53
										B	39.94	0.00	0.00	0.00	0.00	0.00	B	39.94	
										C/D	11.59	0.00	0.00	0.00	0.00	0.00	C/D	11.59	
OS3	0.00%	0.00%	100.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	69.00
										B	0.00	0.00	0.00	0.00	0.00	0.00	B	0.00	
										C/D	69.00	0.00	0.00	0.00	0.00	0.00	C/D	69.00	

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Project Name: West Mountain - Filing 1 - Existing
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Curve Number and Initial Abstraction Adjustment Calculations

Curve Number adjustment calculations based on the Calculations presented in "A Pragmatic Slope-Adjusted Curve Number Model to Reduce Uncertainty in Predicting Flood Runoff from Steep Watershed" by Ajmal, et .al., dated May 21, 2020

Sub-Basin Data		Default SCS Calculation (20% initial abstraction)			Adjusted SCS Calculations (5% initial abstraction		
Basin Id	Basin Area (mi^2)	CN	Maximum Potential Retention, S (in)	Initial Abstraction (in)	CN	Maximum Potential Retention, S (in)	Initial Abstraction (in)
A	0.259090	65.57	5.250	1.050	87.37	1.446	0.072
A1	0.036867	57.50	7.391	1.478	84.85	1.785	0.089
A2	0.017280	48.00	10.833	2.167	82.07	2.184	0.109
A3	0.009302	62.01	6.126	1.225	86.24	1.595	0.080
A4	0.004263	52.24	9.144	1.829	83.29	2.006	0.100
B	0.013471	60.03	6.659	1.332	85.62	1.679	0.084
B1	0.016134	59.24	6.880	1.376	85.38	1.712	0.086
B2	0.014022	56.65	7.653	1.531	84.60	1.821	0.091
B3	0.013228	59.28	6.868	1.374	85.40	1.710	0.086
B4	0.001638	53.52	8.686	1.737	83.67	1.952	0.098
C	0.002679	48.00	10.833	2.167	82.07	2.184	0.109
C1	0.004562	60.91	6.417	1.283	85.90	1.642	0.082
C2	0.011821	54.98	8.189	1.638	84.10	1.891	0.095
D1	0.010584	48.00	10.833	2.167	82.07	2.184	0.109
D2	0.000506	48.00	10.833	2.167	82.07	2.184	0.109
E1	0.004760	48.00	10.833	2.167	82.07	2.184	0.109
OS1	0.001447	48.00	10.833	2.167	82.07	2.184	0.109
OS2	0.003786	51.53	9.407	1.881	83.09	2.036	0.102
OS3	0.005881	69.00	4.493	0.899	88.48	1.302	0.065

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Lag Time Calculations (TLag)

100-year 24-hr Precipitation Depth (P_2)= 1.36

Sub-Basin Data		Initial or Overland Flow Time					Channelized Flow Time					Overall Flow Time		
Basin Id	Basin Area (Ac)	Roughness Coefficient	Length (ft)	Elev Change	Slope (%)	T_i (min)	Length (ft)	Elev Change	Slope (%)	Velocity (FPS)	T_t (min)	Comp. T_c	Lag Time	$Final\ T_{Lag}$ (min)
A	165.82	0.240	300	37	12.3	25.46	4425	203	4.6	3.46	21.3	46.8	28.1	28.1
A1	23.59	0.240	150	7	4.7	21.57	400	31	7.6	4.46	1.5	23.1	13.8	13.8
A2	11.06	0.240	300	14	4.7	37.56	630	24	3.8	3.15	3.3	40.9	24.5	24.5
A3	5.95	0.240	300	41	13.5	24.56	910	36	4.0	3.21	4.7	29.3	17.6	17.6
A4	2.73	0.240	300	40	13.3	24.70	545	23	4.2	3.31	2.7	27.4	16.5	16.5
B	8.62	0.240	150	13	8.3	17.11	990	49	4.9	3.59	4.6	21.7	13.0	13.0
B1	10.33	0.240	280	21	7.3	29.68	601	14	2.2	2.42	4.1	33.8	20.3	20.3
B2	8.97	0.240	300	16	5.3	35.61	427	33	7.7	4.49	1.6	37.2	22.3	22.3
B3	8.47	0.240	300	7	2.3	49.56	726	42	5.7	3.86	3.1	52.7	31.6	31.6
B4	1.05	0.240	30	1	2.3	7.86	1000	34	3.4	2.99	5.6	13.4	8.1	8.1
C	1.71	0.240	41	6	14.6	4.84	71	6	8.5	4.69	0.3	5.1	3.1	5.0
C1	2.92	0.240	155	10	6.5	19.46	422	5	1.1	1.67	4.2	23.7	14.2	14.2
C2	7.57	0.240	300	20	6.7	32.57	850	31	3.6	3.08	4.6	37.2	22.3	22.3
D1	6.77	0.240	300	17	5.7	34.75	480	41	8.5	4.72	1.7	36.5	21.9	21.9
D2	0.32	0.240	35	1	2.9	8.19	730	54	7.4	4.39	2.8	11.0	6.6	6.6
E1	3.05	0.240	300	41	13.7	24.44	370	29	7.8	4.52	1.4	25.8	15.5	15.5
OS1	0.93	0.240	200	15	7.5	22.46	110	24	21.8	7.54	0.2	22.7	13.6	13.6
OS2	2.42	0.240	100	10	9.5	11.74	93	15	16.1	6.48	0.2	12.0	7.2	7.2
OS3	3.76	0.240	200	32	15.8	16.69	213	39	18.1	6.86	0.5	17.2	10.3	10.3

Project Name: **West Mountain - Filing 1 - Existing**
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Reach Time of Concentration Calculations (Tc)

Element Information		**Channelized Flow Path 1**						**Overall Flow Time**
Element ID	**Notes**	**Length (ft)**	**Elev Change**	**Slope (%)**	**Paved?**	**Velocity (FPS)**	**T_c (min)**	**Comp. T_c (min)**
REACH-A1	A1 travel path after leaving basin A1	2640	139	5.27%	N	3.70	11.9	11.9
REACH-A2/3	A2 & A3 travel path after leaving basin A2 or A3	1675	91	5.43%	N	3.76	7.4	7.4
REACH-A4	A4 travel path after leaving basin A4 before A1-Outfall	1865	130	6.97%	N	4.26	7.3	7.3
SWALE B	Swale conveying B1 and B2 runoff to Pond B	990	50	5.05%	N	3.63	4.6	4.6

Project Name: West Mountain - Filing 1 - Proposed
Prepared By: JNS

Curve Number Calculations

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Land Use CN Values						
HSG	Land Use					
	Historic (Good Brush)	Paved Area	Gravel	Commercial	SFH - Rural/Medium Density (1/4 acre lots)	MFH/SFH - High Density
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C/D	69	98	90	94.5	85	91

Basin Id	Soil Type by Percent of Basin			Land Use by Percent of Basin						(Land Use CN Value)*(Soil Type by Percent of Basin)*(Land Use by Percent of Basin)							Sum of CN Values by Soil Number		Composite CN Value
	A	B	C/D	Historic	Paved Area	Gravel	Commercial	SFH - Rural/Medium Density	MFH/SFH - High Density	Soil Type	Historic	Paved Area	Gravel	Commercial	SFH - Rural/Medium Density	MFH/SFH - High Density			
A	0.0%	16.3%	83.7%	64.32%	4.82%	0.00%	1.40%	23.54%	5.93%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	73.17
										B	5.04	0.77	0.00	0.21	2.88	0.82	B	9.72	
										C/D	37.14	3.95	0.00	1.11	16.74	4.51	C/D	63.45	
A1	0.00%	54.76%	45.24%	25.18%	0.00%	0.00%	21.95%	0.00%	52.87%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	81.29
										B	6.62	0.00	0.00	11.06	0.00	24.61	B	42.29	
										C/D	7.86	0.00	0.00	9.38	0.00	21.76	C/D	39.01	
A2	0.00%	100.00%	0.00%	3.52%	13.75%	0.00%	17.42%	0.00%	65.31%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	86.70
										B	1.69	13.48	0.00	16.02	0.00	55.51	B	86.70	
										C/D	0.00	0.00	0.00	0.00	0.00	0.00	C/D	0.00	
A3	0.00%	33.27%	66.73%	29.97%	14.75%	0.00%	0.00%	0.00%	55.28%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	82.24
										B	4.79	4.81	0.00	0.00	0.00	15.64	B	25.23	
										C/D	13.80	9.65	0.00	0.00	0.00	33.57	C/D	57.01	
A4	0.00%	79.83%	20.17%	81.94%	0.00%	0.00%	0.00%	18.06%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	56.71
										B	31.40	0.00	0.00	0.00	10.81	0.00	B	42.21	
										C/D	11.40	0.00	0.00	0.00	3.10	0.00	C/D	14.50	
B	0.00%	42.73%	57.27%	29.84%	0.00%	0.00%	0.00%	33.59%	36.57%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	77.37
										B	6.12	0.00	0.00	0.00	10.77	13.28	B	30.17	
										C/D	11.79	0.00	0.00	0.00	16.35	19.06	C/D	47.20	
B1	0.00%	46.47%	53.53%	24.02%	20.22%	0.00%	0.00%	55.76%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	78.85
										B	5.36	9.21	0.00	0.00	19.43	0.00	B	34.00	
										C/D	8.87	10.61	0.00	0.00	25.37	0.00	C/D	44.85	
B2	0.00%	58.82%	41.18%	6.26%	10.84%	0.00%	0.00%	28.53%	54.37%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	84.30
										B	1.77	6.25	0.00	0.00	12.59	27.18	B	47.78	
										C/D	1.78	4.38	0.00	0.00	9.99	20.37	C/D	36.52	
B3	0.00%	46.27%	53.73%	4.91%	9.35%	0.00%	0.00%	0.00%	85.74%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	87.72
										B	1.09	4.24	0.00	0.00	0.00	33.72	B	39.05	
										C/D	1.82	4.92	0.00	0.00	0.00	41.92	C/D	48.67	
B4	0.00%	73.73%	26.27%	16.61%	83.39%	0.00%	0.00%	0.00%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	90.61
										B	5.88	60.25	0.00	0.00	0.00	0.00	B	66.13	
										C/D	3.01	21.47	0.00	0.00	0.00	0.00	C/D	24.48	

terracina
design
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Project Name: West Mountain - Filing 1 - Proposed
Prepared By: JNS

Curve Number Calculations

Curve Number calculations based on the CN Tables provided in the USACE HEC-HMS Technical Reference Manual and the section of this manual dedicated to the SCS Curve Number Loss Model

Land Use CN Values						
HSG	Land Use					
	Historic (Good Brush)	Paved Area	Gravel	Commercial	SFH - Rural/Medium Density (1/4 acre lots)	MFH/SFH - High Density
A	30	98	76	89	61	77
B	48	98	85	92	75	85
C	65	98	89	94	83	90
D	73	98	91	95	87	92
C/D	69	98	90	94.5	85	91

Basin Id	Soil Type by Percent of Basin			Land Use by Percent of Basin						(Land Use CN Value)*(Soil Type by Percent of Basin)*(Land Use by Percent of Basin)							Sum of CN Values by Soil Number		Composite CN Value
	A	B	C/D	Historic	Paved Area	Gravel	Commercial	SFH - Rural/Medium Density	MFH/SFH - High Density	Soil Type	Historic	Paved Area	Gravel	Commercial	SFH - Rural/Medium Density	MFH/SFH - High Density			
C	0.00%	100.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	48.00
										B	48.00	0.00	0.00	0.00	0.00	0.00	B	48.00	
										C/D	0.00	0.00	0.00	0.00	0.00	0.00	C/D	0.00	
C1	0.00%	38.51%	61.49%	18.61%	16.16%	0.00%	0.00%	65.22%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	80.11
										B	3.44	6.10	0.00	0.00	18.84	0.00	B	28.38	
										C/D	7.90	9.74	0.00	0.00	34.09	0.00	C/D	51.73	
C2	0.00%	66.77%	33.23%	39.72%	22.85%	0.00%	0.00%	37.42%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	73.55
										B	12.73	14.95	0.00	0.00	18.74	0.00	B	46.42	
										C/D	9.11	7.44	0.00	0.00	10.57	0.00	C/D	27.12	
D1	0.00%	100.00%	0.00%	32.51%	13.52%	0.00%	0.00%	53.98%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	69.33
										B	15.60	13.24	0.00	0.00	40.48	0.00	B	69.33	
										C/D	0.00	0.00	0.00	0.00	0.00	0.00	C/D	0.00	
D2	0.00%	100.00%	0.00%	17.23%	82.77%	0.00%	0.00%	0.00%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	89.39
										B	8.27	81.12	0.00	0.00	0.00	0.00	B	89.39	
										C/D	0.00	0.00	0.00	0.00	0.00	0.00	C/D	0.00	
E1	0.00%	100.00%	0.00%	40.92%	17.66%	0.00%	0.00%	41.42%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	68.01
										B	19.64	17.31	0.00	0.00	31.06	0.00	B	68.01	
										C/D	0.00	0.00	0.00	0.00	0.00	0.00	C/D	0.00	
OS1	0.00%	100.00%	0.00%	45.03%	0.00%	0.00%	0.00%	54.97%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	62.84
										B	21.61	0.00	0.00	0.00	41.23	0.00	B	62.84	
										C/D	0.00	0.00	0.00	0.00	0.00	0.00	C/D	0.00	
OS2	0.00%	83.20%	16.80%	5.62%	0.00%	0.00%	0.00%	94.38%	0.00%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	75.27
										B	2.24	0.00	0.00	0.00	58.89	0.00	B	61.14	
										C/D	0.65	0.00	0.00	0.00	13.48	0.00	C/D	14.13	
OS3	0.00%	0.00%	100.00%	68.33%	0.00%	0.00%	0.00%	0.00%	31.67%	A	0.00	0.00	0.00	0.00	0.00	0.00	A	0.00	75.97
										B	0.00	0.00	0.00	0.00	0.00	0.00	B	0.00	
										C/D	47.15	0.00	0.00	0.00	0.00	28.82	C/D	75.97	

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Curve Number and Initial Abstraction Adjustment Calculations

Curve Number adjustment calculations based on the Calculations presented in "A Pragmatic Slope-Adjusted Curve Number Model to Reduce Uncertainty in Predicting Flood Runoff from Steep Watershed" by Ajmal, et .al., dated May 21, 2020

Sub-Basin Data		Default SCS Calculation (20% initial abstraction)			Adjusted SCS Calculations (5% initial abstraction		
Basin Id	Basin Area (mi^2)	CN	Maximum Potential Retention, S (in)	Initial Abstraction (in)	CN	Maximum Potential Retention, S (in)	Initial Abstraction (in)
A	0.259090	73.17	3.666	0.733	89.87	1.127	0.056
A1	0.036867	81.29	2.301	0.460	92.72	0.786	0.039
A2	0.017280	86.70	1.534	0.307	94.71	0.558	0.028
A3	0.009302	82.24	2.159	0.432	93.06	0.746	0.037
A4	0.004263	56.71	7.634	1.527	84.62	1.818	0.091
B	0.013471	77.37	2.925	0.585	91.32	0.950	0.048
B1	0.016134	78.85	2.683	0.537	91.84	0.888	0.044
B2	0.014022	84.30	1.863	0.373	93.81	0.659	0.033
B3	0.013228	87.72	1.400	0.280	95.09	0.516	0.026
B4	0.001638	90.61	1.036	0.207	96.21	0.394	0.020
C	0.002679	48.00	10.833	2.167	82.07	2.184	0.109
C1	0.004562	80.11	2.484	0.497	92.29	0.836	0.042
C2	0.011821	73.55	3.597	0.719	90.00	1.111	0.056
D1	0.010584	69.33	4.424	0.885	88.59	1.288	0.064
D2	0.000506	89.39	1.187	0.237	95.73	0.446	0.022
E1	0.004760	68.01	4.703	0.941	88.16	1.343	0.067
OS1	0.001447	62.84	5.913	1.183	86.50	1.561	0.078
OS2	0.003786	75.27	3.286	0.657	90.59	1.039	0.052
OS3	0.005881	75.97	3.164	0.633	90.83	1.009	0.050

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Lag Time Calculations (TLag)

100-year 24-hr Precipitation Depth (P_2)= 1.36

Sub-Basin Data		Initial or Overland Flow Time					Channelized Flow Time					Overall Flow Time		
Basin Id	Basin Area (Ac)	Roughness Coefficient	Length (ft)	Elev Change	Slope (%)	T_i (min)	Length (ft)	Elev Change	Slope (%)	Velocity (FPS)	T_t (min)	Comp. T_c	Lag Time	$Final\ T_{Lag}$ (min)
A	165.82	0.240	300	37	12.3	25.46	4425	203	4.6	3.46	21.3	46.8	28.1	28.1
A1	23.59	0.240	150	7	4.7	21.57	400	31	7.6	4.46	1.5	23.1	13.8	13.8
A2	11.06	0.240	300	14	4.7	37.56	630	24	3.8	3.15	3.3	40.9	24.5	24.5
A3	5.95	0.240	300	41	13.5	24.56	910	36	4.0	3.21	4.7	29.3	17.6	17.6
A4	2.73	0.240	300	40	13.3	24.70	545	23	4.2	3.31	2.7	27.4	16.5	16.5
B	8.62	0.240	150	13	8.3	17.11	990	49	4.9	3.59	4.6	21.7	13.0	13.0
B1	10.33	0.240	280	21	7.3	29.68	601	14	2.2	2.42	4.1	33.8	20.3	20.3
B2	8.97	0.240	300	16	5.3	35.61	427	33	7.7	4.49	1.6	37.2	22.3	22.3
B3	8.47	0.240	300	7	2.3	49.56	726	42	5.7	3.86	3.1	52.7	31.6	31.6
B4	1.05	0.011	30	1	2.3	0.67	1000	34	3.4	2.99	5.6	6.2	3.7	5.0
C	1.71	0.240	41	6	14.6	4.84	71	6	8.5	4.69	0.3	5.1	3.1	5.0
C1	2.92	0.240	155	10	6.5	19.46	422	5	1.1	1.67	4.2	23.7	14.2	14.2
C2	7.57	0.240	300	20	6.7	32.57	850	31	3.6	3.08	4.6	37.2	22.3	22.3
D1	6.77	0.240	300	17	5.7	34.75	480	41	8.5	4.72	1.7	36.5	21.9	21.9
D2	0.32	0.011	35	1	2.9	0.70	730	54	7.4	4.39	2.8	3.5	2.1	5.0
E1	3.05	0.240	300	41	13.7	24.44	370	29	7.8	4.52	1.4	25.8	15.5	15.5
OS1	0.93	0.240	200	15	7.5	22.46	110	24	21.8	7.54	0.2	22.7	13.6	13.6
OS2	2.42	0.240	100	10	9.5	11.74	93	15	16.1	6.48	0.2	12.0	7.2	7.2
OS3	3.76	0.240	200	32	15.8	16.69	213	39	18.1	6.86	0.5	17.2	10.3	10.3

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Reach Time of Concentration Calculations (Tc)

Element Information		**Channelized Flow Path 1**						**Overall Flow Time**
Element ID	**Notes**	**Length (ft)**	**Elev Change**	**Slope (%)**	**Paved?**	**Velocity (FPS)**	**T_c (min)**	**Comp. T_c (min)**
REACH-A1	A1 travel path after leaving basin A1	2640	139	5.27%	N	3.70	11.9	11.9
REACH-A2/3	A2 & A3 travel path after leaving basin A2 or A3	1675	91	5.43%	N	3.76	7.4	7.4
REACH-A4	A4 travel path after leaving basin A4 before A1-Outfall	1865	130	6.97%	N	4.26	7.3	7.3
SWALE B	Swale conveying B1 and B2 runoff to Pond B	990.000	50	5.05%	N	3.63	4.6	4.6

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Pond Stage Storage Discharge Tables

Pond A Area-Elevation-Discharge Table

Stage (ft)	Elevation (ft)	Area (ft^2)	Discharge (cfs)
0	8697	133440	0
0.1	8697.1	140344	0.4
0.2	8697.2	147248	0.57
0.29	8697.29	153462	0.68
0.3	8697.3	154153	0.82
0.4	8697.4	161057	1.23
0.5	8697.5	167961	1.48
0.59	8697.59	174175	1.67
0.6	8697.6	174865	1.82
0.7	8697.7	181769	2.3
0.8	8697.8	188674	2.63
0.9	8697.9	195578	2.91
1	8698	202482	3.15
1.1	8698.1	208553	3.38
1.2	8698.2	214623	3.6
1.3	8698.3	220694	3.8
1.4	8698.4	226765	3.99
1.5	8698.5	232836	4.17
1.6	8698.6	238906	5.56
1.7	8698.7	244977	7.96
1.8	8698.8	251048	11.02
1.9	8698.9	257118	14.6
2	8699	263189	18.64
2.1	8699.1	266329	23.08
2.2	8699.2	269469	27.9
2.3	8699.3	272609	33.05
2.4	8699.4	275749	38.53
2.5	8699.5	278890	44.32
2.6	8699.6	282030	48.79
2.7	8699.7	285170	49.23
2.75	8699.75	286740	49.44
2.8	8699.8	288310	53.15
2.9	8699.9	291450	68.29
3	8700	294590	89.81
3.1	8700.1	295547	116.22
3.2	8700.2	296504	146.83
3.3	8700.3	297460	181.17
3.4	8700.4	298417	218.93
3.5	8700.5	299374	259.89
3.6	8700.6	300331	303.87
3.7	8700.7	301288	350.71
3.8	8700.8	302244	400.3
3.9	8700.9	303201	452.54
4	8701	304158	507.35
4.1	8701.1	305125	564.66
4.2	8701.2	306093	624.39
4.3	8701.3	307060	686.5
4.4	8701.4	308027	750.93
4.5	8701.5	308994	817.65
4.6	8701.6	309962	886.6
4.7	8701.7	310929	957.77
4.8	8701.8	311896	1031.11
4.9	8701.9	312864	1106.6
5	8702	313831	1184.21

Pond B Area-Elevation-Discharge Table

Stage (ft)	Elevation (ft)	Area (ft^2)	Discharge (cfs)
0	8786	9450	0
0.25	8786.25	9828	0.08
0.5	8786.5	10205	0.12
0.75	8786.75	10583	0.14
1	8787	10960	0.16
1.25	8787.25	11355	0.27
1.5	8787.5	11751	0.32
1.75	8787.75	12146	0.36
2	8788	12541	0.4
2.25	8788.25	12957	0.51
2.5	8788.5	13372	0.58
2.75	8788.75	13788	0.63
3	8789	14203	0.68
3.25	8789.25	14639	0.72
3.5	8789.5	15075	0.77
3.75	8789.75	15511	0.81
4	8790	15947	0.84
4.25	8790.25	16403	0.88
4.5	8790.5	16860	0.91
4.75	8790.75	17316	0.95
5	8791	17773	0.98
5.25	8791.25	17830	1.01
5.5	8791.5	17887	4.26
5.75	8791.75	17943	10.18
6	8792	18000	17.84
6.25	8792.25	18250	20.4
6.5	8792.5	18500	20.84
6.75	8792.75	18750	21.27
6.82	8792.82	18820	21.39
7	8793	19000	24.12
7.25	8793.25	20189	31.73
7.5	8793.5	21379	42.99
7.75	8793.75	22568	57.82
8	8794	23758	76.28
8.25	8794.25	24306	98.46
8.5	8794.5	24854	124.51
8.75	8794.75	25402	154.55
9	8795	25950	188.73

Pond Stage Storage Discharge Tables

Pond C Area-Elevation-Discharge Table

Stage (ft)	Elevation (ft)	Area (ft^2)	Discharge (cfs)
0	8869	12764	0.00
8869.25	8869.25	13315	0.00
8869.5	8869.5	13865	0.00
8869.75	8869.75	14416	0.00
8870	8870	14966	0.00
8870.25	8870.25	15542	0.00
8870.5	8870.5	16117	0.00
8870.58	8870.58	16301	0.00
8870.75	8870.75	16693	0.01
8870.91	8870.91	17061	0.02
8871	8871	17268	0.02
8871.24	8871.24	17844	0.04
8871.25	8871.25	17869	0.04
8871.5	8871.5	18469	0.06
8871.57	8871.57	18637	0.07
8871.75	8871.75	19070	0.09
8871.9	8871.9	19430	0.10
8872	8872	19670	0.12
8872.25	8872.25	20296	0.73
8872.5	8872.5	20921	1.47
8872.75	8872.75	21547	2.75
8873	8873	22173	4.74

OUTFALL ELEMENT

Project: West Mountain - Filing 1
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Date: 11/25/2025

HEC-HMS Flow results

Existing Conditions

Element	Area (Ac)	Q5 (CFS)	Q100 (CFS)
A	165.82	47.7	143.8
A_OUT	-	58.7	183.0
A1	23.59	6.8	26.4
A1_OUTFALL	-	7.0	27.2
A2	11.06	2.5	9.4
A2/3	-	4.2	15.8
A3	5.95	1.8	6.4
A4	2.73	0.6	2.1
B	8.62	3.7	14.6
B1	10.33	2.7	9.1
B2	8.97	2.3	7.7
B3	8.47	2.5	9.1
B4	1.05	0.3	1.1
C	1.71	0.4	1.3
C1	2.92	0.8	2.8
C2	7.57	2.1	8.3
DP_B2	-	5.0	16.8
D1	6.77	1.3	4.2
D2	0.32	0.1	0.3
E1	3.05	0.9	3.7
LELAND CREEK	-	5.3	17.4
OS1	0.93	0.3	1.4
OS2	2.42	0.7	2.9
OS2_OUT	-	0.7	2.9
OS3	3.76	1.9	7.2
OS3_OUT	-	11.1	33.7
POND_A	-	58.7	183.0
POND_B	-	9.9	30.3
POND_C	-	3.1	11.7
REACH-A1	-	7.0	26.6
REACH-A2/3	-	4.2	15.5
REACH-A4	-	0.6	2.1
SWALE B	-	5.0	16.7

Proposed Conditions

Element	Area (Ac)	Q5 (CFS)	Q100 (CFS)
A	165.82	57.5	164.0
A_OUT	-	4.0	49.0
A1	23.59	13.5	41.3
A1_OUTFALL	-	13.9	43.1
A2	11.06	6.0	15.8
A2/3	-	8.9	24.2
A3	5.95	3.2	9.3
A4	2.73	0.7	2.7
B	8.62	4.4	14.1
B1	10.33	4.6	13.7
B2	8.97	4.6	12.7
B3	8.47	4.3	10.5
B4	1.05	1.3	3.5
C	1.71	0.6	2.6
C1	2.92	1.6	5.0
C2	7.57	2.8	8.6
DP_B2	-	9.2	26.2
D1	6.77	2.3	7.2
D2	0.32	0.4	1.1
E1	3.05	1.1	3.9
LELAND CREEK	-	3.7	12.0
OS1	0.93	0.3	1.1
OS2	2.42	1.5	5.3
OS2_OUT	-	1.5	5.3
OS3	3.76	2.1	7.0
OS3_OUT	-	2.2	22.7
POND_A	-	4.0	49.0
POND_B	-	0.9	21.0
POND_C	-	0.1	1.7
REACH-A1	-	13.7	42.6
REACH-A2/3	-	8.9	24.1
REACH-A4	-	0.7	2.7
SWALE B	-	9.2	26.2

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Pond A HEC-HMS Flow results

Existing Conditions Inflow Time-Series Results						
Peak Flow Rate (cfs)	Storm Return Interval (yr)					
	Q2	Q5	Q10	Q25	Q50	Q100
	28	58.7	76.2	103	135	183
Time (hr:min)	Storm Return Interval (yr)					
	Q2	Q5	Q10	Q25	Q50	Q100
0:00	0.0	0.0	0.0	0.0	0.0	0.0
0:05	0.0	0.0	0.0	0.0	0.0	0.0
0:10	0.0	0.0	0.0	0.0	0.1	0.1
0:15	0.1	0.2	0.4	0.7	1.1	1.5
0:20	1.0	1.9	3.0	5.0	7.0	9.3
0:25	3.4	6.2	9.4	15.3	20.9	27.6
0:30	8.0	14.5	21.6	34.5	46.8	61.3
0:35	14.9	27.0	39.7	61.9	83.3	108.6
0:40	21.7	39.1	56.6	86.2	115.2	150.4
0:45	26.1	47.8	68.0	99.7	132.2	174.6
0:50	28.0	53.5	74.1	102.5	134.9	183.0
0:55	27.7	56.8	76.2	97.4	127.1	179.8
1:00	26.3	58.7	76.1	88.7	114.8	171.2
1:05	23.9	58.7	73.7	77.5	99.4	157.7
1:10	21.4	57.5	70.3	67.3	85.6	144.1
1:15	19.0	54.7	65.3	57.9	73.1	129.6
1:20	16.3	49.0	57.7	48.7	61.2	112.1
1:25	13.5	41.3	48.3	39.6	49.5	92.5
1:30	10.7	33.2	38.6	31.1	38.9	73.4
1:35	8.3	25.8	29.9	24.0	29.9	56.7
1:40	6.3	19.6	22.7	18.2	22.7	43.0
1:45	4.7	14.6	17.0	13.6	17.0	32.1
1:50	3.5	11.0	12.8	10.3	12.8	24.2
1:55	2.7	8.3	9.7	7.8	9.8	18.4
2:00	2.1	6.3	7.4	5.9	7.4	14.0
2:05	1.6	4.8	5.6	4.5	5.6	10.6
2:10	1.2	3.7	4.2	3.4	4.3	8.1
2:15	0.9	2.8	3.2	2.6	3.3	6.1
2:20	0.7	2.1	2.5	2.0	2.5	4.7
2:25	0.5	1.6	1.9	1.5	1.9	3.6
2:30	0.4	1.2	1.4	1.2	1.5	2.8
2:35	0.3	0.9	1.1	0.9	1.1	2.1
2:40	0.2	0.7	0.8	0.6	0.8	1.5
2:45	0.2	0.5	0.6	0.4	0.5	1.1
2:50	0.1	0.4	0.4	0.3	0.3	0.7
2:55	0.1	0.3	0.3	0.2	0.2	0.5
3:00	0.1	0.2	0.2	0.1	0.2	0.4
3:05	0	0.1	0.1	0.1	0.1	0.2
3:10	0	0.1	0.1	0.1	0.1	0.2
3:15	0	0	0.1	0	0	0.1
3:20	0	0	0	0	0	0
3:25	0	0	0	0	0	0
3:30	0	0	0	0	0	0
3:35	0	0	0	0	0	0
3:40	0	0	0	0	0	0
3:45	0	0	0	0	0	0
3:50	0	0	0	0	0	0
3:55	0	0	0	0	0	0
4:00	0	0	0	0	0	0
4:05	0	0	0	0	0	0
4:10	0	0	0	0	0	0
4:15	0	0	0	0	0	0
4:20	0	0	0	0	0	0
4:25	0	0	0	0	0	0
4:30	0	0	0	0	0	0
4:35	0	0	0	0	0	0
4:40	0	0	0	0	0	0
4:45	0	0	0	0	0	0
4:50	0	0	0	0	0	0
4:55	0	0	0	0	0	0
5:00	0	0	0	0	0	0
5:05	0	0	0	0	0	0
5:10	0	0	0	0	0	0
5:15	0	0	0	0	0	0
5:20	0	0	0	0	0	0
5:25	0	0	0	0	0	0
5:30	0	0	0	0	0	0
5:35	0	0	0	0	0	0
5:40	0	0	0	0	0	0
5:45	0	0	0	0	0	0
5:50	0	0	0	0	0	0
5:55	0	0	0	0	0	0
6:00	0	0	0	0	0	0

Proposed Conditions Inflow Time-Series Results						
Peak Flow Rate (cfs)	Storm Return Interval (yr)					
	Q2	Q5	Q10	Q25	Q50	Q100
	42	77.9	101	134	172	227
Time (hr:min)	Storm Return Interval (yr)					
	Q2	Q5	Q10	Q25	Q50	Q100
0:00	0.0	0.0	0.0	0.0	0.0	0.0
0:05	0.0	0.0	0.0	0.0	0.0	0.0
0:10	0.0	0.0	0.0	0.1	0.1	0.2
0:15	0.2	0.3	0.6	1.1	1.6	2.2
0:20	1.5	2.8	4.2	6.7	9.2	12.1
0:25	5.1	8.8	12.9	20.2	27.1	35.1
0:30	12.4	20.7	29.9	45.8	60.7	77.7
0:35	23.4	38.8	55.0	82.4	107.9	137.3
0:40	33.9	56.2	78.4	114.6	149.0	189.6
0:45	40.1	67.8	93.1	131.9	170.3	218.8
0:50	42.0	74.3	99.8	134.3	172.4	227.1
0:55	40.5	77.0	100.7	126.2	160.9	220.4
1:00	37.6	77.9	98.8	113.5	143.7	207.0
1:05	33.5	76.5	93.9	98.0	122.9	188.0
1:10	29.7	74.0	88.4	84.1	104.6	169.9
1:15	26.0	69.7	81.5	71.8	88.7	151.7
1:20	22.1	62.3	71.8	60.1	73.9	130.8
1:25	18.1	52.4	60.0	48.7	59.7	108.0
1:30	14.3	42.0	47.9	38.2	46.8	85.6
1:35	11.0	32.5	37.0	29.4	36.0	66.1
1:40	8.3	24.6	28.0	22.2	27.2	50.0
1:45	6.2	18.2	20.8	16.6	20.3	37.2
1:50	4.6	13.7	15.6	12.5	15.3	28.0
1:55	3.5	10.3	11.8	9.5	11.6	21.2
2:00	2.7	7.9	9.0	7.2	8.8	16.1
2:05	2.0	5.9	6.8	5.5	6.7	12.2
2:10	1.5	4.5	5.1	4.1	5.1	9.3
2:15	1.2	3.4	3.9	3.2	3.9	7.1
2:20	0.9	2.6	3.0	2.4	3.0	5.4
2:25	0.7	2.0	2.3	1.8	2.3	4.1
2:30	0.5	1.5	1.7	1.4	1.7	3.1
2:35	0.4	1.1	1.3	1.1	1.3	2.4
2:40	0.3	0.9	1	0.8	0.9	1.7
2:45	0.2	0.6	0.7	0.5	0.6	1.2
2:50	0.1	0.4	0.5	0.3	0.4	0.8
2:55	0.1	0.3	0.3	0.2	0.3	0.6
3:00	0.1	0.2	0.2	0.1	0.2	0.4
3:05	0	0.2	0.2	0.1	0.1	0.3
3:10	0	0.1	0.1	0.1	0.1	0.2
3:15	0	0.1	0.1	0	0	0.1
3:20	0	0	0	0	0	0
3:25	0	0	0	0	0	0
3:30	0	0	0	0	0	0
3:35	0	0	0	0	0	0
3:40	0	0	0	0	0	0
3:45	0	0	0	0	0	0
3:50	0	0	0	0	0	0
3:55	0	0	0	0	0	0
4:00	0	0	0	0	0	0
4:05	0	0	0	0	0	0
4:10	0	0	0	0	0	0
4:15	0	0	0	0	0	0
4:20	0	0	0	0	0	0
4:25	0	0	0	0	0	0
4:30	0	0	0	0	0	0
4:35	0	0	0	0	0	0
4:40	0	0	0	0	0	0
4:45	0	0	0	0	0	0
4:50	0	0	0	0	0	0
4:55	0	0	0	0	0	0
5:00	0	0	0	0	0	0
5:05	0	0	0	0	0	0
5:10	0	0	0	0	0	0
5:15	0	0	0	0	0	0
5:20	0	0	0	0	0	0
5:25	0	0	0	0	0	0
5:30	0	0	0	0	0	0
5:35	0	0	0	0	0	0
5:40	0	0	0	0	0	0
5:45	0	0	0	0	0	0
5:50	0	0	0	0	0	0
5:55	0	0	0	0	0	0
6:00	0	0	0	0	0	0

Project: **West Mountain - Filing 1**
Prepared by: **JNS**
Date: **11/25/2025**

Pond B HEC-HMS Flow results

Existing Conditions Inflow Time-Series Results

Peak Flow Rate (cfs)	Storm Return Interval (yr)					
	Q2	Q5	Q10	Q25	Q50	Q100
	4.3	9.6	12.4	16.4	21.8	29.9
Time (hr:min)	Storm Return Interval (yr)					
	Q2	Q5	Q10	Q25	Q50	Q100
0:00	0.0	0.0	0.0	0.0	0.0	0.0
0:05	0.0	0.0	0.0	0.0	0.0	0.0
0:10	0.0	0.0	0.0	0.0	0.0	0.0
0:15	0.0	0.1	0.1	0.3	0.4	0.6
0:20	0.4	0.8	1.2	2.1	2.9	4.0
0:25	1.4	2.5	3.9	6.3	8.6	11.3
0:30	2.5	4.5	6.7	10.7	14.5	19.0
0:35	3.5	6.2	9.2	14.2	19.1	25.0
0:40	4.1	7.5	10.8	16.0	21.4	28.6
0:45	4.3	8.5	11.8	16.4	21.8	29.9
0:50	4.3	9.1	12.3	15.8	20.8	29.8
0:55	4.1	9.4	12.4	14.4	18.8	28.5
1:00	3.7	9.6	12.1	12.8	16.5	26.6
1:05	3.4	9.5	11.7	11.2	14.3	24.5
1:10	3.0	8.9	10.7	9.5	12.1	21.7
1:15	2.5	7.9	9.3	7.9	9.9	18.5
1:20	2.0	6.6	7.8	6.3	7.9	15.2
1:25	1.6	5.3	6.2	4.9	6.2	12.0
1:30	1.2	4.1	4.8	3.8	4.7	9.3
1:35	0.9	3.1	3.6	2.8	3.5	7.0
1:40	0.7	2.3	2.7	2.1	2.6	5.1
1:45	0.5	1.7	2.0	1.6	2.0	3.8
1:50	0.4	1.2	1.5	1.2	1.5	2.8
1:55	0.3	0.9	1.1	0.9	1.1	2.1
2:00	0.2	0.7	0.8	0.6	0.8	1.6
2:05	0.2	0.5	0.6	0.5	0.6	1.2
2:10	0.1	0.4	0.5	0.4	0.5	0.9
2:15	0.1	0.3	0.3	0.3	0.3	0.7
2:20	0.1	0.2	0.3	0.2	0.3	0.5
2:25	0.0	0.2	0.2	0.1	0.2	0.4
2:30	0	0.1	0.1	0.1	0.1	0.3
2:35	0	0.1	0.1	0.1	0.1	0.2
2:40	0	0.1	0.1	0.1	0.1	0.2
2:45	0	0.1	0.1	0	0.1	0.1
2:50	0	0	0	0	0	0.1
2:55	0	0	0	0	0	0.1
3:00	0	0	0	0	0	0
3:05	0	0	0	0	0	0
3:10	0	0	0	0	0	0
3:15	0	0	0	0	0	0
3:20	0	0	0	0	0	0
3:25	0	0	0	0	0	0
3:30	0	0	0	0	0	0
3:35	0	0	0	0	0	0
3:40	0	0	0	0	0	0
3:45	0	0	0	0	0	0
3:50	0	0	0	0	0	0
3:55	0	0	0	0	0	0
4:00	0	0	0	0	0	0
4:05	0	0	0	0	0	0
4:10	0	0	0	0	0	0
4:15	0	0	0	0	0	0
4:20	0	0	0	0	0	0
4:25	0	0	0	0	0	0
4:30	0	0	0	0	0	0
4:35	0	0	0	0	0	0
4:40	0	0	0	0	0	0
4:45	0	0	0	0	0	0
4:50	0	0	0	0	0	0
4:55	0	0	0	0	0	0
5:00	0	0	0	0	0	0
5:05	0	0	0	0	0	0
5:10	0	0	0	0	0	0
5:15	0	0	0	0	0	0
5:20	0	0	0	0	0	0
5:25	0	0	0	0	0	0
5:30	0	0	0	0	0	0
5:35	0	0	0	0	0	0
5:40	0	0	0	0	0	0
5:45	0	0	0	0	0	0
5:50	0	0	0	0	0	0
5:55	0	0	0	0	0	0
6:00	0	0	0	0	0	0

Proposed Conditions Inflow Time-Series Results

Peak Flow Rate (cfs)	Storm Return Interval (yr)					
	Q2	Q5	Q10	Q25	Q50	Q100
	9.5	17.2	21.8	28.1	35.4	46.1
Time (hr:min)	Storm Return Interval (yr)					
	Q2	Q5	Q10	Q25	Q50	Q100
0:00	0.0	0.0	0.0	0.0	0.0	0.0
0:05	0.0	0.0	0.0	0.0	0.0	0.0
0:10	0.0	0.1	0.1	0.2	0.3	0.4
0:15	0.3	0.5	0.8	1.2	1.7	2.2
0:20	1.6	2.6	3.7	5.6	7.3	9.2
0:25	3.7	5.9	8.3	12.2	15.8	19.9
0:30	5.8	9.2	12.8	18.8	24.2	30.3
0:35	7.8	12.5	17.1	24.5	31.3	39.3
0:40	9.1	14.9	20.0	27.5	35.0	44.5
0:45	9.5	16.4	21.5	28.1	35.4	46.1
0:50	9.3	17.1	21.8	26.7	33.5	45.1
0:55	8.7	17.2	21.4	24.1	30.0	42.3
1:00	7.9	16.9	20.4	21.0	25.9	38.6
1:05	6.9	16.2	19.0	18.0	22.0	34.7
1:10	6.0	14.8	17.1	15.1	18.3	30.2
1:15	5.0	13.0	14.8	12.4	15.0	25.6
1:20	4.1	10.9	12.3	9.9	11.9	20.9
1:25	3.2	8.8	9.8	7.8	9.3	16.6
1:30	2.5	6.9	7.6	6.0	7.2	12.8
1:35	1.9	5.2	5.8	4.5	5.4	9.6
1:40	1.4	3.9	4.3	3.3	4.0	7.1
1:45	1.1	2.9	3.2	2.5	3.0	5.3
1:50	0.8	2.1	2.4	1.9	2.2	3.9
1:55	0.6	1.6	1.8	1.4	1.7	2.9
2:00	0.4	1.2	1.3	1.1	1.3	2.2
2:05	0.3	0.9	1.0	0.8	1.0	1.7
2:10	0.3	0.7	0.8	0.6	0.7	1.2
2:15	0.2	0.5	0.6	0.4	0.5	0.9
2:20	0.1	0.4	0.4	0.3	0.4	0.7
2:25	0.1	0.3	0.3	0.2	0.3	0.5
2:30	0.1	0.2	0.2	0.2	0.2	0.4
2:35	0.1	0.2	0.2	0.1	0.2	0.3
2:40	0	0.1	0.1	0.1	0.1	0.2
2:45	0	0.1	0.1	0.1	0.1	0.2
2:50	0	0.1	0.1	0.1	0.1	0.1
2:55	0	0.1	0.1	0	0.1	0.1
3:00	0	0	0	0	0	0.1
3:05	0	0	0	0	0	0
3:10	0	0	0	0	0	0
3:15	0	0	0	0	0	0
3:20	0	0	0	0	0	0
3:25	0	0	0	0	0	0
3:30	0	0	0	0	0	0
3:35	0	0	0	0	0	0
3:40	0	0	0	0	0	0
3:45	0	0	0	0	0	0
3:50	0	0	0	0	0	0
3:55	0	0	0	0	0	0
4:00	0	0	0	0	0	0
4:05	0	0	0	0	0	0
4:10	0	0	0	0	0	0
4:15	0	0	0	0	0	0
4:20	0	0	0	0	0	0
4:25	0	0	0	0	0	0
4:30	0	0	0	0	0	0
4:35	0	0	0	0	0	0
4:40	0	0	0	0	0	0
4:45	0	0	0	0	0	0
4:50	0	0	0	0	0	0
4:55	0	0	0	0	0	0
5:00	0	0	0	0	0	0
5:05	0	0	0	0	0	0
5:10	0	0	0	0	0	0
5:15	0	0	0	0	0	0
5:20	0	0	0	0	0	0
5:25	0	0	0	0	0	0
5:30	0	0	0	0	0	0
5:35	0	0	0	0	0	0
5:40	0	0	0	0	0	0
5:45	0	0	0	0	0	0
5:50	0	0	0	0	0	0
5:55	0	0	0	0	0	0
6:00	0	0	0	0	0	0

APPENDIX C

DETENTION BASIN/
WATER QUALITY ENHANCEMENT BMP'S

Pond Percent Imperviousness Calculations

Pond A – FAA Method Detention Sizing
Pond A – MHFD-Detention_v4.07

Pond B – FAA Method Detention Sizing
Pond B – MHFD-Detention_v4.07

Temporary Sediment Pond C Exhibit
Temporary Sediment Pond C Stage-Storage Discharge Calculations

Project Name: West Mountain - Filing 1
Prepared By: JNS

Pond Percent Impervious Calculations

Basin Id	Design Point	Basin Area (Ac)	Historic Flow Area	Paved Street, Roof, Drives, Walks Area	Single Family Lot Area	Single Family Lot Area	Multi-family Lots Area	Commercial Area	EDBs Area	Permanent Water Surface Area	Golf Course Area	Weighted % Impervious
			5%	95%	35%	55%	70%	90%	25%	100%	30%	
A	A	165.82	55.24	7.99		39.03	9.83	2.32	2.96	3.06	45.39	35.1%
A1	A1	23.59					12.47	5.18			5.94	64.3%
A2	A2	11.06	0.39	1.52			7.22	1.93				74.6%
A3	A3	5.95	1.78	0.88			3.29					54.2%
A4	A4	2.73	2.24			0.49						14.0%
Pond A		209.15	59.65	10.39		39.52	32.81	9.42	2.96	3.06	51.33	40.8%
B	B	8.62	1.64			2.90	3.15		0.93			47.7%
B1	B1	10.33	2.48	2.09	3.72	2.04						43.9%
B2	B2	8.97	0.56	0.97	2.56		4.88					58.7%
B3	B3	8.47	0.42	0.79			7.26					69.1%
B4	B4	1.05	0.17	0.87								80.0%
Pond B		37.44	5.27	4.73	6.28	4.93	15.29		0.93			55.0%
C	C	1.71	0.70						1.02			16.9%
C1	C1	2.92	0.54	0.47	1.90							39.1%
C2	C2	7.57	3.01	1.73	2.83							36.8%
Temp Sed Pond C		12.20	4.25	2.20	4.74				1.02			34.5%

DETENTION VOLUME BY THE MODIFIED FAA METHOD

Project: **Grand Park - West Mountain**

Basin ID: **Pond A1**

(For catchments less than 160 acres only. For larger catchments, use hydrograph routing method)

Warning: This worksheet is not intended for catchments larger than 160 acres.

Determination of MINOR Detention Volume Using Modified FAA Method

Design Information (Input):

Catchment Drainage Imperviousness		I_a =	40.80	percent
Catchment Drainage Area	**WARNING->**	A =	209.150	acres **<-WARNING**
Predevelopment NRCS Soil Group		Type =	D	A, B, C, or D
Return Period for Detention Control		T =	10	years (2, 5, 10, 25, 50, or 100)
Time of Concentration of Watershed		Tc =	28	minutes
Allowable Unit Release Rate		q =	0.33	cfs/acre
One-hour Precipitation		P_1 =	1.01	inches

Design Rainfall IDF Formula $i = C_1 * P_1/(C_2+T_c)^{\wedge}C_3$

Coefficient One	C_1 =	28.50	
Coefficient Two	C_2 =	10	
Coefficient Three	C_3 =	0.786	

Determination of Average Outflow from the Basin (Calculated):

Runoff Coefficient	C =	0.42	
Inflow Peak Runoff	Qp-in =	144.93	cfs
Allowable Peak Outflow Rate	Qp-out =	**68.60**	cfs
Mod. FAA Minor Storage Volume =		143,136	**cubic feet**
Mod. FAA Minor Storage Volume =		**3.286**	**acre-ft**

Determination of MAJOR Detention Volume Using Modified FAA Method

Design Information (Input):

Catchment Drainage Imperviousness	I_a =	40.80	percent
Catchment Drainage Area	A =	209.150	acres
Predevelopment NRCS Soil Group	Type =	D	A, B, C, or D
Return Period for Detention Control	T =	100	years (2, 5, 10, 25, 50, or 100)
Time of Concentration of Watershed	Tc =	28	minutes
Allowable Unit Release Rate	q =	0.79	cfs/acre
One-hour Precipitation	P_1 =	1.64	inches

Design Rainfall IDF Formula $i = C_1 * P_1/(C_2+T_c)^{\wedge}C_3$

Coefficient One	C_1 =	28.50	
Coefficient Two	C_2 =	10	
Coefficient Three	C_3 =	0.786	

Determination of Average Outflow from the Basin (Calculated):

Runoff Coefficient	C =	0.58	
Inflow Peak Runoff	Qp-in =	324.99	cfs
Allowable Peak Outflow Rate	Qp-out =	**164.60**	cfs
Mod. FAA Major Storage Volume =		296,003	**cubic feet**
Mod. FAA Major Storage Volume =		**6.795**	**acre-ft**

1 <- Enter Rainfall Duration Incremental Increase Value Here (e.g. 5 for 5-Minutes)

Rainfall Duration minutes (input)	Rainfall Intensity inches / hr (output)	Inflow Volume acre-feet (output)	Adjustment Factor "m" (output)	Average Outflow cfs (output)	Outflow Volume acre-feet (output)	Storage Volume acre-feet (output)	Rainfall Duration minutes (input)	Rainfall Intensity inches / hr (output)	Inflow Volume acre-feet (output)	Adjustment Factor "m" (output)	Average Outflow cfs (output)	Outflow Volume acre-feet (output)	Storage Volume acre-feet (output)
0	0.00	0.000	0.00	0.00	0.000	0.000	0	0.00	0.000	0.00	0.00	0.000	0.000
1	4.37	0.529	1.00	68.60	0.094	0.434	1	7.10	1.186	1.00	164.60	0.227	0.959
2	4.08	0.988	1.00	68.60	0.189	0.799	2	6.63	2.215	1.00	164.60	0.453	1.762
3	3.83	1.392	1.00	68.60	0.283	1.108	3	6.22	3.120	1.00	164.60	0.680	2.440
4	3.62	1.750	1.00	68.60	0.378	1.372	4	5.87	3.925	1.00	164.60	0.907	3.018
5	3.43	2.073	1.00	68.60	0.472	1.600	5	5.56	4.647	1.00	164.60	1.134	3.514
6	3.26	2.364	1.00	68.60	0.567	1.797	6	5.29	5.301	1.00	164.60	1.360	3.941
7	3.10	2.630	1.00	68.60	0.661	1.968	7	5.04	5.897	1.00	164.60	1.587	4.310
8	2.97	2.873	1.00	68.60	0.756	2.117	8	4.82	6.443	1.00	164.60	1.814	4.629
9	2.84	3.098	1.00	68.60	0.850	2.248	9	4.62	6.947	1.00	164.60	2.041	4.906
10	2.73	3.306	1.00	68.60	0.945	2.361	10	4.44	7.414	1.00	164.60	2.267	5.146
11	2.63	3.500	1.00	68.60	1.039	2.461	11	4.27	7.848	1.00	164.60	2.494	5.354
12	2.54	3.681	1.00	68.60	1.134	2.547	12	4.12	8.254	1.00	164.60	2.721	5.534
13	2.45	3.851	1.00	68.60	1.228	2.623	13	3.98	8.635	1.00	164.60	2.947	5.688
14	2.37	4.011	1.00	68.60	1.323	2.688	14	3.84	8.993	1.00	164.60	3.174	5.819
15	2.29	4.161	1.00	68.60	1.417	2.744	15	3.72	9.331	1.00	164.60	3.401	5.931
16	2.22	4.304	1.00	68.60	1.512	2.792	16	3.61	9.651	1.00	164.60	3.628	6.024
17	2.16	4.439	1.00	68.60	1.606	2.833	17	3.50	9.955	1.00	164.60	3.854	6.101
18	2.10	4.568	1.00	68.60	1.701	2.867	18	3.41	10.243	1.00	164.60	4.081	6.162
19	2.04	4.691	1.00	68.60	1.795	2.895	19	3.31	10.518	1.00	164.60	4.308	6.211
20	1.99	4.808	1.00	68.60	1.890	2.918	20	3.23	10.781	1.00	164.60	4.534	6.246
21	1.94	4.920	1.00	68.60	1.984	2.935	21	3.14	11.032	1.00	164.60	4.761	6.271
22	1.89	5.027	1.00	68.60	2.079	2.948	22	3.07	11.272	1.00	164.60	4.988	6.284
23	1.84	5.130	1.00	68.60	2.173	2.957	23	2.99	11.503	1.00	164.60	5.215	6.288
24	1.80	5.229	1.00	68.60	2.268	2.961	24	2.92	11.725	1.00	164.60	5.441	6.283
25	1.76	5.324	1.00	68.60	2.362	2.962	25	2.86	11.938	1.00	164.60	5.668	6.270
26	1.72	5.416	1.00	68.60	2.457	2.959	26	2.80	12.144	1.00	164.60	5.895	6.249
27	1.68	5.504	1.00	68.60	2.551	2.953	27	2.74	12.342	1.00	164.60	6.122	6.221
28	1.65	5.590	1.00	68.60	2.646	2.944	28	2.68	12.534	1.00	164.60	6.348	6.186
29	1.62	5.672	0.98	67.42	2.693	2.979	29	2.62	12.719	0.98	161.76	6.462	6.258
30	1.58	5.752	0.97	66.31	2.740	3.012	30	2.57	12.899	0.97	159.11	6.575	6.324
31	1.55	5.830	0.95	65.28	2.788	3.042	31	2.52	13.072	0.95	156.64	6.688	6.384
32	1.53	5.905	0.94	64.31	2.835	3.070	32	2.48	13.241	0.94	154.31	6.802	6.439
33	1.50	5.978	0.92	63.40	2.882	3.096	33	2.43	13.404	0.92	152.13	6.915	6.489
34	1.47	6.049	0.91	62.55	2.929	3.119	34	2.39	13.563	0.91	150.08	7.028	6.535
35	1.44	6.118	0.90	61.74	2.976	3.141	35	2.35	13.718	0.90	148.14	7.142	6.576
36	1.42	6.185	0.89	60.98	3.024	3.161	36	2.31	13.868	0.89	146.31	7.255	6.613
37	1.40	6.250	0.88	60.26	3.071	3.179	37	2.27	14.014	0.88	144.58	7.369	6.646
38	1.37	6.313	0.87	59.57	3.118	3.195	38	2.23	14.157	0.87	142.94	7.482	6.675
39	1.35	6.375	0.86	58.93	3.165	3.210	39	2.19	14.296	0.86	141.39	7.595	6.701
40	1.33	6.436	0.85	58.31	3.213	3.223	40	2.16	14.431	0.85	139.91	7.709	6.723
41	1.31	6.495	0.84	57.73	3.260	3.235	41	2.13	14.564	0.84	138.51	7.822	6.742
42	1.29	6.553	0.83	57.17	3.307	3.245	42	2.09	14.693	0.83	137.17	7.935	6.758
43	1.27	6.609	0.83	56.64	3.354	3.254	43	2.06	14.819	0.83	135.89	8.049	6.771
44	1.25	6.664	0.82	56.13	3.402	3.262	44	2.03	14.943	0.82	134.67	8.162	6.781
45	1.23	6.718	0.81	55.64	3.449	3.269	45	2.00	15.063	0.81	133.51	8.275	6.788
46	1.22	6.770	0.80	55.18	3.496	3.274	46	1.98	15.182	0.80	132.40	8.389	6.793
47	1.20	6.822	0.80	54.74	3.543	3.279	47	1.95	15.297	0.80	131.33	8.502	6.795
48	1.18	6.873	0.79	54.31	3.591	3.282	48	1.92	15.411	0.79	130.31	8.615	6.795
49	1.17	6.922	0.79	53.90	3.638	3.284	49	1.90	15.522	0.79	129.33	8.729	6.793
50	1.15	6.971	0.78	53.51	3.685	3.286	50	1.87	15.631	0.78	128.39	8.842	6.789
51	1.14	7.018	0.77	53.13	3.732	3.286	51	1.85	15.738	0.77	127.49	8.956	6.782
52	1.12	7.065	0.77	52.77	3.780	3.285	52	1.82	15.842	0.77	126.62	9.069	6.773
53	1.11	7.111	0.76	52.42	3.827	3.284	53	1.80	15.945	0.76	125.78	9.182	6.763
54	1.10	7.156	0.76	52.09	3.874	3.282	54	1.78	16.046	0.76	124.97	9.296	6.751
55	1.08	7.200	0.75	51.76	3.921	3.279	55	1.76	16.145	0.75	124.20	9.409	6.736
56	1.07	7.244	0.75	51.45	3.969	3.275	56	1.74	16.243	0.75	123.45	9.522	6.721
57	1.06	7.286	0.75	51.15	4.016	3.271	57	1.72	16.339	0.75	122.73	9.636	6.703
58	1.04	7.328	0.74	50.86	4.063	3.265	58	1.70	16.433	0.74	122.03	9.749	6.684
59	1.03	7.370	0.74	50.58	4.110	3.259	59	1.68	16.525	0.74	121.36	9.862	6.663
60	1.02	7.410	0.73	50.31	4.158	3.253	60	1.66	16.617	0.73	120.71	9.976	6.641

Mod. FAA Minor Storage Volume (cubic ft.) = 143,136

Mod. FAA Minor Storage Volume (acre-ft.) = 3.2860

Mod. FAA Major Storage Volume (cubic ft.) = 296,003

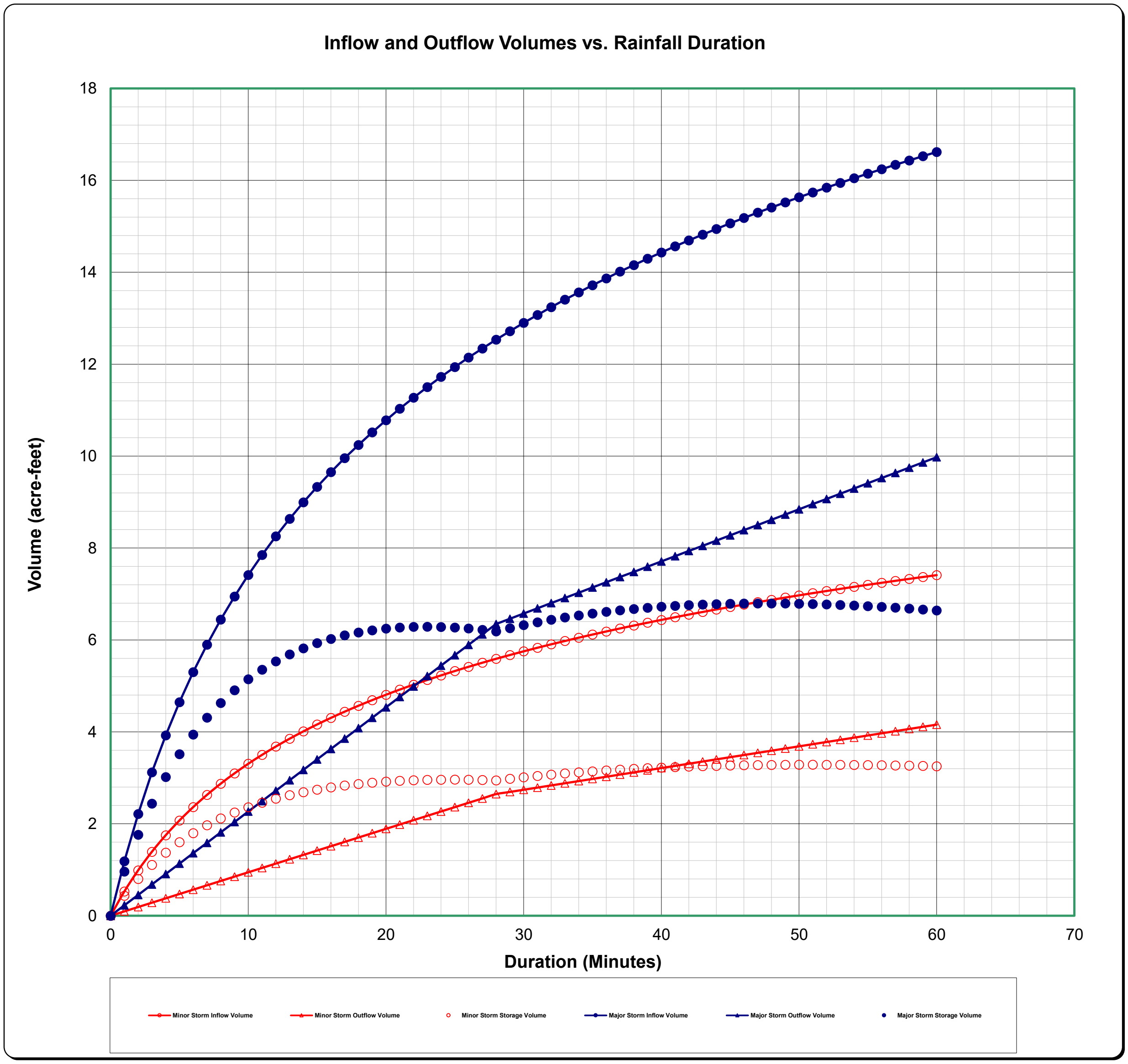
Mod. FAA Major Storage Volume (acre-ft.) = 6.7953

UDFCD DETENTION BASIN VOLUME ESTIMATING WORKBOOK Version 2.35, Released January 2015

DETENTION VOLUME BY THE MODIFIED FAA METHOD

Project: Grand Park - West Mountain

Basin ID: Pond A1

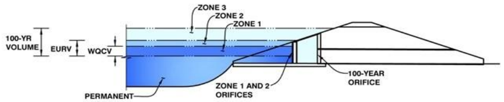


DETENTION BASIN STAGE-STORAGE TABLE BUILDER

MHFD-Detention, Version 4.07 (June 2025)

Project: **Grand Park - West Mountain - Filing 1**

Basin ID: **Pond A**



Example Zone Configuration (Retention Pond)

Watershed Information

Selected SCM Type = **EDB**
Watershed Area = 209.15 acres
Watershed Length = 4,577 ft
Watershed Length to Centroid = 2,062 ft
Watershed Slope = 0.052 ft/ft
Watershed Imperviousness = 40.80% percent
Percentage Hydrologic Soil Group A = 0.0% percent
Percentage Hydrologic Soil Group B = 26.0% percent
Percentage Hydrologic Soil Groups C/D = 74.0% percent
Target WQCV Drain Time = 40.0 hours
Location for 1-hr Rainfall Depths = User Input

After providing required inputs above including 1-hour rainfall depths, click 'Run CUHP' to generate runoff hydrographs using the embedded Colorado Urban Hydrograph Procedure.

			Optional User Overrides	
Water Quality Capture Volume (WQCV) =	3.171	acre-feet		acre-feet
Excess Urban Runoff Volume (EURV) =	8.211	acre-feet		acre-feet
2-yr Runoff Volume (P1 = 0.56 in.) =	2.970	acre-feet	0.56	inches
5-yr Runoff Volume (P1 = 0.88 in.) =	5.546	acre-feet	0.88	inches
10-yr Runoff Volume (P1 = 1.01 in.) =	6.703	acre-feet	1.01	inches
25-yr Runoff Volume (P1 = 1.08 in.) =	8.424	acre-feet	1.08	inches
50-yr Runoff Volume (P1 = 1.26 in.) =	11.263	acre-feet	1.26	inches
100-yr Runoff Volume (P1 = 1.64 in.) =	18.295	acre-feet	1.64	inches
500-yr Runoff Volume (P1 = 3.14 in.) =	45.101	acre-feet		inches
Approximate 2-yr Detention Volume =	3.226	acre-feet		
Approximate 5-yr Detention Volume =	6.093	acre-feet		
Approximate 10-yr Detention Volume =	7.171	acre-feet		
Approximate 25-yr Detention Volume =	7.396	acre-feet		
Approximate 50-yr Detention Volume =	7.998	acre-feet		
Approximate 100-yr Detention Volume =	10.826	acre-feet		

Define Zones and Basin Geometry

Zone 1 Volume (WQCV) = 3.171 acre-feet
Zone 2 Volume (User Defined - Zone 1) = 0.115 acre-feet
Zone 3 Volume (User Defined - Zones 1 & 2) = 6.795 acre-feet
Total Detention Basin Volume = 10.081 acre-feet

Total detention volume is less than 100-year volume.

Initial Surcharge Volume (ISV) = user ft^3
Initial Surcharge Depth (ISD) = user ft
Total Available Detention Depth (H_{total}) = user ft
Depth of Trickle Channel (H_{TC}) = user ft
Slope of Trickle Channel (S_{TC}) = user ft/ft
Slopes of Main Basin Sides (S_{main}) = user H:V
Basin Length-to-Width Ratio ($R_{L/W}$) = user

Initial Surcharge Area (A_{ISV}) = user ft^2
Surcharge Volume Length (L_{ISV}) = user ft
Surcharge Volume Width (W_{ISV}) = user ft
Depth of Basin Floor (H_{FLOOR}) = user ft
Length of Basin Floor (L_{FLOOR}) = user ft
Width of Basin Floor (W_{FLOOR}) = user ft
Area of Basin Floor (A_{FLOOR}) = user ft^2
Volume of Basin Floor (V_{FLOOR}) = user ft^3
Depth of Main Basin (H_{MAIN}) = user ft
Length of Main Basin (L_{MAIN}) = user ft
Width of Main Basin (W_{MAIN}) = user ft
Area of Main Basin (A_{MAIN}) = user ft^2
Volume of Main Basin (V_{MAIN}) = user ft^3
Calculated Total Basin Volume (V_{total}) = **user** acre-feet

Depth Increment = ft

Stage - Storage Description	Stage (ft)	Optional Override Stage (ft)	Length (ft)	Width (ft)	Area (ft^2)	Optional Override Area (ft^2)	Area (acre)	Volume (ft^3)	Volume (ac-ft)
Top of Micropool	--	0.00	--	--	--	133,440	3.063		
8698	--	1.00	--	--	--	202,482	4.648	167,961	3.856
8699	--	2.00	--	--	--	263,189	6.042	400,796	9.201
8700	--	3.00	--	--	--	294,590	6.763	679,686	15.603
8701	--	4.00	--	--	--	304,158	6.983	979,060	22.476
8702	--	5.00	--	--	--	313,831	7.205	1,288,054	29.570
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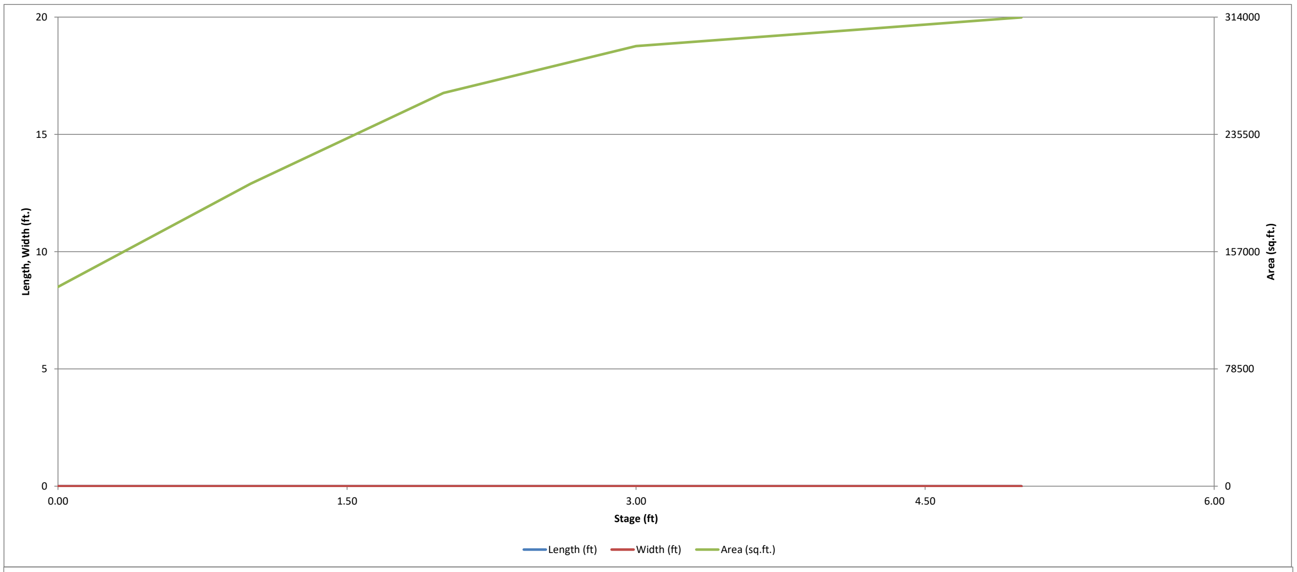
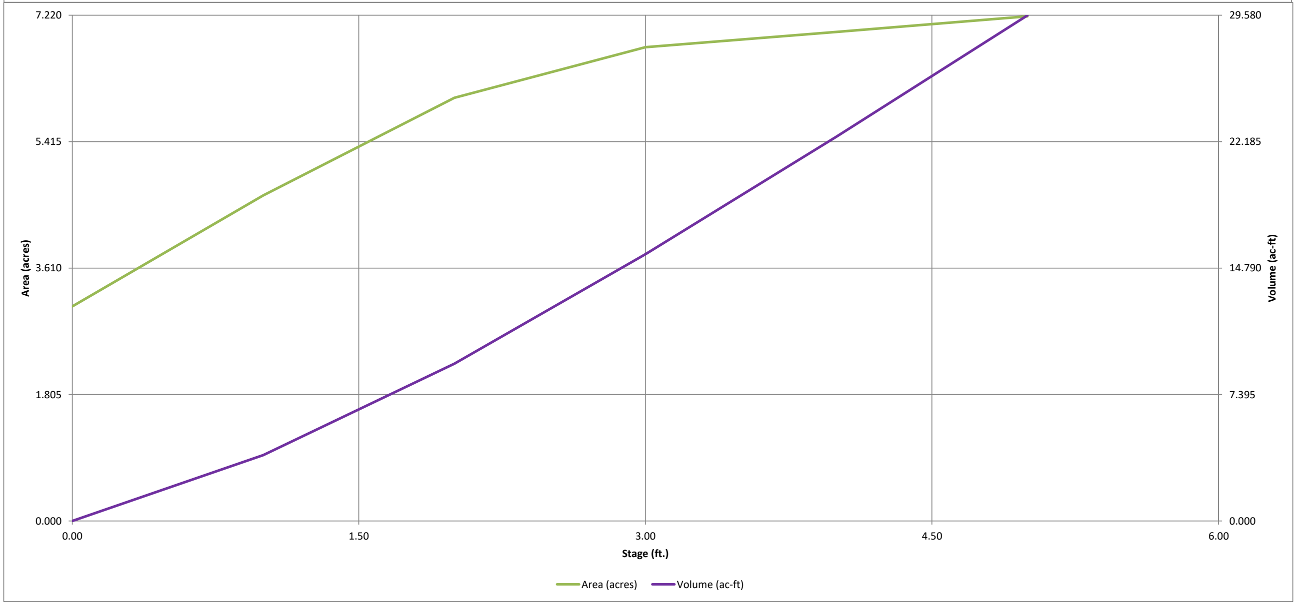
DETENTION BASIN STAGE-STORAGE TABLE BUILDER

MHFD-Detention, Version 4.07 (June 2025)

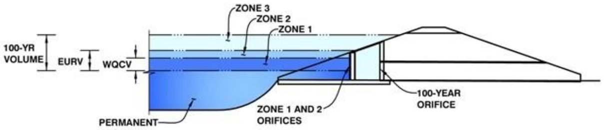




DETENTION BASIN OUTLET STRUCTURE DESIGN

MHFD-Detention, Version 4.07 (June 2025)

Project: Grand Park - West Mountain - Filing 1
Basin ID: Pond A



Example Zone Configuration (Retention Pond)

	Estimated Stage (ft)	Estimated Volume (ac-ft)	Outlet Type
Zone 1 (WQCV)	0.85	3.171	Orifice Plate
Zone 2 (User)	0.88	0.115	Orifice Plate
Zone 3 (User)	2.15	6.795	Weir&Pipe (Restrict)
Total (all zones)		10.081	

User Input: Orifice at Underdrain Outlet (typically used to drain WQCV in a Filtration SCM)

Underdrain Orifice Invert Depth =	N/A	ft (distance below the filtration media surface)
Underdrain Orifice Diameter =	N/A	inches

Calculated Parameters for Underdrain

Underdrain Orifice Area =	N/A	ft^2
Underdrain Orifice Centroid =	N/A	feet

User Input: Orifice Plate with one or more orifices or Elliptical Slot Weir (typically used to drain WQCV and/or EURV in a sedimentation SCM)

Centroid of Lowest Orifice =	0.00	ft (relative to basin bottom at Stage = 0 ft)
Depth at top of Zone using Orifice Plate =	0.88	ft (relative to basin bottom at Stage = 0 ft)
Orifice Plate: Orifice Vertical Spacing =	3.50	inches
Orifice Plate: Orifice Area per Row =	38.00	sq. inches (use rectangular openings)

Calculated Parameters for Plate

WQ Orifice Area per Row =	2.639E-01	ft^2
Elliptical Half-Width =	N/A	feet
Elliptical Slot Centroid =	N/A	feet
Elliptical Slot Area =	N/A	ft^2

User Input: Stage and Total Area of Each Orifice Row (numbered from lowest to highest)

	Row 1 (required)	Row 2 (optional)	Row 3 (optional)	Row 4 (optional)	Row 5 (optional)	Row 6 (optional)	Row 7 (optional)	Row 8 (optional)
Stage of Orifice Centroid (ft)	0.00	0.29	0.59					
Orifice Area (sq. inches)	38.00	38.00	38.00					

	Row 9 (optional)	Row 10 (optional)	Row 11 (optional)	Row 12 (optional)	Row 13 (optional)	Row 14 (optional)	Row 15 (optional)	Row 16 (optional)
Stage of Orifice Centroid (ft)								
Orifice Area (sq. inches)								

User Input: Vertical Orifice (Circular or Rectangular)

	Not Selected	Not Selected	
Invert of Vertical Orifice =	N/A	N/A	ft (relative to basin bottom at Stage = 0 ft)
Depth at top of Zone using Vertical Orifice =	N/A	N/A	ft (relative to basin bottom at Stage = 0 ft)
Vertical Orifice Diameter =	N/A	N/A	inches

Calculated Parameters for Vertical Orifice

	Not Selected	Not Selected	
Vertical Orifice Area =	N/A	N/A	ft^2
Vertical Orifice Centroid =	N/A	N/A	feet

User Input: Overflow Weir (Dropbox with Flat or Sloped Grate and Outlet Pipe OR Rectangular/Trapezoidal Weir and No Outlet Pipe)

	Zone 3 Weir	Not Selected	
Overflow Weir Front Edge Height, Ho =	1.50	N/A	ft (relative to basin bottom at Stage = 0 ft)
Overflow Weir Front Edge Length =	8.00	N/A	feet
Overflow Weir Grate Slope =	0.00	N/A	H:V
Horiz. Length of Weir Sides =	4.00	N/A	feet
Overflow Grate Type =	Type C Grate	N/A	
Debris Clogging % =	50%	N/A	%

Calculated Parameters for Overflow Weir

	Zone 3 Weir	Not Selected	
Height of Grate Upper Edge, H_t =	1.50	N/A	feet
Overflow Weir Slope Length =	4.00	N/A	feet
Grate Open Area / 100-yr Orifice Area =	5.20	N/A	
Overflow Grate Open Area w/o Debris =	22.27	N/A	ft^2
Overflow Grate Open Area w/ Debris =	11.14	N/A	ft^2

User Input: Outlet Pipe w/ Flow Restriction Plate (Circular Orifice, Restrictor Plate, or Rectangular Orifice)

	Zone 3 Restrictor	Not Selected	
Depth to Invert of Outlet Pipe =	4.00	N/A	ft (distance below basin bottom at Stage = 0 ft)
Outlet Pipe Diameter =	36.00	N/A	inches
Restrictor Plate Height Above Pipe Invert =	21.00		inches

Calculated Parameters for Outlet Pipe w/ Flow Restriction Plate

	Zone 3 Restrictor	Not Selected	
Outlet Orifice Area =	4.28	N/A	ft^2
Outlet Orifice Centroid =	1.00	N/A	feet
Half-Central Angle of Restrictor Plate on Pipe =	1.74	N/A	radians

User Input: Emergency Spillway (Rectangular or Trapezoidal)

Spillway Invert Stage=	2.75	ft (relative to basin bottom at Stage = 0 ft)
Spillway Crest Length =	104.00	feet
Spillway End Slopes =	4.00	H:V
Freeboard above Max Water Surface =	1.00	feet

Calculated Parameters for Spillway

Spillway Design Flow Depth=	0.92	feet
Stage at Top of Freeboard =	4.67	feet
Basin Area at Top of Freeboard =	7.13	acres
Basin Volume at Top of Freeboard =	27.20	acre-ft

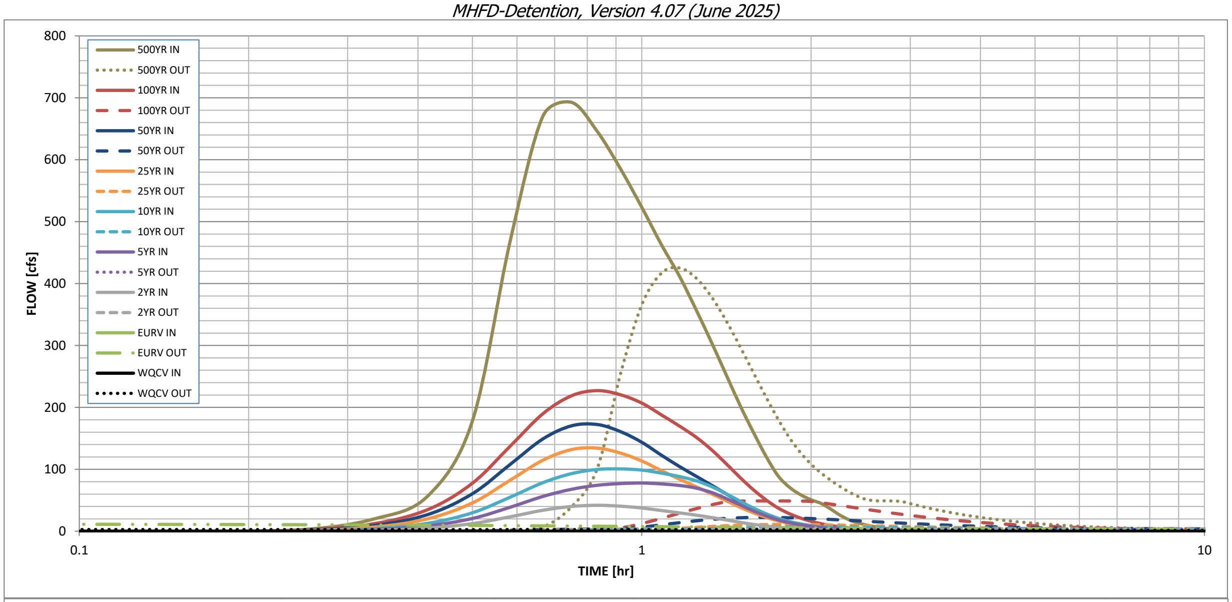
Routed Hydrograph Results

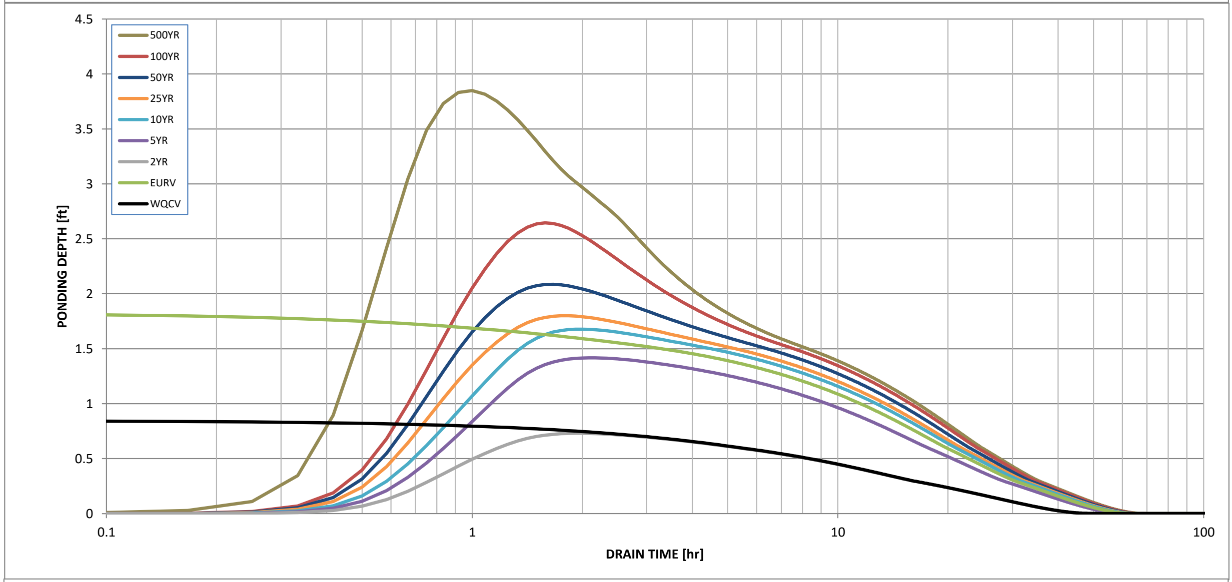
The user can override the default CUHP hydrographs and runoff volumes by entering new values in the Inflow Hydrographs table (Columns W through AF).

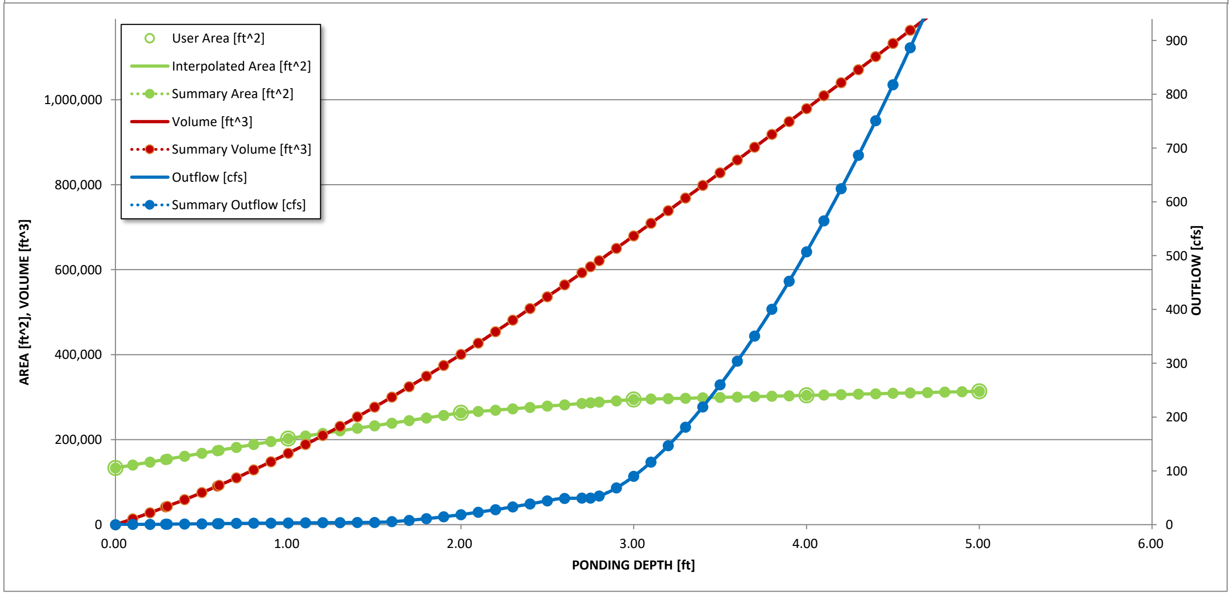
Design Storm Return Period =	WQCV	EURV	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year	500 Year
One-Hour Rainfall Depth (in) =	N/A	N/A	0.56	0.88	1.01	1.08	1.26	1.64	3.14
CUHP Runoff Volume (acre-ft) =	3.171	8.211	2.970	5.546	6.703	8.424	11.263	18.295	45.101
User Override Inflow Hydrograph Volume (acre-ft) =	N/A	N/A	2.925	6.422	8.032	8.930	11.331	16.729	45.101
CUHP Predevelopment Peak Q (cfs) =	N/A	N/A	0.9	5.8	7.6	33.5	67.0	145.1	433.4
OPTIONAL Override Predevelopment Peak Q (cfs) =	N/A	N/A	28	58.7	76.2	102.5	134.9	183	
Predevelopment Unit Peak Flow, q (cfs/acre) =	N/A	N/A	0.13	0.28	0.36	0.49	0.64	0.87	2.07
Peak Inflow Q (cfs) =	N/A	N/A	42.0	77.9	100.7	134.3	172.4	227.1	692.6
Peak Outflow Q (cfs) =	2.8	11.9	2.4	4.0	7.4	11.0	22.4	49.0	425.2
Ratio Peak Outflow to Predevelopment Q =	N/A	N/A	N/A	0.1	0.1	0.1	0.2	0.3	1.0
Structure Controlling Flow =	Plate	Overflow Weir 1	Plate	Plate	Overflow Weir 1	Overflow Weir 1	Overflow Weir 1	Outlet Plate 1	Spillway
Max Velocity through Grate 1 (fps) =	N/A	0.34	N/A	N/A	0.1	0.3	0.8	1.9	2.1
Max Velocity through Grate 2 (fps) =	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Time to Drain 97% of Inflow Volume (hours) =	39	47	40	47	49	49	48	44	31
Time to Drain 99% of Inflow Volume (hours) =	**44**	54	44	53	56	56	56	55	46
Maximum Ponding Depth (ft) =	0.85	1.84	0.73	1.42	1.68	1.80	2.09	2.65	3.85
Area at Maximum Ponding Depth (acres) =	4.41	5.82	4.22	5.22	5.58	5.76	6.10	6.50	6.95
Maximum Volume Stored (acre-ft) =	3.176	8.252	2.659	5.879	7.283	8.020	9.687	13.216	21.362

DETENTION BASIN OUTLET STRUCTURE DESIGN

MHFD-Detention, Version 4.07 (June 2025)







S-A-V-D Chart Axis Override	X-axis	Left Y-Axis	Right Y-Axis
minimum bound			
maximum bound			

DETENTION BASIN OUTLET STRUCTURE DESIGN

Outflow Hydrograph Workbook Filename:

Inflow Hydrographs

The user can override the calculated inflow hydrographs from this workbook with inflow hydrographs developed in a separate program.

	SOURCE	CUHP	CUHP	USER	USER	USER	USER	USER	USER	CUHP
Time Interval	TIME	WQCV [cfs]	EURV [cfs]	2 Year [cfs]	5 Year [cfs]	10 Year [cfs]	25 Year [cfs]	50 Year [cfs]	100 Year [cfs]	500 Year [cfs]
5.00 min	0:00:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0:05:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0:10:00	0	0.00	0.00	0.00	0.00	0.10	0.10	0.20	2.79
	0:15:00	0	0.00	0.20	0.30	0.60	1.10	1.60	2.20	19.68
	0:20:00	0	0.00	1.50	2.80	4.20	6.70	9.20	12.10	57.20
	0:25:00	0	0.00	5.10	8.80	12.90	20.20	27.10	35.10	178.42
	0:30:00	0	0.00	12.40	20.70	29.90	45.80	60.70	77.70	468.36
	0:35:00	0	0.00	23.40	38.80	55.00	82.40	107.90	137.30	669.78
	0:40:00	0	0.00	33.90	56.20	78.40	114.60	149.00	189.60	692.64
	0:45:00	0	0.00	40.10	67.80	93.10	131.90	170.30	218.80	645.66
	0:50:00	0	0.00	42.00	74.30	99.80	134.30	172.40	227.10	585.15
	0:55:00	0	0.00	40.50	77.00	100.70	126.20	160.90	220.40	523.14
	1:00:00	0	0.00	37.60	77.90	98.80	113.50	143.70	207.00	463.00
	1:05:00	0	0.00	33.50	76.50	93.90	98.00	122.90	188.00	411.93
	1:10:00	0	0.00	29.70	74.00	88.40	84.10	104.60	169.90	357.11
	1:15:00	0	0.00	26.00	69.70	81.50	71.80	88.70	151.70	302.96
	1:20:00	0	0.00	22.10	62.30	71.80	60.10	73.90	130.80	250.08
	1:25:00	0	0.00	18.10	52.40	60.00	48.70	59.70	108.00	200.59
	1:30:00	0	0.00	14.30	42.00	47.90	38.20	46.80	85.60	157.68
	1:35:00	0	0.00	11.00	32.50	37.00	29.40	36.00	66.10	119.43
	1:40:00	0	0.00	8.30	24.60	28.00	22.20	27.20	50.00	88.57
	1:45:00	0	0.00	6.20	18.20	20.80	16.60	20.30	37.20	70.49
	1:50:00	0	0.00	4.60	13.70	15.60	12.50	15.30	28.00	58.85
	1:55:00	0	0.00	3.50	10.30	11.80	9.50	11.60	21.20	50.77
	2:00:00	0	0.00	2.70	7.90	9.00	7.20	8.80	16.10	44.94
	2:05:00	0	0.00	2.00	5.90	6.80	5.50	6.70	12.20	35.88
	2:10:00	0	0.00	1.50	4.50	5.10	4.10	5.10	9.30	26.03
	2:15:00	0	0.00	1.20	3.40	3.90	3.20	3.90	7.10	18.74
	2:20:00	0	0.00	0.90	2.60	3.00	2.40	3.00	5.40	13.92
	2:25:00	0	0.00	0.70	2.00	2.30	1.80	2.30	4.10	10.36
	2:30:00	0	0.00	0.50	1.50	1.70	1.40	1.70	3.10	7.70
	2:35:00	0	0.00	0.40	1.10	1.30	1.10	1.30	2.40	5.65
	2:40:00	0	0.00	0.30	0.90	1.00	0.80	0.90	1.70	4.20
	2:45:00	0	0.00	0.20	0.60	0.70	0.50	0.60	1.20	3.00
	2:50:00	0	0.00	0.10	0.40	0.50	0.30	0.40	0.80	2.00
	2:55:00	0	0.00	0.10	0.30	0.30	0.20	0.30	0.60	1.20
	3:00:00	0	0.00	0.10	0.20	0.20	0.10	0.20	0.40	0.60
	3:05:00	0	0.00	0.00	0.20	0.20	0.10	0.10	0.30	0.20
	3:10:00	0	0.00	0.00	0.10	0.10	0.10	0.10	0.20	0.00
	3:15:00	0	0.00	0.00	0.10	0.10	0.00	0.00	0.10	0.00
	3:20:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:25:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:30:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:35:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:40:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:45:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:50:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:55:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:00:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:05:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:10:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:15:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:20:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:25:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:30:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:35:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:40:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:45:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:50:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:55:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:00:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:05:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:10:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:15:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:20:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:25:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:30:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:35:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:40:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:45:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:50:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:55:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	6:00:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

DETENTION BASIN OUTLET STRUCTURE DESIGN

MHFD-Detention, Version 4.07 (June 2025)

Summary Stage-Area-Volume-Discharge Relationships

The user can create a summary S-A-V-D by entering the desired stage increments and the remainder of the table will populate automatically.

The user should graphically compare the summary S-A-V-D table to the full S-A-V-D table in the chart to confirm it captures all key transition points.

Stage - Storage Description	Stage [ft]	Elevation [ft]	Area [ft ^{2}]	Area [acres]	Volume [ft ^{3}]	Volume [ac-ft]	Total Outflow [cfs]
Orifice 1	0.00	8697.00	133440	3.063	0	0.000	0.00
	0.10	8697.10	140344	3.222	13689	0.314	0.40
	0.20	8697.20	147248	3.380	28069	0.644	0.57
Orifice 2	0.29	8697.29	153462	3.523	41601	0.955	0.68
	0.30	8697.30	154153	3.539	43139	0.990	0.82
	0.40	8697.40	161057	3.697	58899	1.352	1.23
	0.50	8697.50	167961	3.856	75350	1.730	1.48
Orifice 3	0.59	8697.59	174175	3.999	90746	2.083	1.67
	0.60	8697.60	174865	4.014	92491	2.123	1.82
	0.70	8697.70	181769	4.173	110323	2.533	2.30
	0.80	8697.80	188674	4.331	128845	2.958	2.63
	0.90	8697.90	195578	4.490	148058	3.399	2.91
	1.00	8698.00	202482	4.648	167961	3.856	3.15
	1.10	8698.10	208553	4.788	188513	4.328	3.38
	1.20	8698.20	214623	4.927	209671	4.813	3.60
	1.30	8698.30	220694	5.066	231437	5.313	3.80
	1.40	8698.40	226765	5.206	253810	5.827	3.99
Overflow Weir Rim Invert	1.50	8698.50	232836	5.345	276790	6.354	4.17
	1.60	8698.60	238906	5.485	300377	6.896	5.56
	1.70	8698.70	244977	5.624	324571	7.451	7.96
	1.80	8698.80	251048	5.763	349373	8.020	11.02
	1.90	8698.90	257118	5.903	374781	8.604	14.60
	2.00	8699.00	263189	6.042	400796	9.201	18.64
	2.10	8699.10	266329	6.114	427272	9.809	23.08
	2.20	8699.20	269469	6.186	454062	10.424	27.90
	2.30	8699.30	272609	6.258	481166	11.046	33.05
	2.40	8699.40	275749	6.330	508584	11.675	38.53
	2.50	8699.50	278890	6.402	536316	12.312	44.32
	2.60	8699.60	282030	6.475	564362	12.956	48.79
	2.70	8699.70	285170	6.547	592722	13.607	49.23
Spillway Invert Elevation	2.75	8699.75	286740	6.583	607020	13.935	49.44
	2.80	8699.80	288310	6.619	621396	14.265	53.15
	2.90	8699.90	291450	6.691	650384	14.931	68.29
	3.00	8700.00	294590	6.763	679686	15.603	89.81
	3.10	8700.10	295547	6.785	709193	16.281	116.22
	3.20	8700.20	296504	6.807	738795	16.960	146.83
	3.30	8700.30	297460	6.829	768493	17.642	181.17
	3.40	8700.40	298417	6.851	798287	18.326	218.93
	3.50	8700.50	299374	6.873	828177	19.012	259.89
	3.60	8700.60	300331	6.895	858162	19.701	303.87
	3.70	8700.70	301288	6.917	888243	20.391	350.71
	3.80	8700.80	302244	6.939	918420	21.084	400.30
	3.90	8700.90	303201	6.961	948692	21.779	452.54
	4.00	8701.00	304158	6.983	979060	22.476	507.35
	4.10	8701.10	305125	7.005	1009524	23.175	564.66
	4.20	8701.20	306093	7.027	1040085	23.877	624.39
	4.30	8701.30	307060	7.049	1070742	24.581	686.50
	4.40	8701.40	308027	7.071	1101497	25.287	750.93
	4.50	8701.50	308994	7.094	1132348	25.995	817.65
	4.60	8701.60	309962	7.116	1163296	26.706	886.60
	4.70	8701.70	310929	7.138	1194340	27.418	957.77
	4.80	8701.80	311896	7.160	1225482	28.133	1031.11
	4.90	8701.90	312864	7.182	1256720	28.850	1106.60
	5.00	8702.00	313831	7.205	1288054	29.570	1184.21

For best results, include the stages of all grade slope changes (e.g. ISV and Floor) from the S-A-V table on
Sheet 'Basin'.

Also include the inverts of all outlets (e.g. vertical orifice, overflow grate, and spillway, where applicable).

DETENTION VOLUME BY THE MODIFIED FAA METHOD

Project: Grand Park - West Mountain

Basin ID: Pond B

(For catchments less than 160 acres only. For larger catchments, use hydrograph routing method)

(NOTE: for catchments larger than 90 acres, CUHP hydrograph and routing are recommended)

Determination of MINOR Detention Volume Using Modified FAA Method

Design Information (Input):

Catchment Drainage Imperviousness	I_a =	55.00	percent
Catchment Drainage Area	A =	37.440	acres
Predevelopment NRCS Soil Group	Type =	D	A, B, C, or D
Return Period for Detention Control	T =	10	years (2, 5, 10, 25, 50, or 100)
Time of Concentration of Watershed	Tc =	23	minutes
Allowable Unit Release Rate	q =	0.33	cfs/acre
One-hour Precipitation	P_1 =	1.01	inches

Design Rainfall IDF Formula $i = C_1 * P_1/(C_2+T_c)^\wedge C_3$

Coefficient One	C_1 =	28.50
Coefficient Two	C_2 =	10
Coefficient Three	C_3 =	0.786

Determination of Average Outflow from the Basin (Calculated):

Runoff Coefficient	C =	0.48	
Inflow Peak Runoff	Qp-in =	33.13	cfs
Allowable Peak Outflow Rate	Qp-out =	**12.39**	cfs
Mod. FAA Minor Storage Volume =		35,195	**cubic feet**
Mod. FAA Minor Storage Volume =		**0.808**	**acre-ft**

Determination of MAJOR Detention Volume Using Modified FAA Method

Design Information (Input):

Catchment Drainage Imperviousness	I_a =	55.00	percent
Catchment Drainage Area	A =	37.440	acres
Predevelopment NRCS Soil Group	Type =	D	A, B, C, or D
Return Period for Detention Control	T =	100	years (2, 5, 10, 25, 50, or 100)
Time of Concentration of Watershed	Tc =	23	minutes
Allowable Unit Release Rate	q =	0.80	cfs/acre
One-hour Precipitation	P_1 =	1.64	inches

Design Rainfall IDF Formula $i = C_1 * P_1/(C_2+T_c)^\wedge C_3$

Coefficient One	C_1 =	28.50
Coefficient Two	C_2 =	10
Coefficient Three	C_3 =	0.786

Determination of Average Outflow from the Basin (Calculated):

Runoff Coefficient	C =	0.62	
Inflow Peak Runoff	Qp-in =	69.48	cfs
Allowable Peak Outflow Rate	Qp-out =	**29.91**	cfs
Mod. FAA Major Storage Volume =		64,777	**cubic feet**
Mod. FAA Major Storage Volume =		**1.487**	**acre-ft**

1 <- Enter Rainfall Duration Incremental Increase Value Here (e.g. 5 for 5-Minutes)

Rainfall Duration minutes (input)	Rainfall Intensity inches / hr (output)	Inflow Volume acre-feet (output)	Adjustment Factor "m" (output)	Average Outflow cfs (output)	Outflow Volume acre-feet (output)	Storage Volume acre-feet (output)	Rainfall Duration minutes (input)	Rainfall Intensity inches / hr (output)	Inflow Volume acre-feet (output)	Adjustment Factor "m" (output)	Average Outflow cfs (output)	Outflow Volume acre-feet (output)	Storage Volume acre-feet (output)
0	0.00	0.000	0.00	0.00	0.000	0.000	0	0.00	0.000	0.00	0.00	0.000	0.000
1	4.37	0.108	1.00	12.39	0.017	0.091	1	7.10	0.227	1.00	29.91	0.041	0.186
2	4.08	0.202	1.00	12.39	0.034	0.168	2	6.63	0.424	1.00	29.91	0.082	0.342
3	3.83	0.285	1.00	12.39	0.051	0.233	3	6.22	0.597	1.00	29.91	0.124	0.473
4	3.62	0.358	1.00	12.39	0.068	0.290	4	5.87	0.751	1.00	29.91	0.165	0.586
5	3.43	0.424	1.00	12.39	0.085	0.339	5	5.56	0.889	1.00	29.91	0.206	0.683
6	3.26	0.484	1.00	12.39	0.102	0.381	6	5.29	1.014	1.00	29.91	0.247	0.767
7	3.10	0.538	1.00	12.39	0.119	0.418	7	5.04	1.128	1.00	29.91	0.288	0.840
8	2.97	0.588	1.00	12.39	0.137	0.451	8	4.82	1.233	1.00	29.91	0.330	0.903
9	2.84	0.634	1.00	12.39	0.154	0.480	9	4.62	1.329	1.00	29.91	0.371	0.958
10	2.73	0.676	1.00	12.39	0.171	0.506	10	4.44	1.419	1.00	29.91	0.412	1.007
11	2.63	0.716	1.00	12.39	0.188	0.528	11	4.27	1.502	1.00	29.91	0.453	1.049
12	2.54	0.753	1.00	12.39	0.205	0.548	12	4.12	1.579	1.00	29.91	0.494	1.085
13	2.45	0.788	1.00	12.39	0.222	0.566	13	3.98	1.652	1.00	29.91	0.536	1.117
14	2.37	0.821	1.00	12.39	0.239	0.582	14	3.84	1.721	1.00	29.91	0.577	1.144
15	2.29	0.851	1.00	12.39	0.256	0.595	15	3.72	1.786	1.00	29.91	0.618	1.168
16	2.22	0.881	1.00	12.39	0.273	0.607	16	3.61	1.847	1.00	29.91	0.659	1.188
17	2.16	0.908	1.00	12.39	0.290	0.618	17	3.50	1.905	1.00	29.91	0.700	1.204
18	2.10	0.935	1.00	12.39	0.307	0.627	18	3.41	1.960	1.00	29.91	0.742	1.218
19	2.04	0.960	1.00	12.39	0.324	0.635	19	3.31	2.013	1.00	29.91	0.783	1.230
20	1.99	0.984	1.00	12.39	0.341	0.642	20	3.23	2.063	1.00	29.91	0.824	1.239
21	1.94	1.007	1.00	12.39	0.358	0.648	21	3.14	2.111	1.00	29.91	0.865	1.246
22	1.89	1.028	1.00	12.39	0.376	0.653	22	3.07	2.157	1.00	29.91	0.907	1.251
23	1.84	1.050	1.00	12.39	0.393	0.657	23	2.99	2.201	1.00	29.91	0.948	1.253
24	1.80	1.070	0.98	12.13	0.401	0.669	24	2.92	2.244	0.98	29.29	0.968	1.275
25	1.76	1.089	0.96	11.90	0.410	0.680	25	2.86	2.284	0.96	28.72	0.989	1.296
26	1.72	1.108	0.94	11.68	0.418	0.690	26	2.80	2.324	0.94	28.19	1.010	1.314
27	1.68	1.126	0.93	11.47	0.427	0.699	27	2.74	2.362	0.93	27.70	1.030	1.332
28	1.65	1.144	0.91	11.29	0.435	0.708	28	2.68	2.398	0.91	27.24	1.051	1.348
29	1.62	1.160	0.90	11.11	0.444	0.717	29	2.62	2.434	0.90	26.82	1.071	1.363
30	1.58	1.177	0.88	10.95	0.452	0.724	30	2.57	2.468	0.88	26.42	1.092	1.376
31	1.55	1.193	0.87	10.79	0.461	0.732	31	2.52	2.501	0.87	26.05	1.113	1.389
32	1.53	1.208	0.86	10.65	0.469	0.739	32	2.48	2.534	0.86	25.71	1.133	1.401
33	1.50	1.223	0.85	10.51	0.478	0.745	33	2.43	2.565	0.85	25.38	1.154	1.411
34	1.47	1.237	0.84	10.39	0.486	0.751	34	2.39	2.595	0.84	25.08	1.174	1.421
35	1.44	1.252	0.83	10.27	0.495	0.757	35	2.35	2.625	0.83	24.79	1.195	1.430
36	1.42	1.265	0.82	10.16	0.504	0.762	36	2.31	2.654	0.82	24.51	1.216	1.438
37	1.40	1.279	0.81	10.05	0.512	0.767	37	2.27	2.682	0.81	24.26	1.236	1.446
38	1.37	1.292	0.80	9.95	0.521	0.771	38	2.23	2.709	0.80	24.01	1.257	1.452
39	1.35	1.304	0.79	9.85	0.529	0.775	39	2.19	2.736	0.79	23.78	1.277	1.458
40	1.33	1.317	0.79	9.76	0.538	0.779	40	2.16	2.762	0.79	23.56	1.298	1.464
41	1.31	1.329	0.78	9.67	0.546	0.783	41	2.13	2.787	0.78	23.35	1.319	1.468
42	1.29	1.341	0.77	9.59	0.555	0.786	42	2.09	2.812	0.77	23.15	1.339	1.472
43	1.27	1.352	0.77	9.51	0.563	0.789	43	2.06	2.836	0.77	22.96	1.360	1.476
44	1.25	1.363	0.76	9.44	0.572	0.791	44	2.03	2.859	0.76	22.78	1.380	1.479
45	1.23	1.374	0.76	9.36	0.580	0.794	45	2.00	2.882	0.76	22.60	1.401	1.482
46	1.22	1.385	0.75	9.29	0.589	0.796	46	1.98	2.905	0.75	22.44	1.422	1.484
47	1.20	1.396	0.74	9.23	0.597	0.798	47	1.95	2.927	0.74	22.28	1.442	1.485
48	1.18	1.406	0.74	9.17	0.606	0.800	48	1.92	2.949	0.74	22.12	1.463	1.486
49	1.17	1.416	0.73	9.10	0.615	0.802	49	1.90	2.970	0.73	21.98	1.483	1.487
50	1.15	1.426	0.73	9.05	0.623	0.803	50	1.87	2.991	0.73	21.84	1.504	1.487
51	1.14	1.436	0.73	8.99	0.632	0.804	51	1.85	3.011	0.73	21.70	1.525	1.487
52	1.12	1.445	0.72	8.94	0.640	0.805	52	1.82	3.032	0.72	21.57	1.545	1.486
53	1.11	1.455	0.72	8.89	0.649	0.806	53	1.80	3.051	0.72	21.45	1.566	1.485
54	1.10	1.464	0.71	8.84	0.657	0.807	54	1.78	3.071	0.71	21.33	1.586	1.484
55	1.08	1.473	0.71	8.79	0.666	0.807	55	1.76	3.090	0.71	21.21	1.607	1.483
56	1.07	1.482	0.71	8.74	0.674	0.808	56	1.74	3.108	0.71	21.10	1.628	1.481
57	1.06	1.491	0.70	8.70	0.683	0.808	57	1.72	3.127	0.70	20.99	1.648	1.478
58	1.04	1.499	0.70	8.65	0.691	0.808	58	1.70	3.145	0.70	20.89	1.669	1.476
59	1.03	1.508	0.69	8.61	0.700	0.808	59	1.68	3.162	0.69	20.79	1.689	1.473
60	1.02	1.516	0.69	8.57	0.708	0.808	60	1.66	3.180	0.69	20.69	1.710	1.470

Mod. FAA Minor Storage Volume (cubic ft.) = **35,195**

Mod. FAA Minor Storage Volume (acre-ft.) = **0.8080**

Mod. FAA Major Storage Volume (cubic ft.) = **64,777**

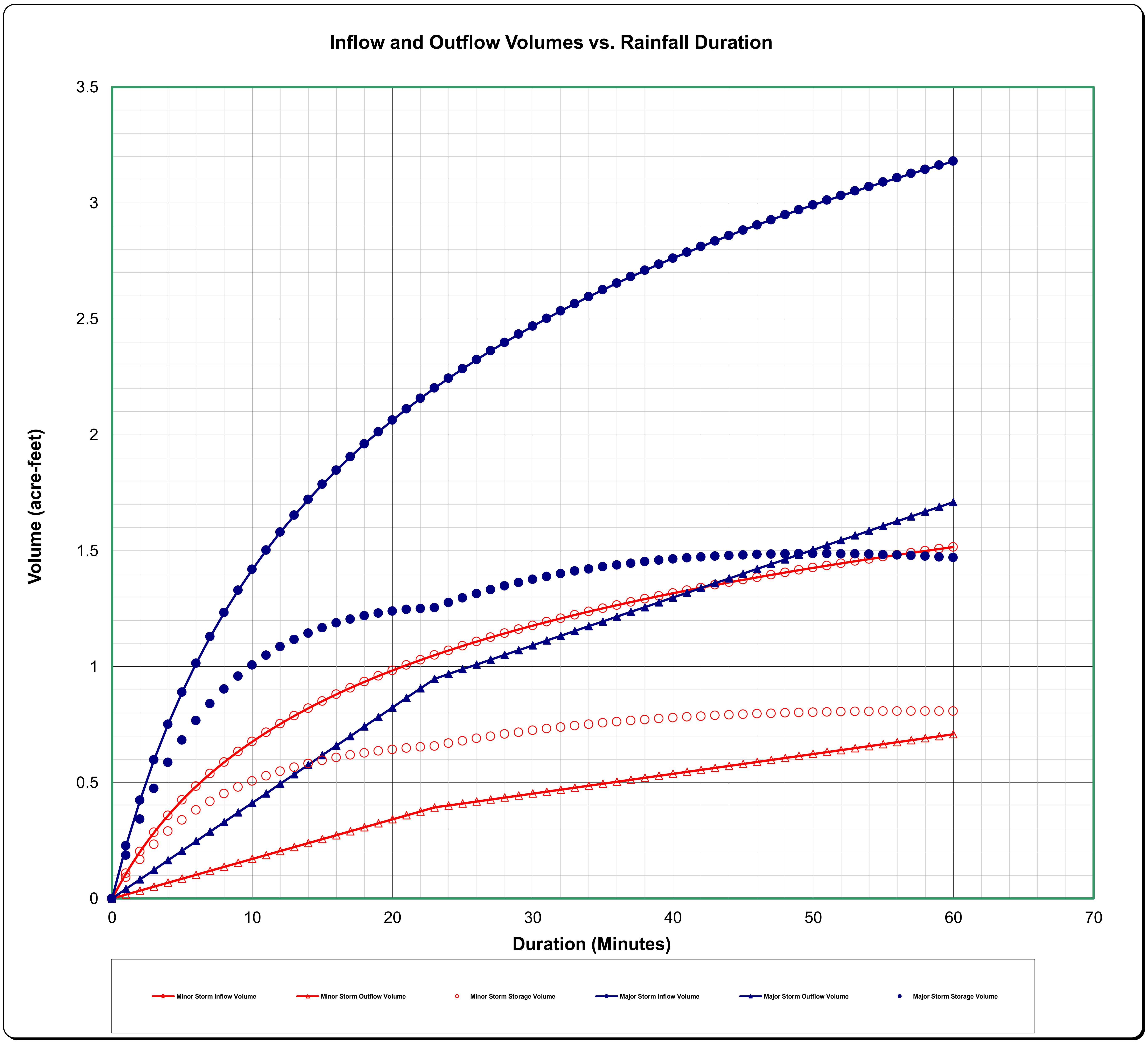
Mod. FAA Major Storage Volume (acre-ft.) = **1.4871**

UDFCD DETENTION BASIN VOLUME ESTIMATING WORKBOOK Version 2.35, Released January 2015

DETENTION VOLUME BY THE MODIFIED FAA METHOD

Project: Grand Park - West Mountain

Basin ID: Pond B

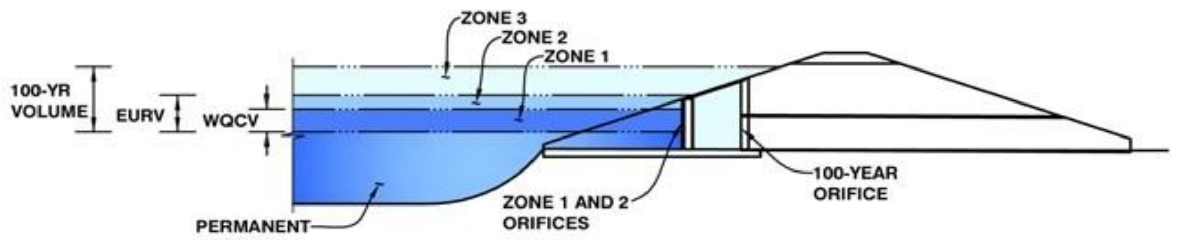


DETENTION BASIN STAGE-STORAGE TABLE BUILDER

MHFD-Detention, Version 4.07 (June 2025)

Project: **Grand Park - Filing 1**

Basin ID: **Pond B**



Example Zone Configuration (Retention Pond)

Watershed Information

Selected SCM Type =	**EDB**	
Watershed Area =	37.44	acres
Watershed Length =	3,250	ft
Watershed Length to Centroid =	1,640	ft
Watershed Slope =	0.043	ft/ft
Watershed Imperviousness =	55.00%	percent
Percentage Hydrologic Soil Group A =	0.0%	percent
Percentage Hydrologic Soil Group B =	49.0%	percent
Percentage Hydrologic Soil Groups C/D =	51.0%	percent
Target WQCV Drain Time =	40.0	hours
Location for 1-hr Rainfall Depths =	User Input	

After providing required inputs above including 1-hour rainfall depths, click 'Run CUHP' to generate runoff hydrographs using the embedded Colorado Urban Hydrograph Procedure.

			Optional User Overrides	
Water Quality Capture Volume (WQCV) =	0.688	acre-feet		acre-feet
Excess Urban Runoff Volume (EURV) =	2.088	acre-feet		acre-feet
2-yr Runoff Volume (P1 = 0.56 in.) =	0.780	acre-feet	0.56	inches
5-yr Runoff Volume (P1 = 0.88 in.) =	1.381	acre-feet	0.88	inches
10-yr Runoff Volume (P1 = 1.01 in.) =	1.644	acre-feet	1.01	inches
25-yr Runoff Volume (P1 = 1.08 in.) =	1.918	acre-feet	1.08	inches
50-yr Runoff Volume (P1 = 1.26 in.) =	2.449	acre-feet	1.26	inches
100-yr Runoff Volume (P1 = 1.64 in.) =	3.712	acre-feet	1.64	inches
500-yr Runoff Volume (P1 = 3.14 in.) =	8.576	acre-feet		inches
Approximate 2-yr Detention Volume =	0.808	acre-feet		
Approximate 5-yr Detention Volume =	1.422	acre-feet		
Approximate 10-yr Detention Volume =	1.703	acre-feet		
Approximate 25-yr Detention Volume =	1.723	acre-feet		
Approximate 50-yr Detention Volume =	1.856	acre-feet		
Approximate 100-yr Detention Volume =	2.399	acre-feet		

Define Zones and Basin Geometry

Zone 1 Volume (WQCV) =	0.688	acre-feet
Zone 2 Volume (User Defined - Zone 1) =	0.120	acre-feet
Zone 3 Volume (User Defined - Zones 1 & 2) =	1.487	acre-feet
Total Detention Basin Volume =	2.295	acre-feet
Initial Surcharge Volume (ISV) =	user	ft^3
Initial Surcharge Depth (ISD) =	user	ft
Total Available Detention Depth (H_{total}) =	user	ft
Depth of Trickle Channel (H_{TC}) =	user	ft
Slope of Trickle Channel (S_{TC}) =	user	ft/ft
Slopes of Main Basin Sides (S_{main}) =	user	H:V
Basin Length-to-Width Ratio ($R_{L/W}$) =	user	
Initial Surcharge Area (A_{ISV}) =	user	ft^2
Surcharge Volume Length (L_{ISV}) =	user	ft
Surcharge Volume Width (W_{ISV}) =	user	ft
Depth of Basin Floor (H_{FLOOR}) =	user	ft
Length of Basin Floor (L_{FLOOR}) =	user	ft
Width of Basin Floor (W_{FLOOR}) =	user	ft
Area of Basin Floor (A_{FLOOR}) =	user	ft^2
Volume of Basin Floor (V_{FLOOR}) =	user	ft^3
Depth of Main Basin (H_{MAIN}) =	user	ft
Length of Main Basin (L_{MAIN}) =	user	ft
Width of Main Basin (W_{MAIN}) =	user	ft
Area of Main Basin (A_{MAIN}) =	user	ft^2
Volume of Main Basin (V_{MAIN}) =	user	ft^3
Calculated Total Basin Volume (V_{total}) =	**user**	acre-feet

Total detention volume is less than 100-year volume.

Depth Increment = ft

Stage - Storage Description	Stage (ft)	Optional Override Stage (ft)	Length (ft)	Width (ft)	Area (ft^2)	Optional Override Area (ft^2)	Area (acre)	Volume (ft^3)	Volume (ac-ft)
Top of Micropool	--	0.00	--	--	--	9,450	0.217		
8787	--	1.00	--	--	--	10,960	0.252	10,205	0.234
8788	--	2.00	--	--	--	12,541	0.288	21,955	0.504
8789	--	3.00	--	--	--	14,203	0.326	35,327	0.811
8790	--	4.00	--	--	--	15,947	0.366	50,402	1.157
8791	--	5.00	--	--	--	17,773	0.408	67,262	1.544
8792	--	6.00	--	--	--	18,000	0.413	85,149	1.955
8793	--	7.00	--	--	--	19,000	0.436	103,649	2.379
8794	--	8.00	--	--	--	23,758	0.545	125,028	2.870
8795	--	9.00	--	--	--	25,950	0.596	149,882	3.441
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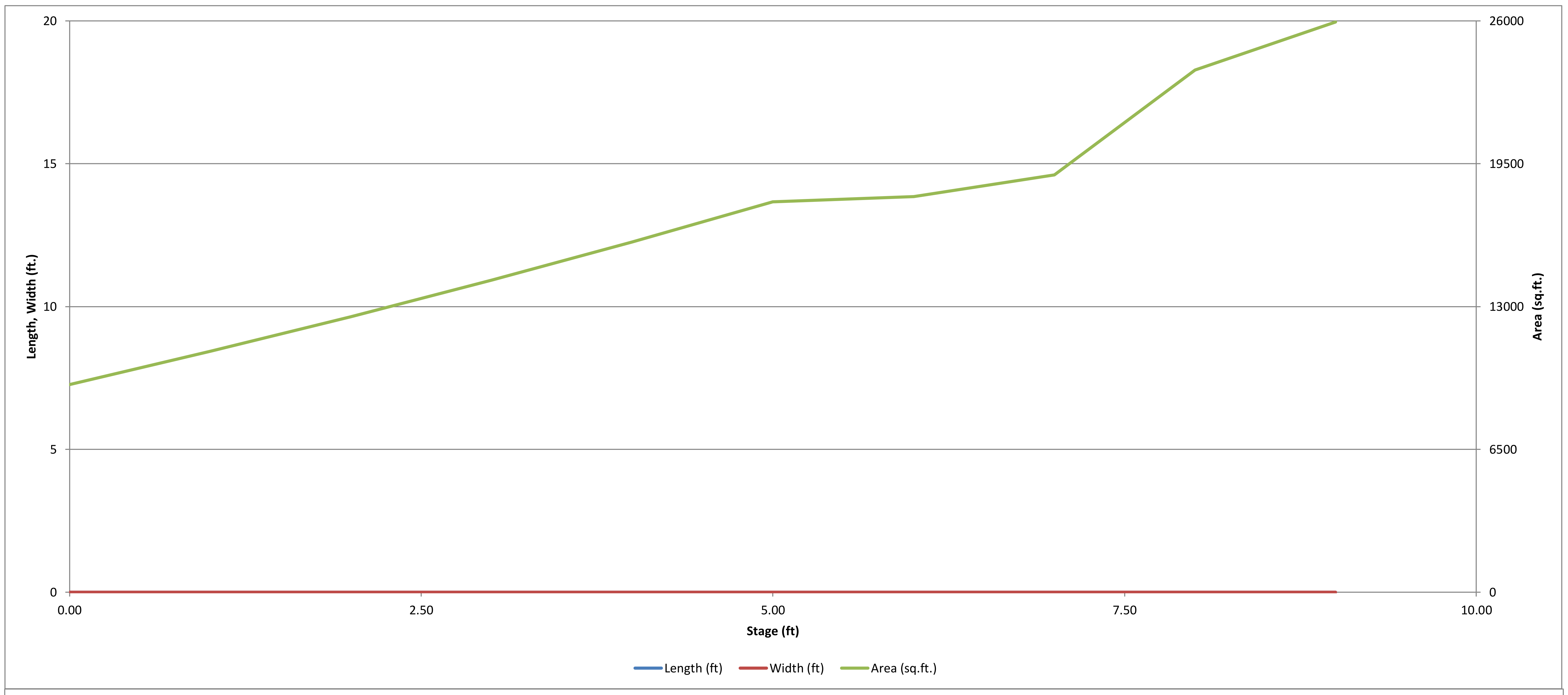
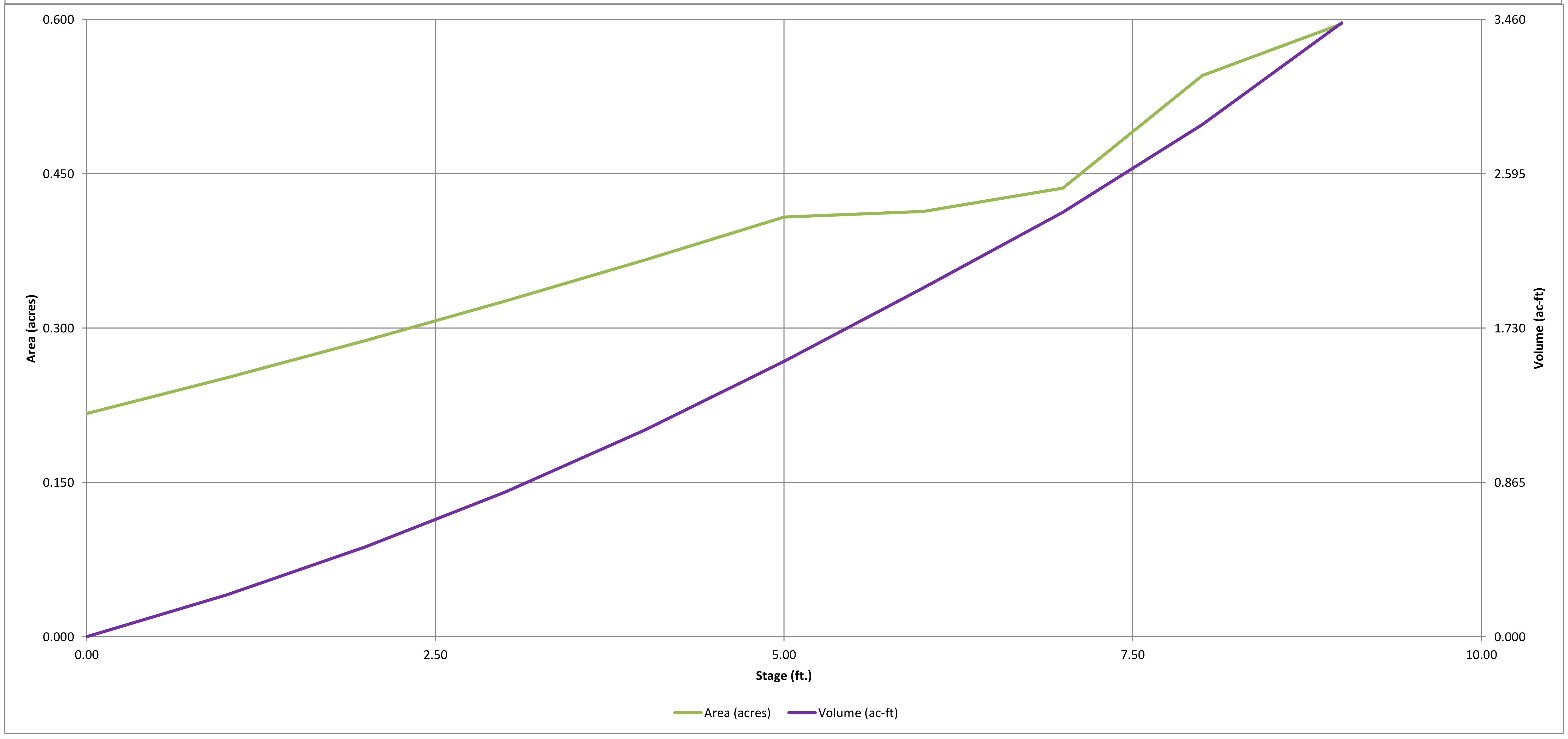
DETENTION BASIN STAGE-STORAGE TABLE BUILDER

MHFD-Detention, Version 4.07 (June 2025)

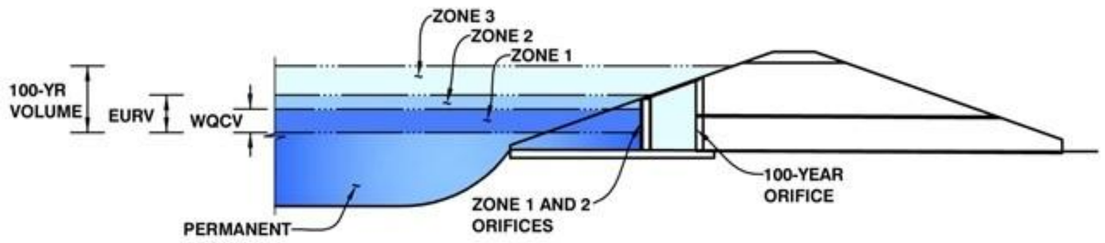




DETENTION BASIN OUTLET STRUCTURE DESIGN

MHFD-Detention, Version 4.07 (June 2025)

Project: **Grand Park - Filing 1**
Basin ID: **Pond B**



Example Zone Configuration (Retention Pond)

	Estimated Stage (ft)	Estimated Volume (ac-ft)	Outlet Type
Zone 1 (WQCV)	2.62	0.688	Orifice Plate
Zone 2 (User)	2.99	0.120	Orifice Plate
Zone 3 (User)	6.81	1.487	Weir&Pipe (Restrict)
Total (all zones)		2.295	

User Input: Orifice at Underdrain Outlet (typically used to drain WQCV in a Filtration SCM)

Underdrain Orifice Invert Depth =	N/A	ft (distance below the filtration media surface)
Underdrain Orifice Diameter =	N/A	inches

Calculated Parameters for Underdrain

Underdrain Orifice Area =	N/A	ft^2
Underdrain Orifice Centroid =	N/A	feet

User Input: Orifice Plate with one or more orifices or Elliptical Slot Weir (typically used to drain WQCV and/or EURV in a sedimentation SCM)

Centroid of Lowest Orifice =	0.00	ft (relative to basin bottom at Stage = 0 ft)
Depth at top of Zone using Orifice Plate =	2.62	ft (relative to basin bottom at Stage = 0 ft)
Orifice Plate: Orifice Vertical Spacing =	12.00	inches
Orifice Plate: Orifice Area per Row =	4.90	sq. inches (use rectangular openings)

Calculated Parameters for Plate

WQ Orifice Area per Row =	3.403E-02	ft^2
Elliptical Half-Width =	N/A	feet
Elliptical Slot Centroid =	N/A	feet
Elliptical Slot Area =	N/A	ft^2

User Input: Stage and Total Area of Each Orifice Row (numbered from lowest to highest)

	Row 1 (required)	Row 2 (optional)	Row 3 (optional)	Row 4 (optional)	Row 5 (optional)	Row 6 (optional)	Row 7 (optional)	Row 8 (optional)
Stage of Orifice Centroid (ft)	0.00	1.00	2.00					
Orifice Area (sq. inches)	4.90	4.90	4.90					

	Row 9 (optional)	Row 10 (optional)	Row 11 (optional)	Row 12 (optional)	Row 13 (optional)	Row 14 (optional)	Row 15 (optional)	Row 16 (optional)
Stage of Orifice Centroid (ft)								
Orifice Area (sq. inches)								

User Input: Vertical Orifice (Circular or Rectangular)

	Not Selected	Not Selected	
Invert of Vertical Orifice =	N/A	N/A	ft (relative to basin bottom at Stage = 0 ft)
Depth at top of Zone using Vertical Orifice =	N/A	N/A	ft (relative to basin bottom at Stage = 0 ft)
Vertical Orifice Diameter =	N/A	N/A	inches

Calculated Parameters for Vertical Orifice

	Not Selected	Not Selected	
Vertical Orifice Area =	N/A	N/A	ft^2
Vertical Orifice Centroid =	N/A	N/A	feet

User Input: Overflow Weir (Dropbox with Flat or Sloped Grate and Outlet Pipe OR Rectangular/Trapezoidal Weir and No Outlet Pipe)

	Zone 3 Weir	Not Selected	
Overflow Weir Front Edge Height, Ho =	5.25	N/A	ft (relative to basin bottom at Stage = 0 ft)
Overflow Weir Front Edge Length =	4.00	N/A	feet
Overflow Weir Grate Slope =	0.00	N/A	H:V
Horiz. Length of Weir Sides =	4.00	N/A	feet
Overflow Grate Type =	Type C Grate	N/A	
Debris Clogging % =	50%	N/A	%

Calculated Parameters for Overflow Weir

	Zone 3 Weir	Not Selected	
Height of Grate Upper Edge, H_t =	5.25	N/A	feet
Overflow Weir Slope Length =	4.00	N/A	feet
Grate Open Area / 100-yr Orifice Area =	6.30	N/A	
Overflow Grate Open Area w/o Debris =	11.14	N/A	ft^2
Overflow Grate Open Area w/ Debris =	5.57	N/A	ft^2

User Input: Outlet Pipe w/ Flow Restriction Plate (Circular Orifice, Restrictor Plate, or Rectangular Orifice)

	Zone 3 Restrictor	Not Selected	
Depth to Invert of Outlet Pipe =	0.25	N/A	ft (distance below basin bottom at Stage = 0 ft)
Outlet Pipe Diameter =	18.00	N/A	inches
Restrictor Plate Height Above Pipe Invert =	18.00		inches

Calculated Parameters for Outlet Pipe w/ Flow Restriction Plate

	Zone 3 Restrictor	Not Selected	
Outlet Orifice Area =	1.77	N/A	ft^2
Outlet Orifice Centroid =	0.75	N/A	feet
Half-Central Angle of Restrictor Plate on Pipe =	3.14	N/A	radians

User Input: Emergency Spillway (Rectangular or Trapezoidal)

Spillway Invert Stage=	6.82	ft (relative to basin bottom at Stage = 0 ft)
Spillway Crest Length =	10.00	feet
Spillway End Slopes =	4.00	H:V
Freeboard above Max Water Surface =	1.00	feet

Calculated Parameters for Spillway

Spillway Design Flow Depth=	1.09	feet
Stage at Top of Freeboard =	8.91	feet
Basin Area at Top of Freeboard =	0.59	acres
Basin Volume at Top of Freeboard =	3.39	acre-ft

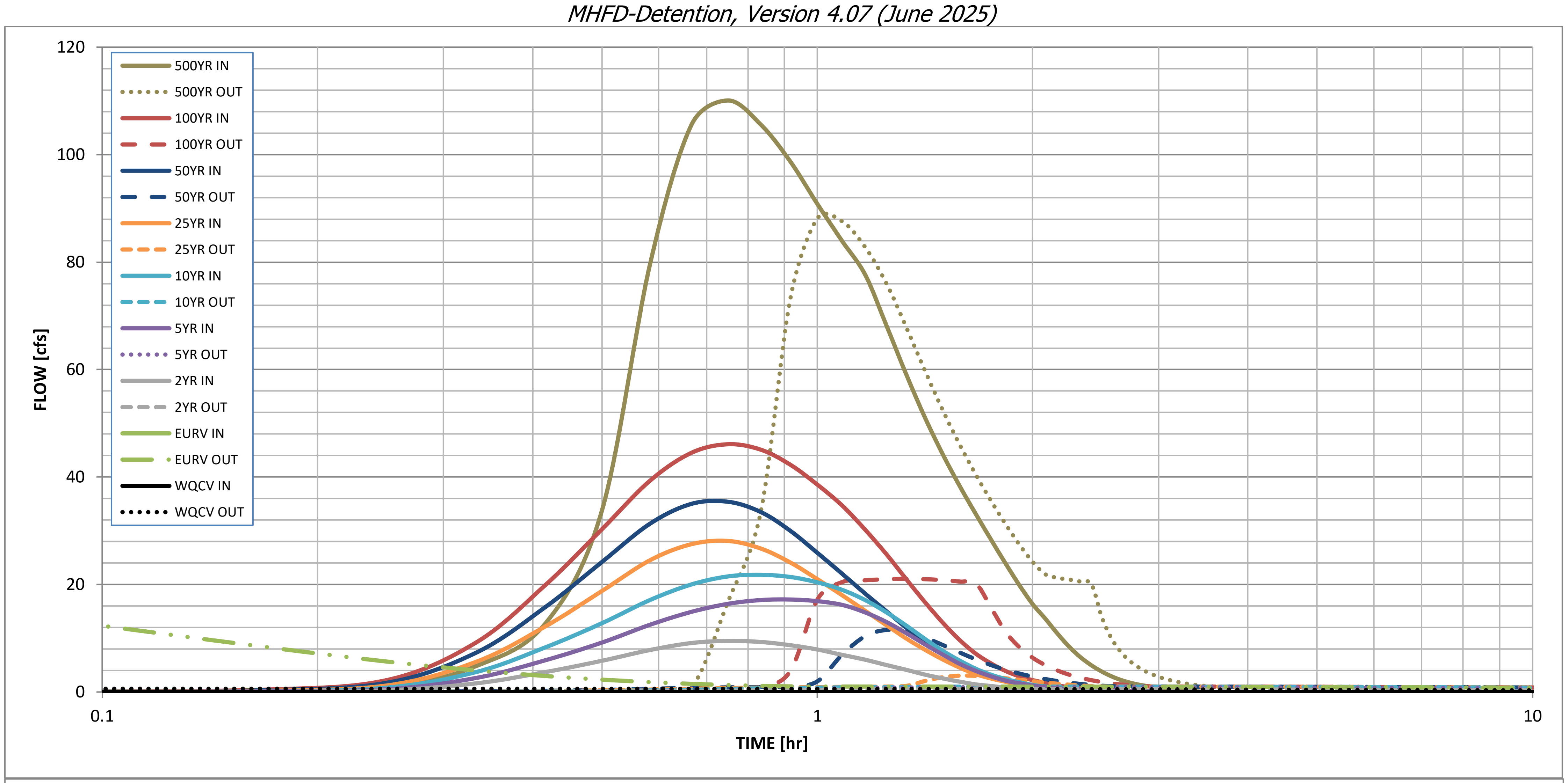
Routed Hydrograph Results

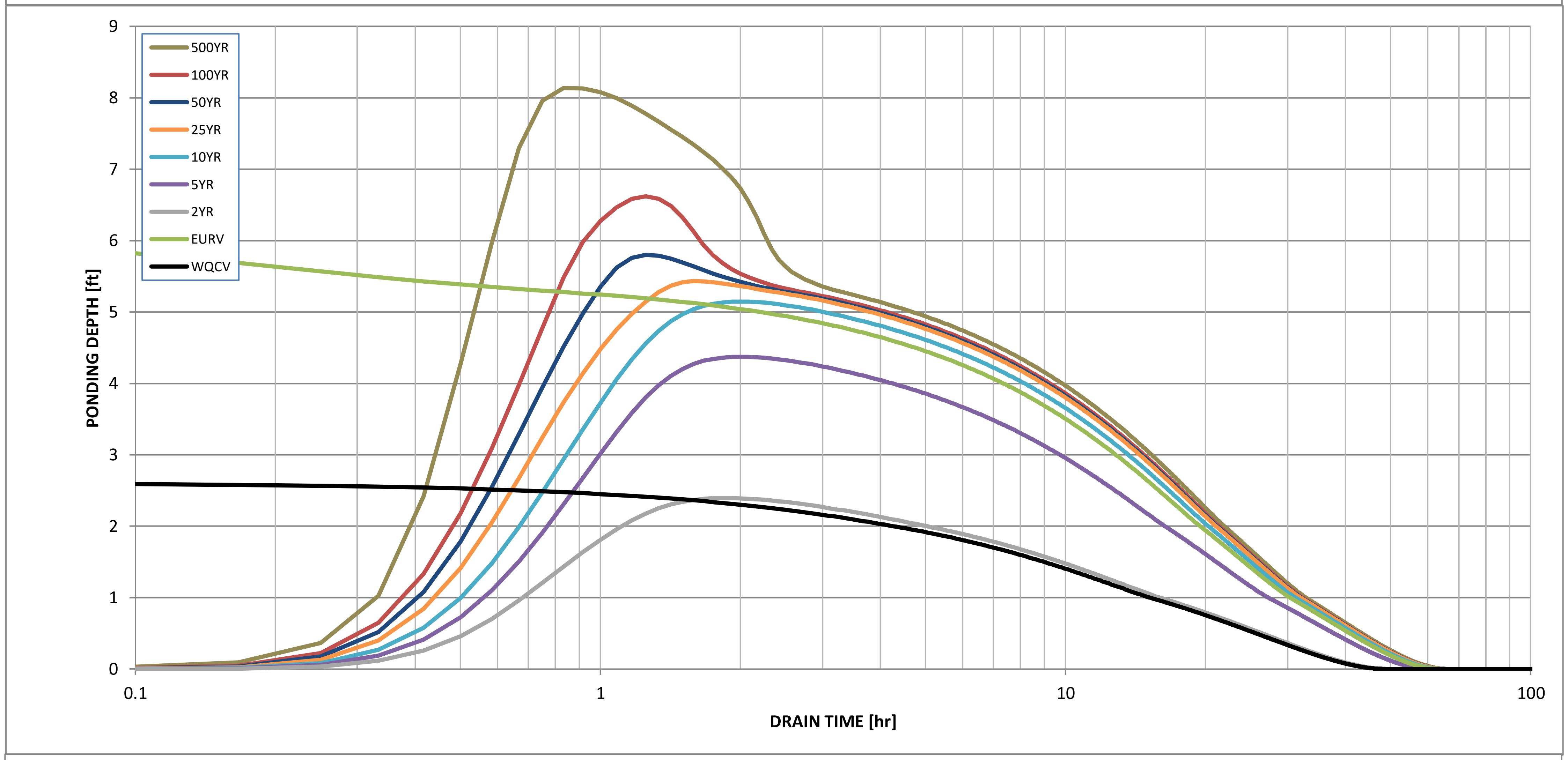
The user can override the default CUHP hydrographs and runoff volumes by entering new values in the Inflow Hydrographs table (Columns W through AF).

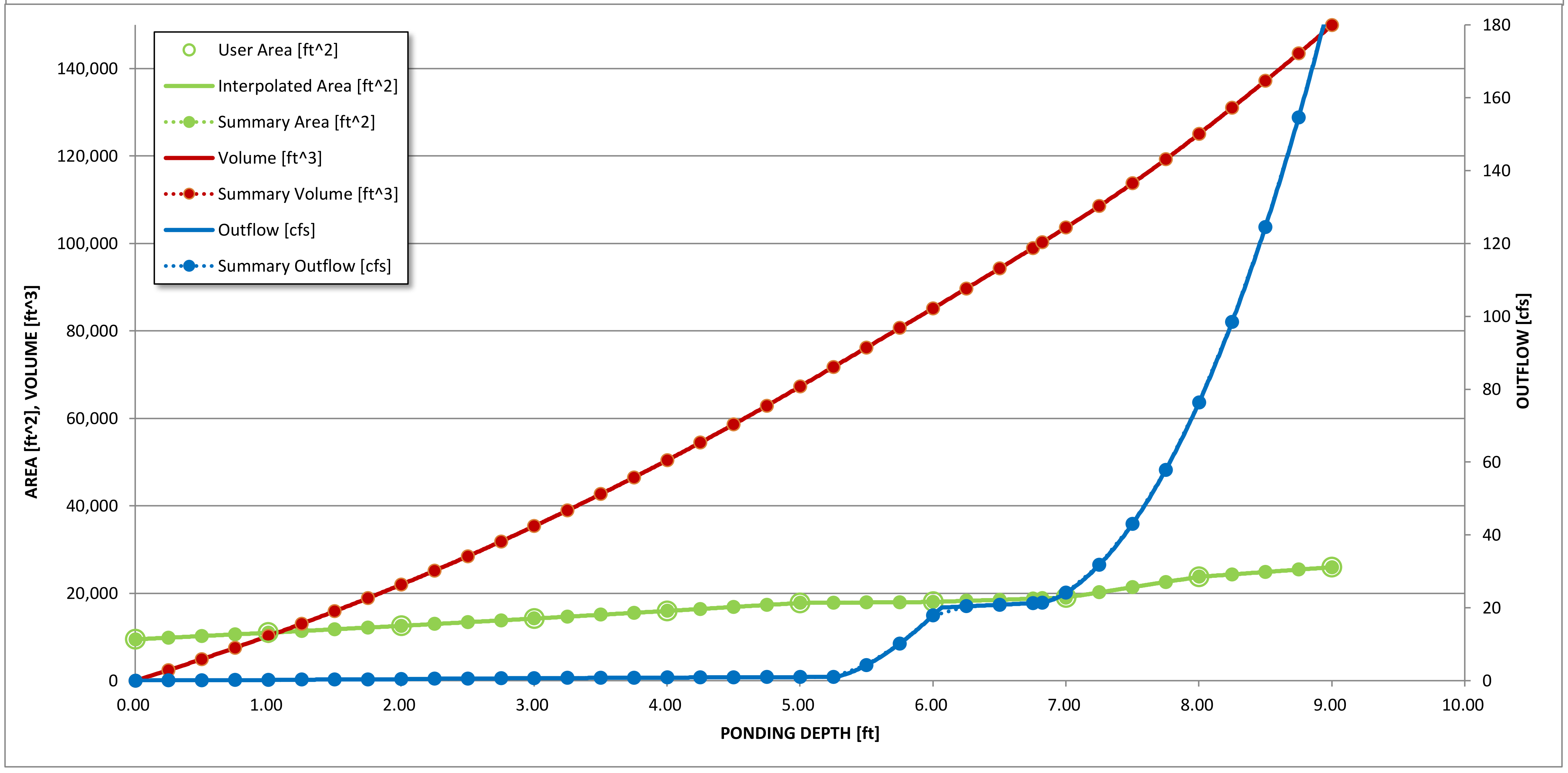
Design Storm Return Period =	WQCV	EURV	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year	500 Year
One-Hour Rainfall Depth (in) =	N/A	N/A	0.56	0.88	1.01	1.08	1.26	1.64	3.14
CUHP Runoff Volume (acre-ft) =	0.688	2.088	0.780	1.381	1.644	1.918	2.449	3.712	8.576
User Override Inflow Hydrograph Volume (acre-ft) =	N/A	N/A	0.680	1.408	1.730	1.906	2.379	3.417	8.576
CUHP Predevelopment Peak Q (cfs) =	N/A	N/A	0.1	0.7	0.9	3.4	7.6	17.6	53.8
OPTIONAL Override Predevelopment Peak Q (cfs) =	N/A	N/A	4.3	9.6	12.4	16.4	21.8	29.9	
Predevelopment Unit Peak Flow, q (cfs/acre) =	N/A	N/A	0.11	0.26	0.33	0.44	0.58	0.80	1.44
Peak Inflow Q (cfs) =	N/A	N/A	9.5	17.2	21.8	28.1	35.4	46.1	110.1
Peak Outflow Q (cfs) =	0.6	20.2	0.6	0.9	1.0	3.0	11.5	21.0	88.1
Ratio Peak Outflow to Predevelopment Q =	N/A	N/A	N/A	0.1	0.1	0.2	0.5	0.7	1.6
Structure Controlling Flow =	Plate	Outlet Plate 1	Plate	Plate	Plate	Overflow Weir 1	Overflow Weir 1	Outlet Plate 1	Spillway
Max Velocity through Grate 1 (fps) =	N/A	1.74	N/A	N/A	N/A	0.2	0.9	1.8	2.0
Max Velocity through Grate 2 (fps) =	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Time to Drain 97% of Inflow Volume (hours) =	39	47	40	47	49	49	47	44	32
Time to Drain 99% of Inflow Volume (hours) =	**43**	54	44	53	56	56	55	53	46
Maximum Ponding Depth (ft) =	2.62	6.32	2.40	4.37	5.15	5.43	5.80	6.62	8.14
Area at Maximum Ponding Depth (acres) =	0.31	0.42	0.30	0.38	0.41	0.41	0.41	0.43	0.55
Maximum Volume Stored (acre-ft) =	0.690	2.088	0.619	1.295	1.601	1.720	1.868	2.211	2.942

DETENTION BASIN OUTLET STRUCTURE DESIGN

MHFD-Detention, Version 4.07 (June 2025)







S-A-V-D Chart Axis Override	X-axis	Left Y-Axis	Right Y-Axis
minimum bound			
maximum bound			

DETENTION BASIN OUTLET STRUCTURE DESIGN

Outflow Hydrograph Workbook Filename:

Inflow Hydrographs

The user can override the calculated inflow hydrographs from this workbook with inflow hydrographs developed in a separate program.

	SOURCE	CUHP	CUHP	USER	USER	USER	USER	USER	USER	CUHP
Time Interval	TIME	WQCV [cfs]	EURV [cfs]	2 Year [cfs]	5 Year [cfs]	10 Year [cfs]	25 Year [cfs]	50 Year [cfs]	100 Year [cfs]	500 Year [cfs]
5.00 min	0:00:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0:05:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0:10:00	0	0.00	0.00	0.10	0.10	0.20	0.30	0.40	0.71
	0:15:00	0	0.00	0.30	0.50	0.80	1.20	1.70	2.20	4.81
	0:20:00	0	0.00	1.60	2.60	3.70	5.60	7.30	9.20	12.74
	0:25:00	0	0.00	3.70	5.90	8.30	12.20	15.80	19.90	33.82
	0:30:00	0	0.00	5.80	9.20	12.80	18.80	24.20	30.30	79.50
	0:35:00	0	0.00	7.80	12.50	17.10	24.50	31.30	39.30	105.52
	0:40:00	0	0.00	9.10	14.90	20.00	27.50	35.00	44.50	110.09
	0:45:00	0	0.00	9.50	16.40	21.50	28.10	35.40	46.10	105.63
	0:50:00	0	0.00	9.30	17.10	21.80	26.70	33.50	45.10	98.75
	0:55:00	0	0.00	8.70	17.20	21.40	24.10	30.00	42.30	90.85
	1:00:00	0	0.00	7.90	16.90	20.40	21.00	25.90	38.60	83.92
	1:05:00	0	0.00	6.90	16.20	19.00	18.00	22.00	34.70	77.67
	1:10:00	0	0.00	6.00	14.80	17.10	15.10	18.30	30.20	68.14
	1:15:00	0	0.00	5.00	13.00	14.80	12.40	15.00	25.60	58.94
	1:20:00	0	0.00	4.10	10.90	12.30	9.90	11.90	20.90	50.87
	1:25:00	0	0.00	3.20	8.80	9.80	7.80	9.30	16.60	44.08
	1:30:00	0	0.00	2.50	6.90	7.60	6.00	7.20	12.80	38.22
	1:35:00	0	0.00	1.90	5.20	5.80	4.50	5.40	9.60	33.07
	1:40:00	0	0.00	1.40	3.90	4.30	3.30	4.00	7.10	28.33
	1:45:00	0	0.00	1.10	2.90	3.20	2.50	3.00	5.30	23.92
	1:50:00	0	0.00	0.80	2.10	2.40	1.90	2.20	3.90	19.88
	1:55:00	0	0.00	0.60	1.60	1.80	1.40	1.70	2.90	16.37
	2:00:00	0	0.00	0.40	1.20	1.30	1.10	1.30	2.20	13.65
	2:05:00	0	0.00	0.30	0.90	1.00	0.80	1.00	1.70	10.87
	2:10:00	0	0.00	0.30	0.70	0.80	0.60	0.70	1.20	8.43
	2:15:00	0	0.00	0.20	0.50	0.60	0.40	0.50	0.90	6.47
	2:20:00	0	0.00	0.10	0.40	0.40	0.30	0.40	0.70	4.96
	2:25:00	0	0.00	0.10	0.30	0.30	0.20	0.30	0.50	3.78
	2:30:00	0	0.00	0.10	0.20	0.20	0.20	0.20	0.40	2.86
	2:35:00	0	0.00	0.10	0.20	0.20	0.10	0.20	0.30	2.16
	2:40:00	0	0.00	0.00	0.10	0.10	0.10	0.10	0.20	1.66
	2:45:00	0	0.00	0.00	0.10	0.10	0.10	0.10	0.20	1.29
	2:50:00	0	0.00	0.00	0.10	0.10	0.10	0.10	0.10	1.02
	2:55:00	0	0.00	0.00	0.10	0.10	0.00	0.10	0.10	0.79
	3:00:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.58
	3:05:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41
	3:10:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27
	3:15:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15
	3:20:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07
	3:25:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
	3:30:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:35:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:40:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:45:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:50:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:55:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:00:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:05:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:10:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:15:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:20:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:25:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:30:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:35:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:40:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:45:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:50:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:55:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:00:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:05:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:10:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:15:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:20:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:25:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:30:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:35:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:40:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:45:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:50:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:55:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	6:00:00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

DETENTION BASIN OUTLET STRUCTURE DESIGN

MHFD-Detention, Version 4.07 (June 2025)

Summary Stage-Area-Volume-Discharge Relationships

The user can create a summary S-A-V-D by entering the desired stage increments and the remainder of the table will populate automatically.

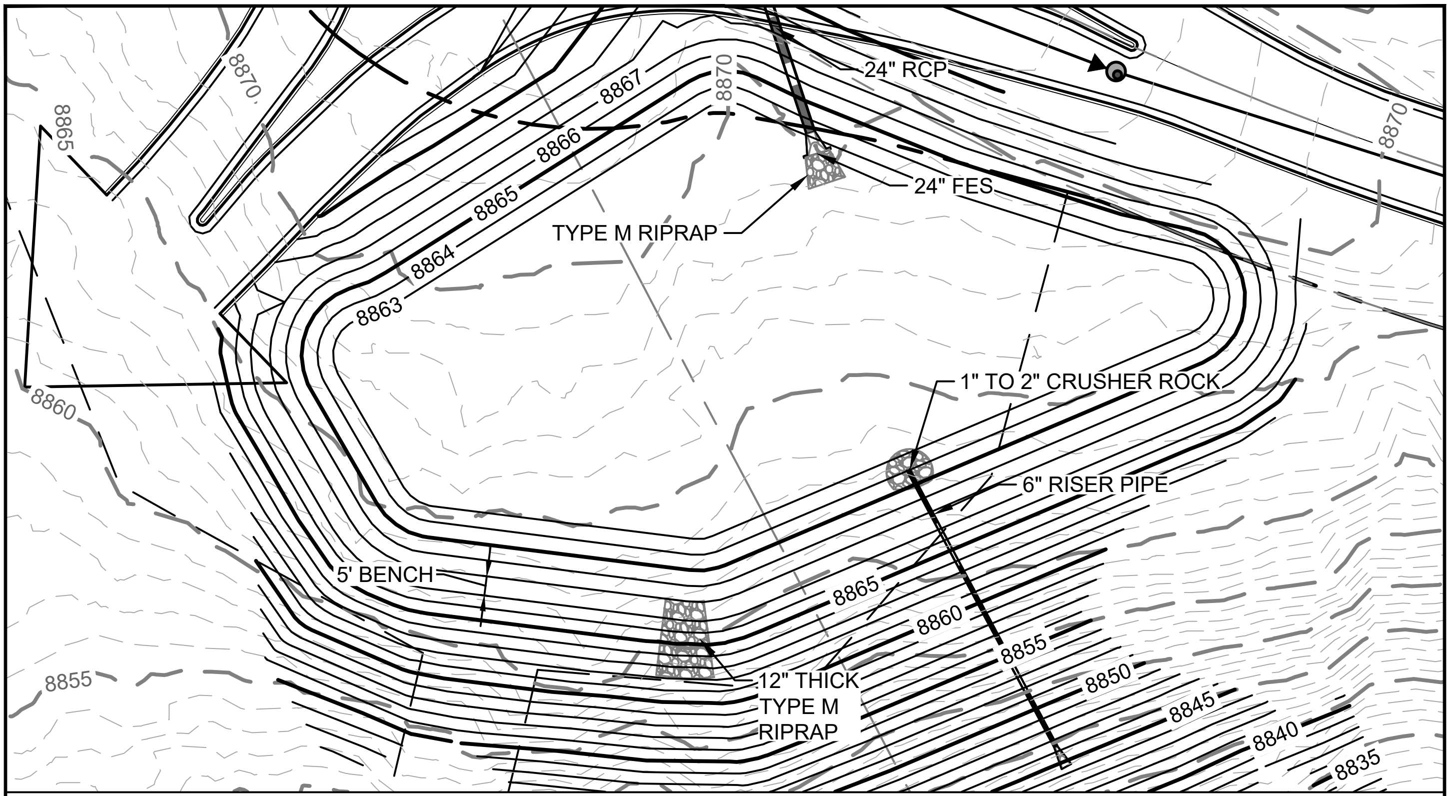
The user should graphically compare the summary S-A-V-D table to the full S-A-V-D table in the chart to confirm it captures all key transition points.

Stage - Storage Description	Stage [ft]	Elevation [ft]	Area [ft ^{2}]	Area [acres]	Volume [ft ^{3}]	Volume [ac-ft]	Total Outflow [cfs]
Orifice 1	0.00	8786.00	9450	0.217	0	0.000	0.00
	0.25	8786.25	9828	0.226	2410	0.055	0.08
	0.50	8786.50	10205	0.234	4914	0.113	0.12
	0.75	8786.75	10583	0.243	7512	0.172	0.14
Orifice 2	1.00	8787.00	10960	0.252	10205	0.234	0.16
	1.25	8787.25	11355	0.261	12994	0.298	0.27
	1.50	8787.50	11751	0.270	15883	0.365	0.32
	1.75	8787.75	12146	0.279	18870	0.433	0.36
Orifice 3	2.00	8788.00	12541	0.288	21955	0.504	0.40
	2.25	8788.25	12957	0.297	25143	0.577	0.51
	2.50	8788.50	13372	0.307	28434	0.653	0.58
	2.75	8788.75	13788	0.317	31829	0.731	0.63
	3.00	8789.00	14203	0.326	35327	0.811	0.68
	3.25	8789.25	14639	0.336	38933	0.894	0.72
	3.50	8789.50	15075	0.346	42647	0.979	0.77
	3.75	8789.75	15511	0.356	46470	1.067	0.81
	4.00	8790.00	15947	0.366	50402	1.157	0.84
	4.25	8790.25	16403	0.377	54446	1.250	0.88
	4.50	8790.50	16860	0.387	58604	1.345	0.91
	4.75	8790.75	17316	0.398	62876	1.443	0.95
	5.00	8791.00	17773	0.408	67262	1.544	0.98
Overflow Weir Rim Elevation	5.25	8791.25	17830	0.409	71713	1.646	1.01
	5.50	8791.50	17887	0.411	76177	1.749	4.26
	5.75	8791.75	17943	0.412	80656	1.852	10.18
	6.00	8792.00	18000	0.413	85149	1.955	17.84
	6.25	8792.25	18250	0.419	89680	2.059	20.40
	6.50	8792.50	18500	0.425	94274	2.164	20.84
	6.75	8792.75	18750	0.430	98930	2.271	21.27
Spillway Invert	6.82	8792.82	18820	0.432	100245	2.301	21.39
	7.00	8793.00	19000	0.436	103649	2.379	24.12
	7.25	8793.25	20189	0.463	108548	2.492	31.73
	7.50	8793.50	21379	0.491	113744	2.611	42.99
	7.75	8793.75	22568	0.518	119237	2.737	57.82
	8.00	8794.00	23758	0.545	125028	2.870	76.28
	8.25	8794.25	24306	0.558	131036	3.008	98.46
	8.50	8794.50	24854	0.571	137181	3.149	124.51
	8.75	8794.75	25402	0.583	143463	3.293	154.55
	9.00	8795.00	25950	0.596	149882	3.441	188.73

For best results, include the stages of all grade slope changes (e.g. ISV and Floor) from the S-A-V table on Sheet 'Basin'.

Also include the inverts of all outlets (e.g. vertical orifice, overflow grate, and spillway, where applicable).

12/1/2025 4:35 PM ; X:\GRAND PARK\DOCUMENTS\REPORTS\DRAINAGE\16.1 - FILING 1 - 8WB, 9W, 10W, 11W\PHASE 2\C - POND & WQ CALCS\TEMP SEDIMENT POND EXHIBIT.DWG;



TEMP SED POND VOLUME CALCULATION PER MHFD DETAIL SC-7

Basins	Developed?	Area (AC)	Imperviousness	Additional Volume per Table SB-1 (CF/AC)	Volume Req. (CF)
C	Y	1.71	16.9%	1230	2103
C1	Y	2.92	39.1%	2030	5928
C2	Y	7.57	36.8%	2030	15367
Total Developed Area		12.2	-	3600	43920
				TOTAL REQUIRED VOLUME	67318

STAGE STORAGE TABLE

ELEV	AREA (sq. ft.)	DEPTH (ft)	AVG END INC. VOL. (cu. ft.)	AVG END TOTAL VOL. (cu. ft.)	CONIC INC. VOL. (cu. ft.)	CONIC TOTAL VOL. (cu. ft.)
8,863.00	15,310.80	N/A	N/A	0.00	N/A	0.00
8,864.00	17,546.28	1.00	16428.54	16428.54	16415.85	16415.85
8,865.00	19,887.36	1.00	18716.82	35145.36	18704.61	35120.46
8,866.00	22,334.08	1.00	21110.72	56256.09	21098.90	56219.36
8,867.00	24,886.35	1.00	23610.22	79866.30	23598.71	79818.07

terracina
design
10200 E. Girard Ave, A-314
Denver, CO 80231
ph: 303.632.8867

WEST MOUNTAIN
FILING 1
TEMP SED POND EXHIBIT

TOWN OF FRASER
DATE: 2025-12-01

0
50'
1" = 50'

N

Project Name: **West Mountain - Filing 1 - Proposed**
Prepared By: **JNS**

Temporary Sediment Basin - Pond C - Riser Pipe Stage-Storage Discharge Calculations

Pond C - Pond Volume Calculations							Cicular Orifice 1		Cicular Orifice 2		Cicular Orifice 3		Cicular Orifice 4		Cicular Orifice 5		Riser Pipe Opening		Spillway		Total Flow
							Cd =	0.6	Cd =	0.6	Cd =	0.6	Cd =	0.6	Cd =	0.6	Cd =	0.6			
							Diameter (in) =	1.5	Diameter (in) =	1.5	Diameter (in) =	1.5	Diameter (in) =	1.5	Diameter (in) =	1.5	Diameter (in) =	8			
							CL =	8870.62	CL =	8870.95	CL =	8871.28	CL =	8871.61	CL =	8871.94	CL =	8872.00	Cbcw =	3	
							FL =	8870.58	FL =	8870.91	FL =	8871.24	FL =	8871.57	FL =	8871.9	FL =	8872	Z =	3	
Elev	Notes	Area		Volume			A(sf) =	0.00616	A(sf) =	0.00616	A(sf) =	0.00616	A(sf) =	0.00616	A(sf) =	0.00616	A(sf) =	0.196349541	Invert =	8872	
				Incr.	Total	Total	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	Q
		[SF]	[AC]	[CF]	[CF]	[AC-FT]	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(cfs)
8869.00		12764	0.2930	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8869.25		13315	0.3057	3260	3260	0.0748	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8869.50		13865	0.3183	3398	6657	0.1528	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8869.75		14416	0.3309	3535	10193	0.2340	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8870.00		14966	0.3436	3673	13865	0.3183	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8870.25		15542	0.3568	3814	17679	0.4058	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8870.50		16117	0.3700	3957	21636	0.4967	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8870.58	Orifice 1	16301	0.3742	1297	22933	0.5265	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8870.75		16693	0.3832	2804	25737	0.5908	0.13	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
8870.91	Orifice 2	17061	0.3917	2700	28438	0.6528	0.29	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
8871.00		17268	0.3964	1545	29982	0.6883	0.38	0.02	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
8871.24	Orifice 3	17844	0.4096	4213	34196	0.7850	0.62	0.02	0.29	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
8871.25		17869	0.4102	179	34374	0.7891	0.63	0.02	0.30	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
8871.50		18469	0.4240	4542	38917	0.8934	0.88	0.03	0.55	0.02	0.22	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06
8871.57	Orifice 4	18637	0.4278	1299	40215	0.9232	0.95	0.03	0.62	0.02	0.29	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07
8871.75		19070	0.4378	3394	43609	1.0011	1.13	0.03	0.80	0.03	0.47	0.02	0.14	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.09
8871.90	Orifice 5	19430	0.4461	2887	46497	1.0674	1.28	0.03	0.95	0.03	0.62	0.02	0.29	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.10
8872.00	Riser Pipe Opening/Spillway Invert	19670	0.4516	1955	48452	1.1123	1.38	0.03	1.05	0.03	0.72	0.03	0.39	0.02	0.06	0.01	0.00	0.00	0.00	0.00	0.12
8872.25		20296	0.4659	4996	53447	1.2270	1.63	0.04	1.30	0.03	0.97	0.03	0.64	0.02	0.31	0.02	0.25	0.47	0.25	0.11	0.73
8872.50		20921	0.4803	5152	58599	1.3453	1.88	0.04	1.55	0.04	1.22	0.03	0.89	0.03	0.56	0.02	0.50	0.67	0.50	0.64	1.47
8872.75		21547	0.4947	5309	63908	1.4671	2.13	0.04	1.80	0.04	1.47	0.04	1.14	0.03	0.81	0.03	0.75	0.82	0.75	1.75	2.75
8873.00		22173	0.5090	5465	69372.93	1.5926	2.38	0.05	2.05	0.04	1.72	0.04	1.39	0.03	1.06	0.03	1.00	0.95	1.00	3.60	4.74

APPENDIX D

REFERENCES

Storm Drainage Master Plan for Grand Park by High Country Engineering, Inc. Dated February 17, 2006.

A Pragmatic Slope-Adjusted Curve Number Model to Reduce Uncertainty in Predicting Flood Runoff from Steep Watersheds. Ajmal, Wassem, Kim, & Kim. 2020.

Sediment Basin Details from MHFD's *Urban Storm Drainage Criteria Manual vol. 3*, 2010 (Revised March 2024), pp. 486-492.

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

CIVIL ENGINEERING AND SURVEYING
An Employee Owned Company

EXCERPTS FROM

STORM DRAINAGE MASTER PLAN

FOR

GRAND PARK

FRASER, COLORADO

October 10, 2005
Revised February 17, 2006

PREPARED FOR:

Cornerstone Winter Park Holdings, LLC

HCE JOB NO. 2052014.00

Prepared by:

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2/17/06

Excerpt from High Country Engineering Final
Drainage Report for Town Center at Grand Park

TABLE OF CONTENTS

SECTION PAGE

1.0 EXECUTIVE SUMMARY 2
2.0 INTRODUCTION 4
  2.1 GENERAL 4
  2.2 PURPOSE 4
  2.3 MASTER PLAN – GENERAL 4
  2.4 PROPOSED LAND USE 5
3.0 HYDROLOGY / HYDRAULIC ANALYSIS 7
  3.1 GENERAL 7
  3.2 DESIGN RAINFALL 7
  3.3 BASIN CHARACTERISTICS 7
  3.4 CURVE NUMBER "CN" 8
  3.5 EXISTING FACILITIES 8
4.0 PROPOSED DRAINAGE IMPROVEMENTS 11
  4.1 GENERAL 11
  4.2 DESIGN BASIS 13
  4.3 MINOR DRAINAGE SYSTEMS 14
  4.4 PHASING OF IMPROVEMENTS 14
  4.5 FEMA FIRM MAPPING 14
5.0 REFERENCES 16

LIST OF FIGURES
  FIGURE 1 VICINITY MAP 3
  FIGURE 2 SCS SURVEY 9
  FIGURE 3 EXISTING DRAINAGE MAP 10
  FIGURE 4 PROPOSED DRAINAGE BASIN MAP 12
  FIGURE 5 FIRM MAP 15

APPENDIX A: HYDROLOGIC INPUT

APPENDIX B: HYDROLOGIC OUTPUT

APPENDIX C: CULVERT CALCULATIONS

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

1.0 EXECUTIVE SUMMARY

The "Grand Park Storm Drainage Master Plan" was prepared for Cornerstone Winterpark Holdings LLC. The purpose of this report is to identify regional drainage facilities required to safely convey the developed storm events, up to the 100 year storm, to the historic receiving basins while improving the water quality of the developed flows prior to discharging to the receiving streams. These facilities will consist of regional detention ponds / water quality facilities to reduce the developed flow rates to historic rates and recommendations for proposed culverts and channels.

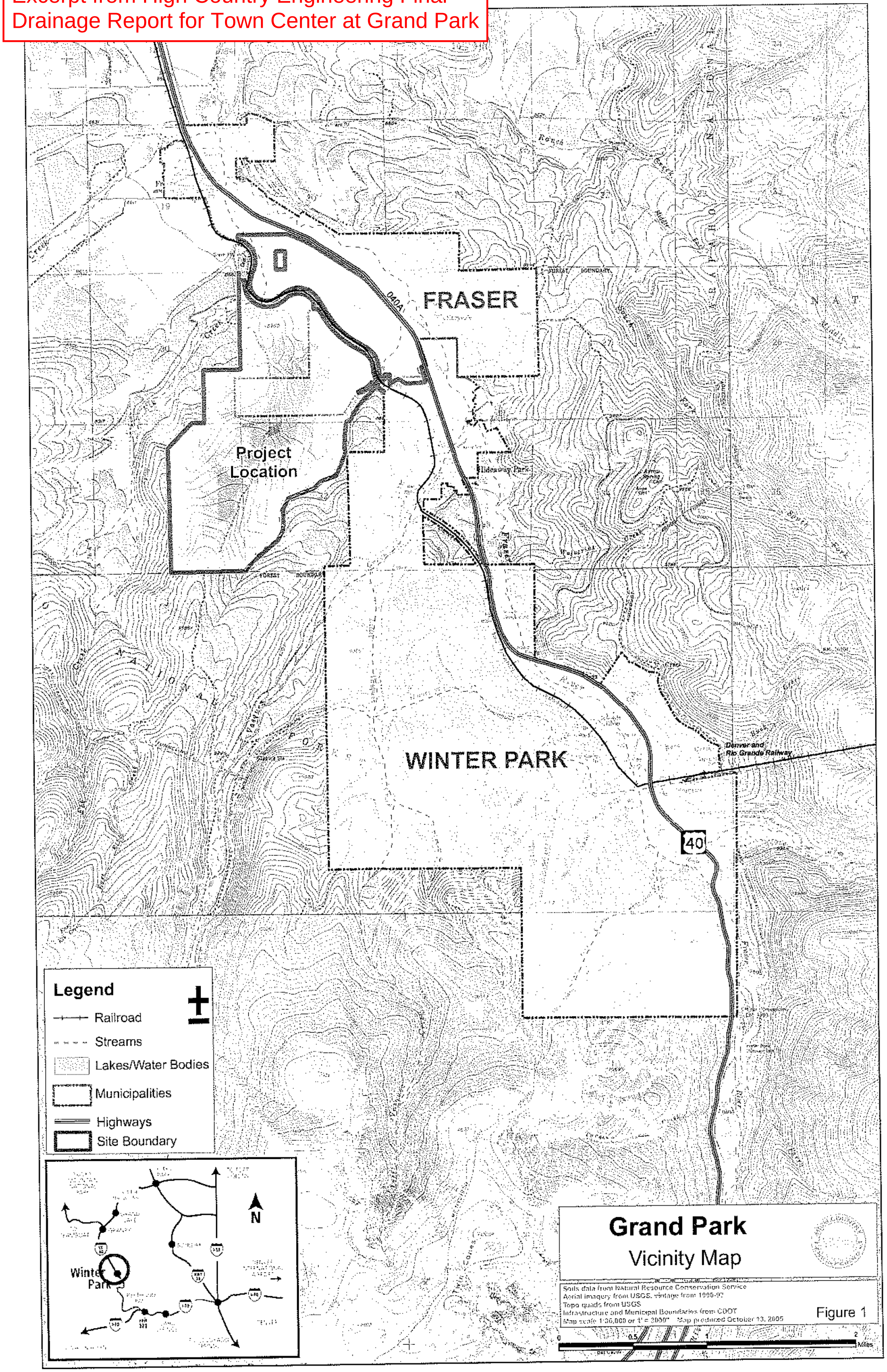
The results of this study are: identifying the historic and developed drainage basin boundaries, determining the respective 2 year and 100 year stormwater flow rates and volumes, determining sizing of the detention facilities to reduce the peak flow rates, and providing designs for water quality features to be incorporated in the regional facilities and proposed developments. Structural and non-structural water quality enhancement measures were incorporated based on the guidelines provided in the Urban Drainage Criteria Manual, Volume III.

The overall drainage of the Grand Park area has been divided into two major subareas: drainage to Elk Creek and drainage to Leland Creek; see Figure 1. The land generally flows from the south toward the Denver and Rio Grande Railroad and ultimate discharge to the Fraser River.

Under the existing conditions, the Denver and Rio Grande Railroad embankment attenuates stormwater flows prior to discharging to the Fraser Draw. There are three existing culverts located under the Denver and Rio Grande Railroad within the project limits: one on the east side for Elk Creek, one in the middle of the development for a no-name drainage way, and a third on the east side for Leland Creek. The Leland Creek and Fraser River are a part of a FEMA designated floodplain. This report does not address any potential FEMA CLOMR applications.

For proposed conditions, the existing culverts will be used to convey flows under the Railroad, from the regional detention ponds located south of the railroad to the plateau between US 40 and the Railroad. The plateau area contains wetland areas that will not be disturbed with the proposed development. At this time, no pipe borings under the railroad or US 40 are being proposed. Discharge from the development, in general, will be to the north toward the Fraser River. Conveyance of stormwater will be accommodated via a combination of storm drainage pipes, grass-lined swales, regional detention facilities, and potentially check dams and drop structures. Water quality enhancement features will be incorporated into the design of the swales and detention facilities. These facilities will be constructed to accommodate up to the 100 year developed flows.

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park



Grand Park

Vicinity Map

Soils data from Natural Resource Conservation Service
Aerial imagery from USGS, vintage from 1996-97
Topo quads from USGS
Infrastructure and Municipal Boundaries from CDOT
Map scale 1:36,000 or 1" = 3000"   Map produced October 13, 2005

Figure 1

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

2.0 INTRODUCTION

2.1 GENERAL

The Grand Park Storm Drainage Master Plan has been prepared to provide an overall guide to the management of stormwater associated with the proposed development of Grand Park and tributary drainage areas. This Master Plan is a dynamic document and should be revised periodically to reflect changes from conceptual to actual. The Master Drainage Plan presents the results of hydrologic and hydraulic analyses evaluating the effects of the proposed development on the historic runoff patterns, based on current available information. Grand County Storm Drainage Design Criteria and the Urban Drainage and Flood Control District criteria were utilized for the development of this report.

The Grand Park subdivision is located in Grand County, and is approximately 1,311-acres of land. Grand Park is located in Sections 20, 28, 29, 30, 31, 32, Township 1 South, Range 75 West of the Sixth Principal Meridian, Town of Fraser, Grand County, Colorado. The proposed development is a Planned Unit Development consisting of a wide range of single family, multi-family, commercial, lodging, and open space uses.

2.2 PURPOSE

The purpose of this study is to prepare a master drainage study for the Grand Park development area. The Master Plan includes:

1. Development and evaluation of the results of a hydrologic model for the basins.
2. Determine the sizes of major culverts, and detention structures.
3. Establish design criteria for water quality treatment and stormwater management.

2.3 MASTER PLAN – GENERAL

Due to the substantial size of Grand Park, long-term planning for the phased development of Grand Park is essential. Paramount to the planning is the phased development of the infrastructure necessary to serve Grand Park.

It was anticipated that the planning for infrastructure to service Grand Park would be done in three stages: 1. Master Plans, 2. Preliminary Plans, 3. Final Subdivision Platting.

1. Master Plans. The first stage of planning is to be comprised of the development and approval of the "Storm Drainage Master Plan" for Grand Park. The Master Plan is intended to serve as conceptual preliminary long-term planning and forecasting document, and may be updated, from time to time, as development actually occurs. It is anticipated that the Storm

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

Drainage Master Plan would address the necessary regional storm drainage facilities for Grand Park.

2. Preliminary Plans. The second stage of planning is to consist of the development and approval of Preliminary Plans for the individual phases of Grand Park.

In preparing Phased Preliminary Plans, if upstream development occurs prior to the construction of downstream storm drainage improvements, it is contemplated that the upstream property will cause to be constructed necessary downstream storm drainage improvements as reflected in this Storm Drainage Master Plan. As all property in Grand Park is developed, the property will be required to establish or set aside such land areas as may be necessary to accomplish upstream and downstream drainage and water quality mitigation, in general accordance with this Storm Drainage Master Plan.

The precise boundaries of the basins are subject to modification as more accurate topographic information becomes available, or as the subject land is graded for final development. Lands located in one basin as reflected in the Proposed Drainage Basin Map (Figure 5) may be later graded to drain into a different basin, provided appropriate measures are taken to accommodate such modifications. The grading and basin utilization patterns of a particular parcel of land shall be set forth in the Phased Preliminary Plan(s) and Final plat(s) affecting the parcel of land.

Each Phased Preliminary Plan shall set forth the development assumptions under which it was prepared (regarding land uses and densities) and will address: the impact of the development of the Phased Area on other Phase Areas already developed or approved; (2) the estimated timing of the improvements to be installed; and (3) phasing of improvements

3. Final Subdivision Platting. The third and final stage of planning is to be comprised of the development and approval of plats. The platting process shall be conducted consistent with the then-existing City ordinances, rules, regulations and guidelines for platting, amended, as appropriate, by any applicable Annexation Agreements affecting the land to be platted.

2.4 PROPOSED LAND USE

The land usage is outlined in the Grand Park Planned Unit Development Master Land Use Plan. A list of the land usage by area is presented in Table 1.

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

Table 1. Master Plan Areas

Designation	Type	Density (Units per Acre)
1Wa	Multi-family Attached, Lodging Units, Commercial	7.6 units / acre
1Wb	Multi- Family Attached	6.8 units / acre
2W	Single Family, Multi-family Attached, Lodging Units, Commercial	7.6 units / acre
3Wa	Multi- Family Attached	13.1 units / acre
3Wb	Single Family, Multi-family Attached	4.7 units / acre
3Wc	Multi-family Attached, Commercial	5.2 units / acre
4W	Multi-family Attached, Commercial	9.3 units / acre
5W	Single Family, Multi-family Attached	4.5 units / acre
6W	Public Site	
7W	Single Family, Multi-family Attached	8.1 units / acre
8Wa	Single Family, Multi-family Attached	2.0 units / acre
8Wb	Multi- Family Attached	2.2 units / acre
9W	Single Family, Multi-family Attached, Lodging Units, Commercial	4.7 units / acre
10W	Single Family, Multi-family Attached, Lodging Units, Commercial	4.7 units / acre
11W	Single Family, Multi-family Attached, Lodging Units	2.6 units / acre
12W	Multi-family Attached, Lodging Units	3.5 units / acre
13Wa	Single family	1.4 units / acre
13Wb	Single family	0.6 units / acre
14W	Single family	1.5 units / acre
15W	Single family	0.5 units / acre
16W	Single family	1.0 units / acre
17W	Single family	0.5 units / acre
18W	Single family	2.5 units / acre
19W	Single Family, Multi-family Attached	3.1 units / acre
20W	Single Family, Multi-family Attached	2.1 units / acre
21W	Single Family, Multi-family Attached	5.1 units / acre

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

3.0 HYDROLOGY / HYDRAULIC ANALYSIS

3.1 GENERAL

A hydrologic analysis was performed on the study area to define the peak runoff flows and volumes for the 2- and 100-year, 24 hour design storm frequencies. The peak flow information obtained from the analysis was used to evaluate existing drainage facilities, identify potential drainage problems, and to design drainage improvements.

The computer program HEC-HMS was used to determine runoff quantities for each basin. Runoff hydrographs were developed for each basin. The basin parameter required for HEC-HMS input include:

- Area,
- Flow length,
- Slope,
- Time of Concentration / Lag Time,
- Percent Impervious,
- Runoff coefficient
- Rainfall Hyetograph.

Appendix A provides the parameters used in the existing and proposed conditions in the HEC-HMS model.

3.2 DESIGN RAINFALL

Rainfall depths for each storm frequency were taken from the NOAA Atlas:

Table 2. Storm Duration Precipitation Depths

2 Year – 6 Hour	0.98 inch
2 Year – 24 Hour	1.32 inches
100 Year – 6 Hour	2.17 inches
100 Year – 24 Hour	2.98 inches

3.3 BASIN CHARACTERISTICS

The amount of impervious area within each basin was estimated for existing and future development conditions. These values are presented in Appendix A. Impervious percentages were calculated using values from Volume I of the Urban Drainage and Flood Control District Criteria Manual (2001). The soils types within the onsite and offsite drainage basins consist of:

Cowdrey Loam (15 – 45% slope)	Hydrologic Group: C
Cumilic Cryaquolis	Hydrologic Group: D

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

Frisco Peeler Gravelly Sandy Loam (2 – 6%)	Hydrologic Group: B
Frisco Peeler Gravelly Sandy Loam (6 – 25%)	Hydrologic Group: B
Frisco Peeler Gravelly Sandy Loam (25 – 65%)	Hydrologic Group: B
Scott Cobbly Sandy Loam (15 – 65%)	Hydrologic Group: B
Tine Gravelly Sandy Loam (0 – 3%)	Hydrologic Group: A

The basin soil type is predominantly representative of Soils Group B in accordance with the National Resources Conservation Service (NRCS) soils classifications. See Figure 2 – Soils Survey.

3.4 CURVE NUMBER "CN"

The National Resources Conservation Service (SCS Method) was used in this study to approximate peak runoff. The curve number is based on the soils type, the land usage and the vegetative cover.

3.5 EXISTING FACILITIES

Denver and Rio Grande Culvert Crossing Analysis

Based on the results of field observations by High Country Engineering, Inc., three major culvert crossings under the Denver and Rio Grande Railroad were identified. These major crossings are Design Point 4 – Elk Creek, Design Point 6 – No name drainage, Design Point 9 – Leland Creek. A summary of their hydraulic properties is presented below.

Design Point	Description	2 yr – 24 hr Existing Flow (cfs)	100 yr – 24 hr Existing Flow (cfs)
4	Elk Creek at Railroad	2.4	39.6
6	No name drainage at Railroad	0.75	19.3
9	Leland Creek at Railroad	9.2	182
8	Elk Creek at US 40	6.9	145
7	No name drainage at US 40	2.9	50.5
11	Leland Creek at US 40	9.5	189

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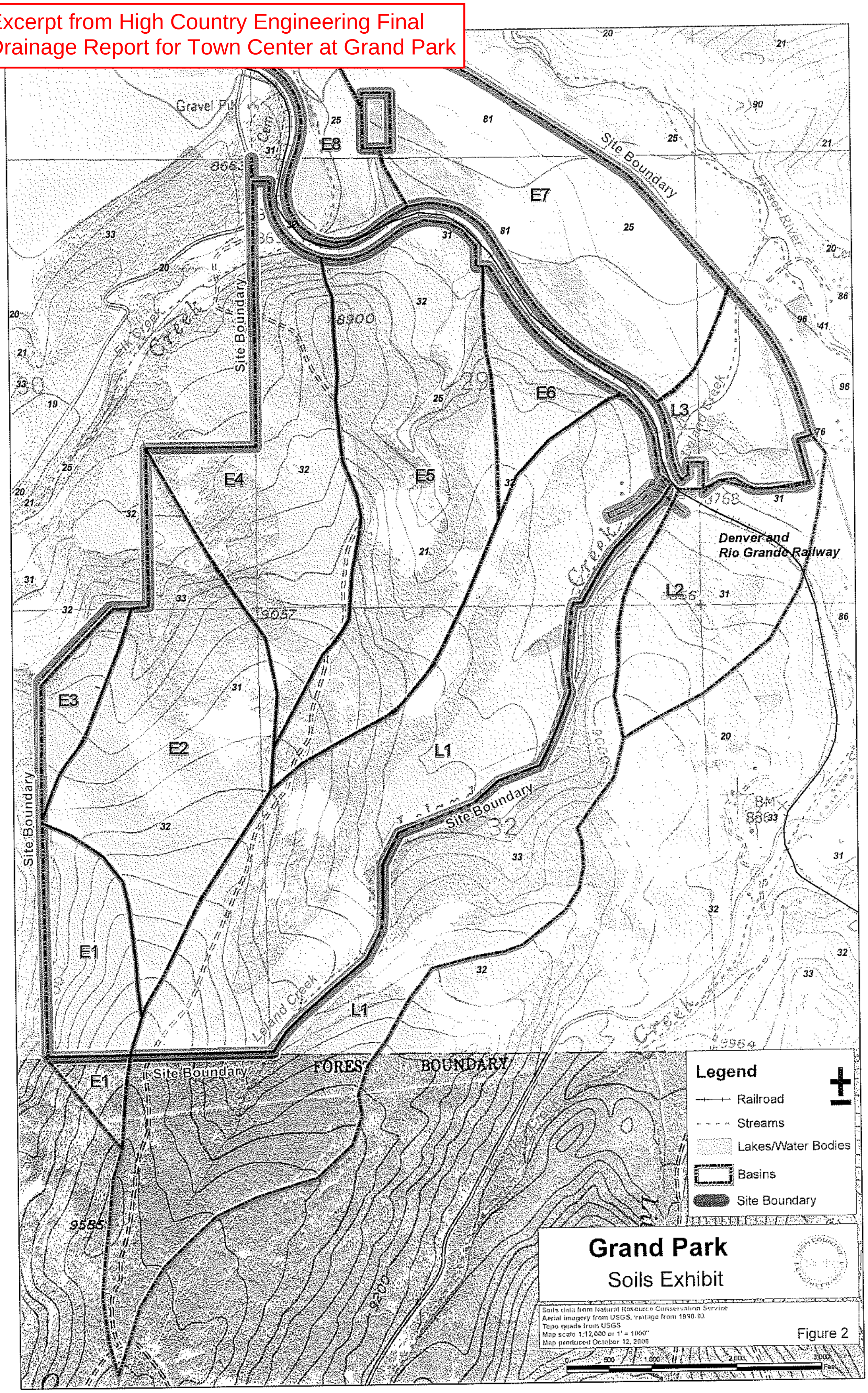


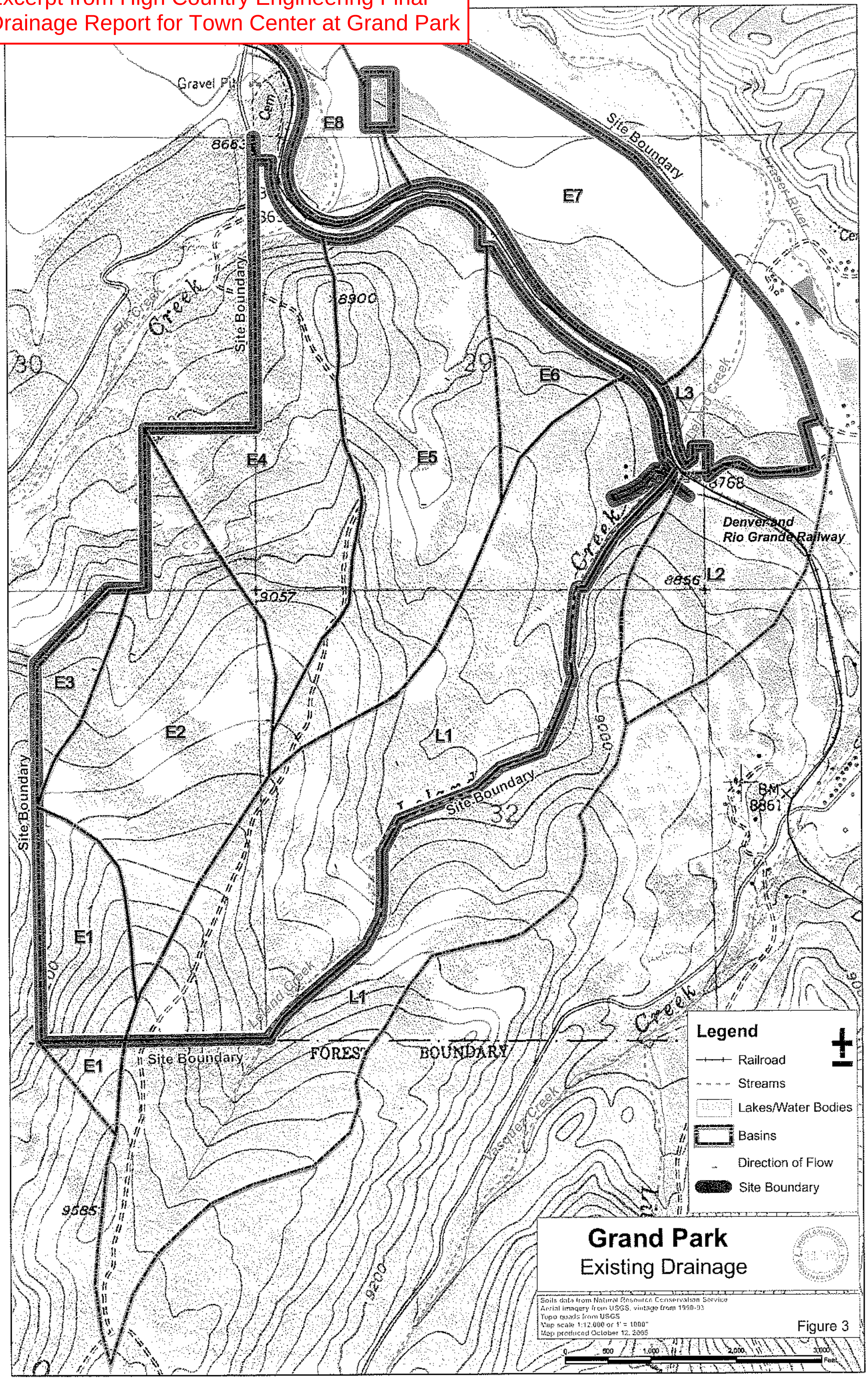
Grand Park

Soils Exhibit

Soils data from Natural Resource Conservation Service
Aerial imagery from USGS, vintage from 1990-93
Topo quads from USGS
Map scale 1:12,000 or 1' = 1000'
Map produced October 12, 2005

Figure 2

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

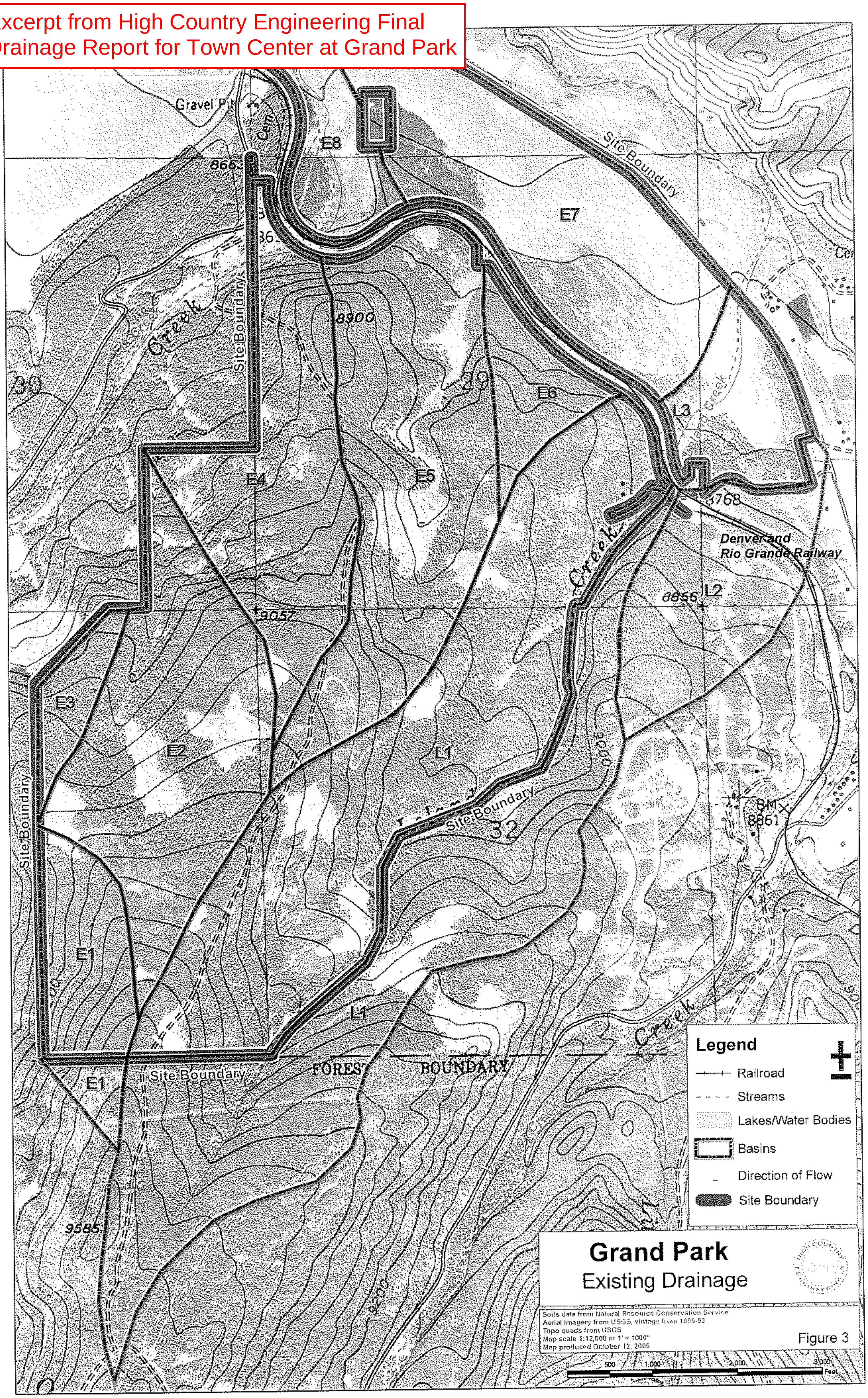


Grand Park
Existing Drainage

Soils data from Natural Resource Conservation Service
Aerial imagery from USGS, vintage from 1990-93
Topo quads from USGS
Map scale 1:12,000 or 1" = 1000"
Map produced October 12, 2005

Figure 3

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park



Grand Park

Existing Drainage

Soils data from Natural Resource Conservation Service
Aerial imagery from USGS, vintage from 1990-93
Topo quads from USGS
Map scale 1:12,000 or 1' = 1000"
Map produced October 12, 2005

Figure 3

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

These culvert crossings are constructed with reinforced concrete pipe or corrugated metal pipe. The capacity of these culverts was determined using the top of the rail elevation and also at three feet below the top of rail (bottom of ballast elevation). Capacity analysis of the major stormwater culverts was performed using Autocad Hydrology, which utilizes the FHWA's HY-8 program. The software uses headwater elevation, tailwater elevation and pipe friction for capacity analysis. The results are shown in Table 3.

Table 3. Existing Culvert Capacities

Design Point	Size (ft)	Quantity	Invert	Max. Water Surface Elevation	Estimated Capacity (cfs)
Elk Creek	3.5	1	8634	8652.75	196
No name	4.0	1	8692.7	8698.8	56.5
Leland Creek	4.0	1	8760.0	8765.0	237.2

4.0 PROPOSED DRAINAGE IMPROVEMENTS

4.1 GENERAL

Proposed drainage improvements were developed for each drainage basin, utilizing Grand County Storm Drainage Criteria and Urban Drainage and Flood Control District's criteria.

This study did not attempt to forecast lot-specific drainage improvements, but limited itself to the overall stormwater management of each drainage basin.

The proposed drainage improvements were evaluated based on the stormwater routing results and consists of the following:

1. Grass-lined swales and stormwater conveyance channels,

2. Local and regional detention facilities,

3. Culvert crossings (reinforced concrete pipes and box culverts).

Grass-lined swales and channels will be used to convey flows to detention facilities. Storm runoff will be detained in detention facilities for all storm frequencies up to and including the 100-year event. The size and discharge from these detention facilities will be determined based on the capacities of downstream drainage facilities and land availability. Improved channels with drop structures and check dams will be sized to convey the peak 100 year discharges based on fully developed conditions or detained flows, as applicable. The 100 year detention volumes were

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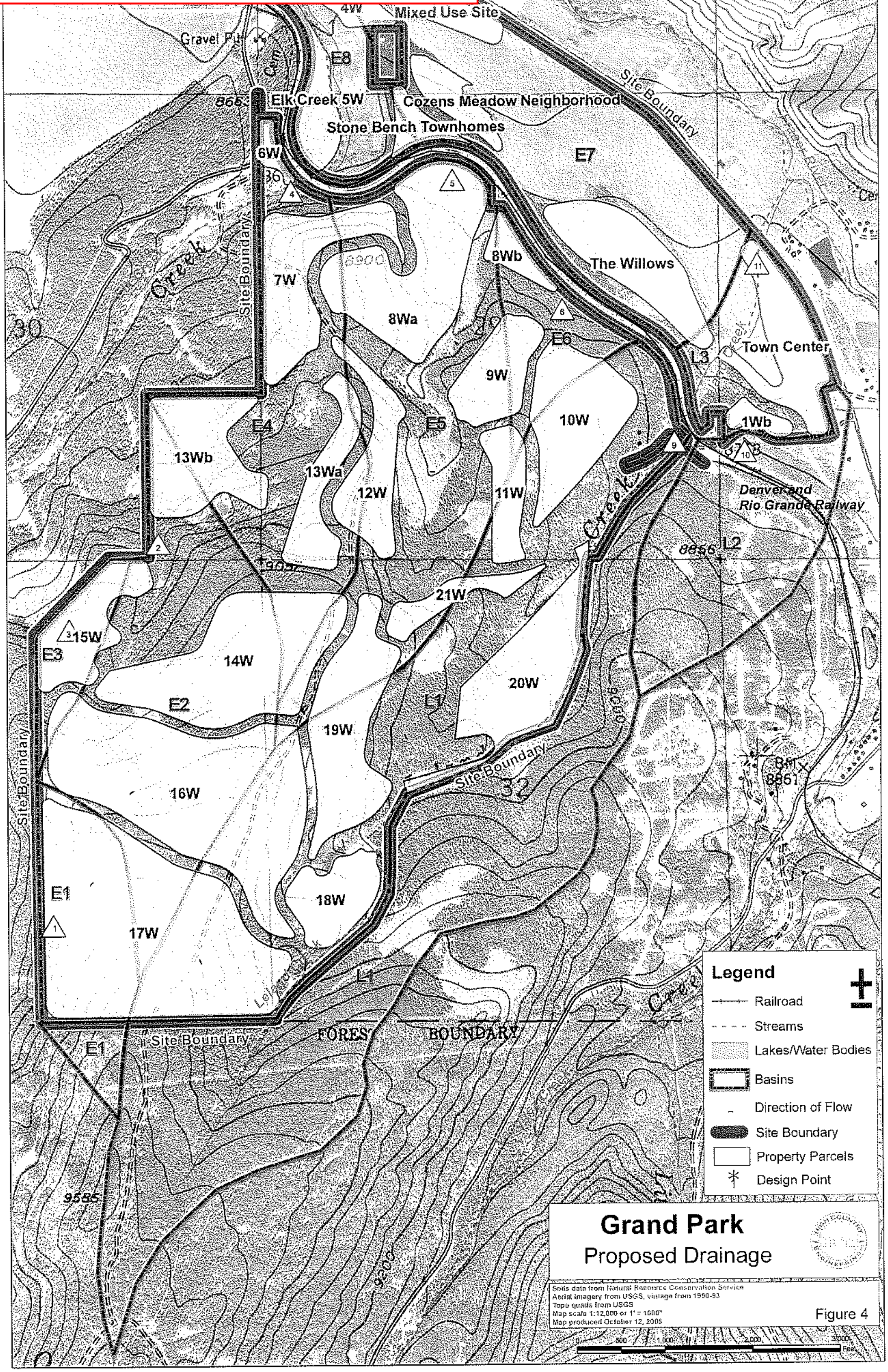


Grand Park

Proposed Drainage

Soils data from Natural Resource Conservation Service
Aerial imagery from USGS, vintage from 1990-93
Topo grads from USGS
Map scale 1:12,000 or 1" = 1000'
Map produced October 12, 2005

Figure 4

Excerpt from High Country Engineering Final
Drainage Report for Town Center at Grand Park

calculated using both the SCS Tabular Method and the UDFCD's equation V=K*A. The results of the analysis are included in the Appendix.

The proposed channels will in general, be grass-lined trapezoidal type channels with a variable width bottom and side slopes typically designed at a maximum ratio of three (horizontal) to one (vertical) ratio. The longitudinal slope is adjusted to limit the velocities to a maximum of 5 feet per second during the 100 year event. Some of the large grass-lined channels are proposed to include grade control structures (drop structures) to reduce the amount of earthwork required to construct the channel. Of note, in areas where deep excavations would be required to construct a channel, utilization of storm drain pipe was also considered, to avoid excavating larger areas of land that would be taken up by the side-slopes of the channel excavations.

Below is a summary of developed flows prior to entering the proposed detention facilities:

Design Point	**Description**	**2 yr – 24 hr Proposed Flow (cfs)**	**100 yr – 24 hr Proposed Flow (cfs)**
4	Elk Creek at Railroad	6.2	104
6	No name drainage at Railroad	7.4	56.5
9	Leland Creek at Railroad	8.2	186
8	Elk Creek at US 40	44.1	371
7	No name drainage at US 40	90.4	389
11	Leland Creek at US 40	16.6	197

Water quality enhancement features will be incorporated into the swales, channels, and detention facilities to enhance the water quality resulting from the impacts of future urbanization, on the drainage basins.

1.1 DESIGN BASIS

Preliminary and final design of proposed facilities will be performed in accordance with Town of Fraser's and Grand County's requirements. Detention ponds will incorporate multi-level outlets to control 10-year and 100-year storm events, as well as less frequent events. The applicable Best Management (BMP) of Volume III of the UDFCD Criteria Manual will be used during final design to mitigate potential adverse water quality impacts resulting from development. Detention pond and cell layouts as well as configuration of outlet structures will be established during the Preliminary Design phase, at which time a design report will be prepared presenting development of design concepts. Design reports will include preliminary plans and profiles of channels, storm sewers and culverts.

Excerpt from High Country Engineering Final
Drainage Report for Town Center at Grand Park

Railroad culvert capacities and US 40 capacities or historic discharge rates, which ever is less. Discharges from areas south of US 40 are proposed to be detained discharges to ensure that discharges to off-site areas are at or below historic discharge rates.

4.3 MINOR DRAINAGE SYSTEMS

Minor drainage systems will be designed and implemented in accordance with this study during the platting phase of development throughout Grand Park.

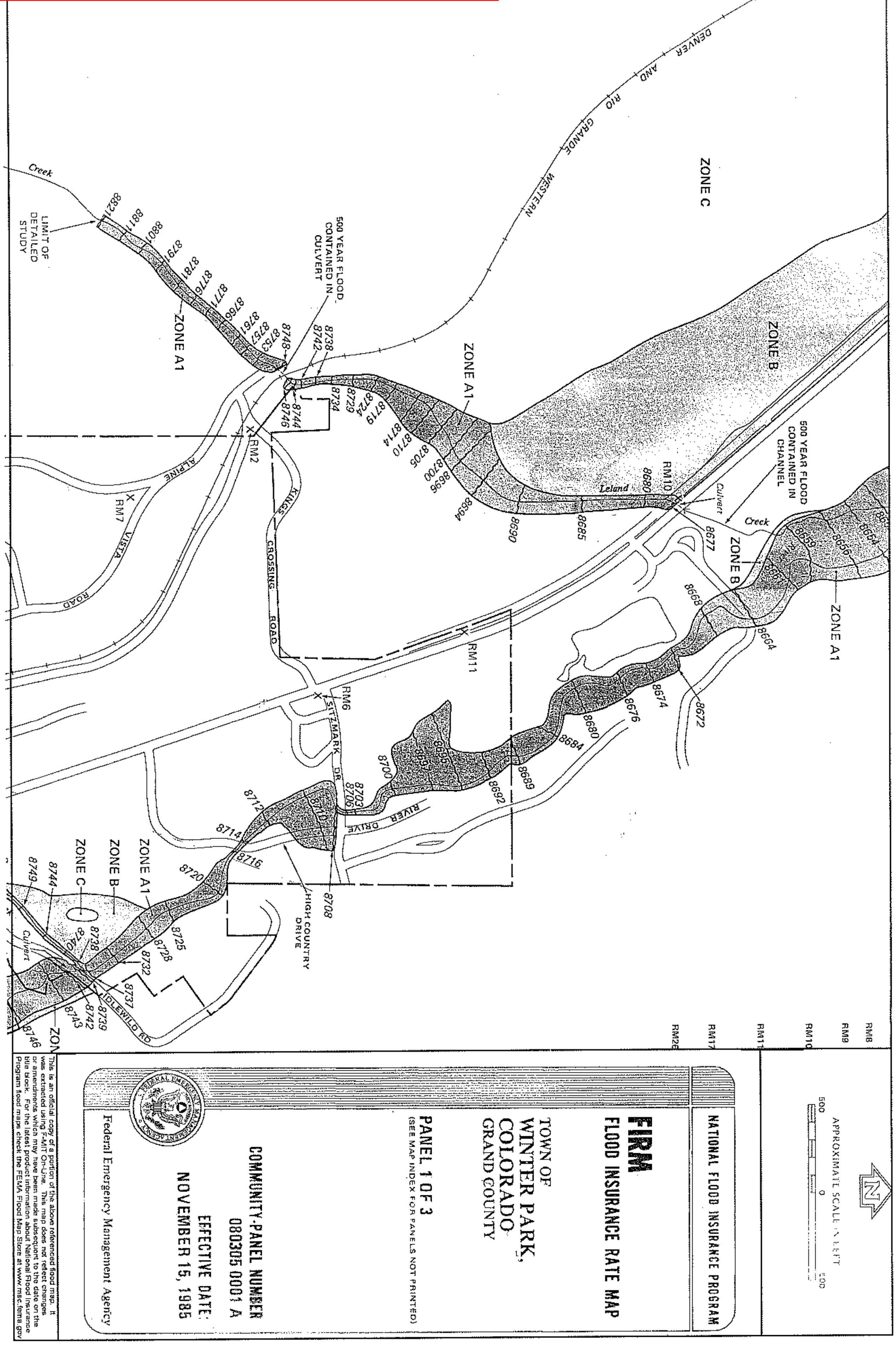
4.4 PHASING OF IMPROVEMENTS

Phasing of the stormwater management system will depend on the timing of various developments throughout Grand Park. Regional drainage facilities will be implemented as demand warrants. It is anticipated that each Phased Preliminary Plan to be prepared for Grand Park, will provide design and construction details concerning the drainage facilities to be constructed in such Phase Area, or which may need to be constructed outside of the Phase Area, as a result of the Phase Area development.

4.5 FEMA FIRM MAPPING

The proposed development is contained within the FEMA FIRM map, 080305 001A – Town of Winter Park, Colorado, (Effective Date November 15, 1985). The FIRM map provides 100 year water surface elevations for Leland Creek and the Fraser River. A portion of the site adjacent to US Highway 40 is contained within Zone B – areas subject to 500 year flooding. The remainder of the development is outside the 500 year flooding limits.

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park



Excerpt from High Country Engineering Final
Drainage Report for Town Center at Grand Park

5.0 REFERENCES

1. Soil Survey of Grand County Area, Colorado, U.S. Department of Agriculture, Natural Resource Conservation Service, Denver, Colorado.

2. Urban Storm Drainage Criteria Manual, Urban Drainage & Flood Control District (UD&FCD), prepared by Wright – McLaughlin Engineers, March 1969, Revised June 2001.

3. Grand County Storm Drainage Design and Criteria Manual.

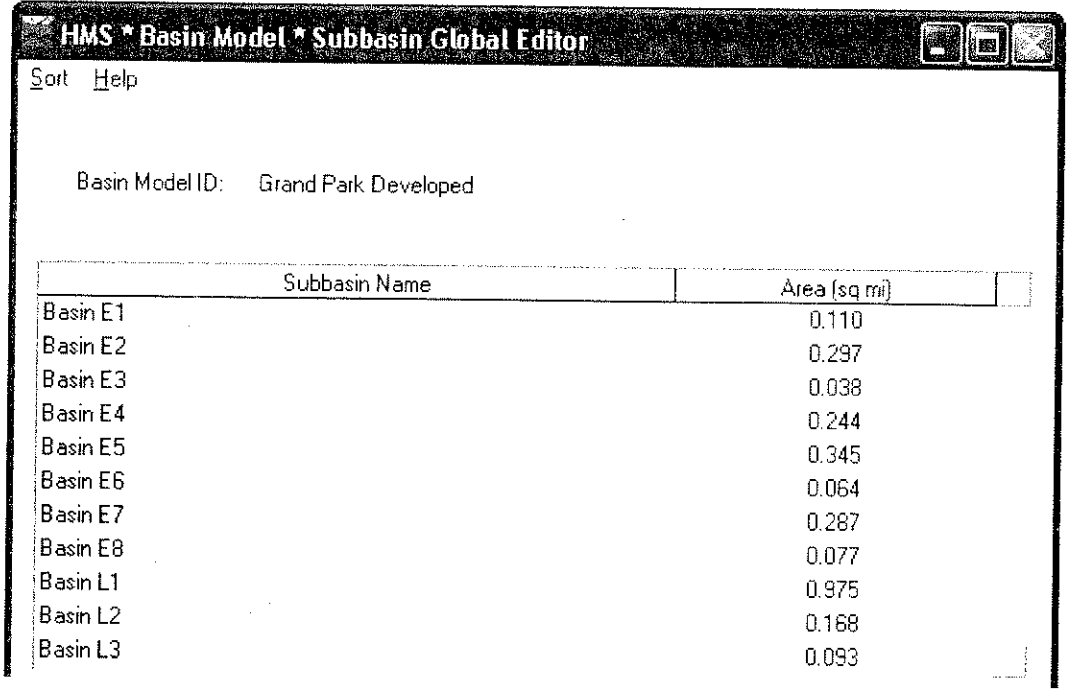
4. NOAA Atlas No. 2, "Precipitation - Frequency Atlas of the Western United Stated, Volume III - Colorado", Miller, J. F., R. H. Frederick, R. J. Tracy, National Weather Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 1976.

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

APPENDIX A – HYDROLOGIC INPUT

Excerpt from High Country Engineering Final
Drainage Report for Town Center at Grand Park

Subbasin Area

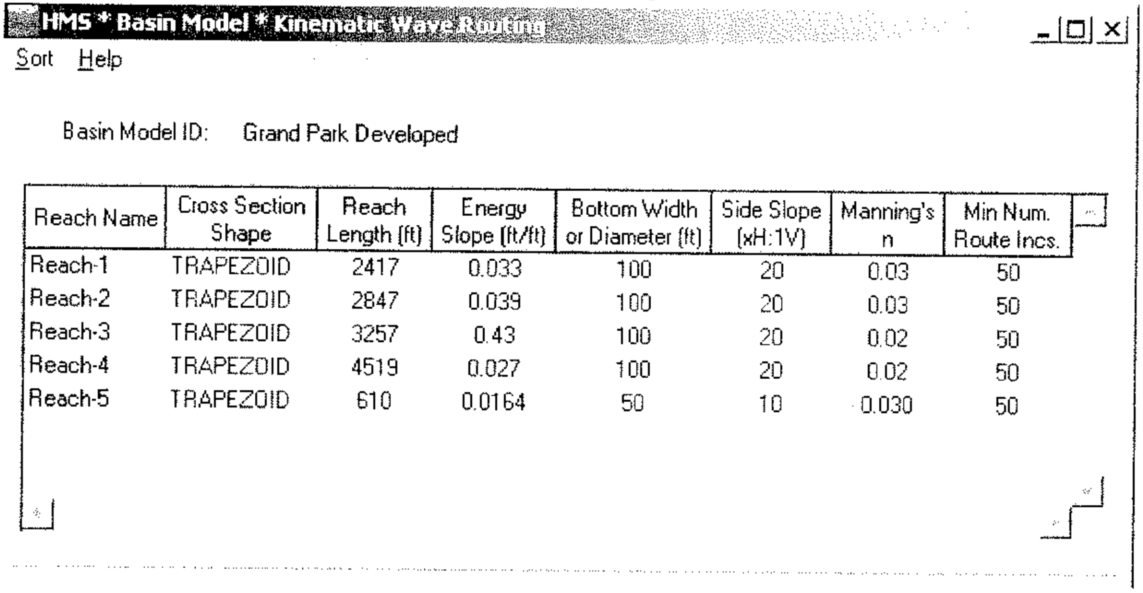


Basin Model ID: Grand Park Developed

Subbasin Name	Area (sq mi)
Basin E1	0.110
Basin E2	0.297
Basin E3	0.038
Basin E4	0.244
Basin E5	0.345
Basin E6	0.064
Basin E7	0.287
Basin E8	0.077
Basin L1	0.975
Basin L2	0.168
Basin L3	0.093

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

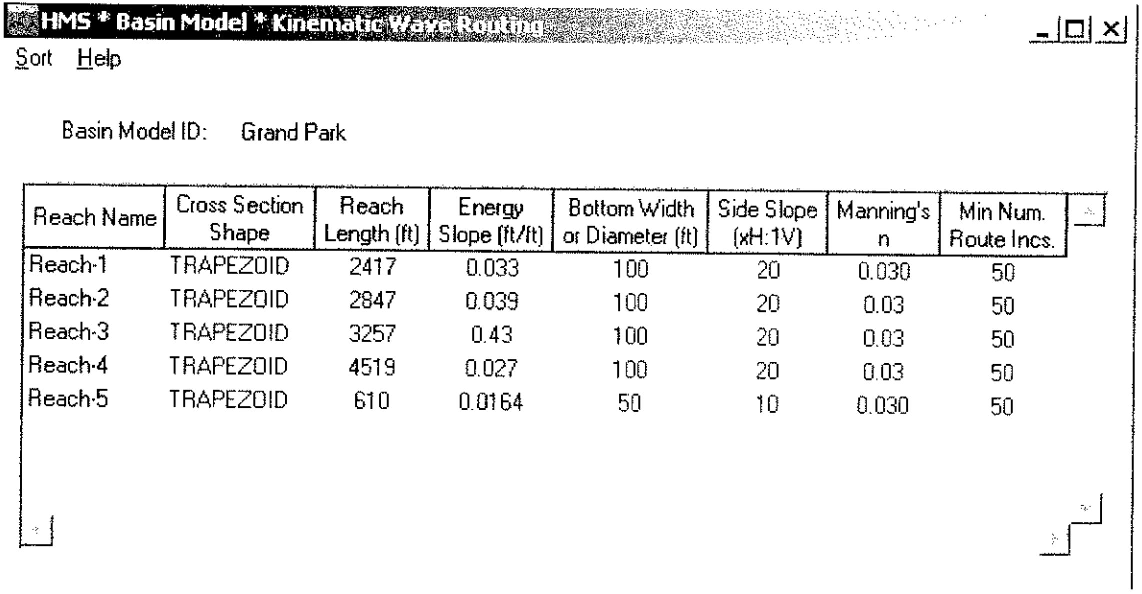
Reach Parameters – Developed Conditions



Basin Model ID: Grand Park Developed

Reach Name	Cross Section Shape	Reach Length (ft)	Energy Slope (ft/ft)	Bottom Width or Diameter (ft)	Side Slope (xH:1V)	Manning's n	Min Num. Route Incs.
Reach-1	TRAPEZOID	2417	0.033	100	20	0.03	50
Reach-2	TRAPEZOID	2847	0.039	100	20	0.03	50
Reach-3	TRAPEZOID	3257	0.43	100	20	0.02	50
Reach-4	TRAPEZOID	4519	0.027	100	20	0.02	50
Reach-5	TRAPEZOID	610	0.0164	50	10	0.030	50

Reach Parameters – Existing Conditions



Basin Model ID: Grand Park

Reach Name	Cross Section Shape	Reach Length (ft)	Energy Slope (ft/ft)	Bottom Width or Diameter (ft)	Side Slope (xH:1V)	Manning's n	Min Num. Route Incs.
Reach-1	TRAPEZOID	2417	0.033	100	20	0.030	50
Reach-2	TRAPEZOID	2847	0.039	100	20	0.03	50
Reach-3	TRAPEZOID	3257	0.43	100	20	0.03	50
Reach-4	TRAPEZOID	4519	0.027	100	20	0.03	50
Reach-5	TRAPEZOID	610	0.0164	50	10	0.030	50

Precipitation Frequency Data Output

NOAA Atlas 2
Colorado 39.90199?N 105.77495?W
Site-specific Estimates

Map	Precipitation (inches)	Precipitation Intensity (in/hr)
2-year 6-hour	0.98	0.16
2-year 24-hour	1.32	0.06
100-year 6-hour	2.17	0.36
100-year 24-hour	2.98	0.12

Hydrometeorological Design Studies Center - NOAA/National Weather Service
1325 East-West Highway - Silver Spring, MD 20910 - (301) 713-1669
Fri Oct 14 11:58:44 2005

Region 2

2-Year Rainfall

Y_2: 2-yr 1-hr estimated value
X_1: 0.98 = (6-hr)
X_2: 1.32 = (24-hr)

$Y_2 = 0.011 + 0.942 [(X_1)(X_1 / X_2)]$
$= 0.011 + 0.942 [0.98 (0.98 / 1.32)]$
$= 0.696$ = (1-hr)

2hr = 0.341(6-hr) + 0.659(1-hr) = 0.793
3hr = 0.569(6-hr) + 0.431(1-hr) = 0.858
12hr = 1.2 (from figure 17)

5min = 0.29(1-hr) = 0.202
10min = 0.45(1-hr) = 0.313
15min = 0.57(1-hr) = 0.397
30min = 0.79(1-hr) = 0.550

10-Year Rainfall

Y_{10} = 10-yr 1-hr estimated value
X_1 = 6-hr = 1.40
X_2 = 24-hr = 1.98

100-Year Rainfall

$Y_{100} = 0.494 + 0.755 [(X_3)(X_3 / X_4)]$
X_3 = 2.17 = (6-hr)
X_4 = 2.98 = (24-hr)

$Y_{100} = 0.494 + 0.755 [(2.17)(2.17 / 2.98)]$
$= 1.687$ = (1-hr)

2hr = 0.341(6-hr) + 0.659(1-hr) = 1.851
3hr = 0.569(6-hr) + 0.431(1-hr) = 1.962
12hr ≈ 2.5 (from figure 17)

5min = 0.29(1-hr) = 0.489
10min = 0.45(1-hr) = 0.759
15min = 0.57(1-hr) = 0.962
30 min = 0.79(1-hr) = 1.333

22-141 50 SHEETS
22-142 100 SHEETS
200 SHEETS

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Colorado

Discussion of Maps

Figures 20 through 43 present precipitation-frequency maps for Colorado for 6- and 24-hr durations. Figures 20 through 31 are for annual (or all-season) values for the 2-, 5-, 10-, 25-, 50, and 100-yr return periods. Figures 32 through 43 are for the May through October season and are for probabilities of 0.50, 0.20, 0.10, 0.04, 0.02, and 0.01 The isopluvial maps represent the 360- and 1,440-min durations for the partial-duration series. Data were tabulated for clock and observation-day intervals for the annual series and were adjusted by the empirical factors given in the ANALYSIS section.

Isoline interval. The isoline interval selected was designed to provide a reasonably complete description of the isopluvial pattern in various regions of the state The isoline interval over most of the state on maps for the 24-hr duration is 0 2 in. for precipitation-frequency values below 3.0 in., 0.4 in. between 3.0 in and 5.0 in., and 0.5 in at values greater than 5.0 in. However, in southwestern Colorado along the San Juan Mountains, the annual maps use an isoline interval of 0 2 in below precipitation-frequency values of 2 0 in., and 0 5 in for values over 2.0 in. On the maps for the 6-hr duration, the interval is 0 1 in. for precipitation-frequency values under 1.2 in. at the 2-yr and 0.50 and 0 20 probability level (on maps for the May through October season). At longer return periods (or lower probabilities), the upper limit of the 0.1-in isoline interval increases in order to maintain the isopluvial gradient and degree of detail. On all maps for the 6-hr duration, the isoline interval changes from 0 2 in. below 3 0 in. to 0.4 in. over 3.0-in. precipitation-frequency values. Dashed intermediate lines have been placed between widely separated isolines and in regions where a linear interpolation between the normal isopluvial interval would lead to erroneous interpolation "Lows" that close within the boundaries of a particular map have been hatched on the low-valued side of the isoline.

Importance of snow in precipitation-frequency values. The annual maps in this Atlas represent frequency values of precipitation regardless of type. For many hydrologic purposes, precipitation falling as rain must be treated in a different manner from that falling as snow. The contribution of snow amounts to precipitation-frequency values in Colorado and the Rocky Mountain States (roughly Montana, Wyoming, Colorado, New Mexico, and Utah) was investigated. In this area, there were about 50 stations per state having 10 to 15 yrs of observation of snowfall as part of the precipitation observing program. For each such station, two data series were formed as discussed under Interpretation of Results, Importance of Snow in Estimating Frequency Values.

A ratio was formed of the 2-yr 24-hr value for the series containing maximum annual events without regard to the type of precipitation and the 2-yr 24-hr value for the series with snow occurrences eliminated. A plot of this ratio vs latitude (fig. 15) shows that the ratio tends to be at a maximum in the latitude of Colorado and Utah. Over all of Colorado, the all-precipitation series tends to average about 10 percent higher than the series with snow eliminated. However, examination of the data shows that in the relatively flat areas east of a smoothed 6,000-ft contour the differences between the two series are minor. With data from this area eliminated, the difference between the two series averages about 15 percent, with some individual differences as large as 40 to 50 percent. About half the stations have differences greater than 10 percent These differences indicate that frequency values computed from an annual series of rainfall amounts only would be different from those composed of all-precipitation values, and two separate sets of precipitation-frequency maps were needed.

Snowfall observations are made at only about 15 percent of the precipitation stations used in this study. For this reason, a rainfall-frequency study could not be made by direct methods. Since most snowfall occurs during the colder half of the year, a series containing only values for the May to October season was compared with the series that was based on rainfall only. The two series were in good agreement, except for a slight bias toward higher values for the May to October season This bias results from some large amounts in late October and early May occurring as snow and thus excluded from the rainfall-only series. The average difference is only about 4 percent, with no consistent preference toward higher elevations or particular geographic regions

Two sets of maps were prepared for Colorado. The first set consists of annual maps based on precipitation data from all months of the year without regard to the type of precipitation, rain, rain and snow mixed, all snow, hail, etc. The second series takes precipitation values from the months May to October. No attempt was made in this second series to differentiate between types of precipitation occurring within these months, but the investigations mentioned in the preceding paragraph indicate that these maps will approximate the values that would be obtained by using a data series made up of precipitation events that are exclusively rain. Since data for only part of the year were used, these maps have been labeled with the appropriate probabilities rather than with a return period in years (figs 32–43).

Table 11. *Equations for estimating 1-hr values in Colorado with statistical parameters for each equation*

Region of applicability*	Equation	Corr. coeff.	No. of stations	Mean of computed stn. values (inches)	Standard error of estimate (inches)
South Platte, Republican, Arkansas, and Cimarron River Basins (1)	$Y_2 = 0.218 + 0.709[(X_1)(X_1/X_2)]$	0.94	75	1.01	0.074
	$Y_{100} = 1.897 + 0.439[(X_3)(X_3/X_4)] - 0.008Z$	.84	75	2.68	.317
San Juan, Upper Rio Grande, Upper Colorado, and Gunnison River Basins and Green River Basin below confluence with the Yampa River (2)	$Y_2 = -0.011 + 0.942[(X_1)(X_1/X_2)]$	.95	86	0.72	.085
	$Y_{100} = 0.494 + 0.755[(X_3)(X_3/X_4)]$	.90	65	1.96	.290
Yampa and Green River Basins above confluence of Green and Yampa Rivers (3)	$Y_2 = 0.019 + 0.711[(X_1)(X_1/X_2)] + 0.001Z$	.82	98	0.40	.031
	$Y_{100} = 0.338 + 0.670[(X_3)(X_3/X_4)] + 0.001Z$	.80	79	1.04	.141
North Platte (4)	$Y_2 = 0.028 + 0.890[(X_1)(X_1/X_2)]$	.93	90	0.60	.062
	$Y_{100} = 0.671 + 0.757[(X_3)(X_3/X_4)] - 0.003Z$	.91	89	1.71	.236

* Numbers in parentheses refer to geographic regions shown in figure 19. See text for more complete description.

List of variables

Y_2 = 2-yr 1-hr estimated value

Y_{100} = 100-yr 1-hr estimated value

X_1 = 2-yr 6-hr value from precipitation-frequency maps

X_2 = 2-yr 24-hr value from precipitation-frequency maps

X_3 = 100-yr 6-hr value from precipitation-frequency maps

X_4 = 100-yr 24-hr value from precipitation-frequency maps

Z = point elevation in hundreds of feet

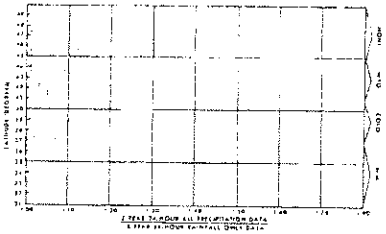

Figure 15. *Ratio of 2-yr 24-hr value for all data to 2-yr 24-hr value for rainfall only vs latitude.*

Table 12. *Adjustment factors to obtain n-min estimates from 1-hr values*

Duration (min)	5	10	15	30
Ratio to 1-hr	0.29	0.45	0.57	0.79

(Adopted from *U.S. Weather Bureau Technical Paper* No. 40, 1961.)

Procedures for Estimating Values for Durations Other Than 6 and 24 Hrs

The isopluvial maps in this Atlas are for 6- and 24-hr durations For many hydrologic purposes, values for other durations are necessary. Such values can be estimated using the 6- and 24-hr maps and the empirical methods outlined in the following sections The procedures detailed below for obtaining 1-, 2-, and 3-hr estimates were developed specifically for this Atlas The procedures for obtaining estimates for less than 1-hr duration and for 12-hr duration were adopted from *Weather Bureau Technical Paper* No 40 (U S. Weather Bureau 1961) only after investigation demonstrated their applicability to data from the area covered by this Atlas.

Procedures for estimating 1-hr (60-min) precipitation-frequency values. Multiple-regression screening techniques were used to develop equations for estimating 1-hr duration values Factors considered in the screening process were restricted to those that could be determined easily from the maps of this Atlas or from generally available topographic maps.

The 11 western states were separated into several geographic regions. The regions were chosen on the basis of meteorological and climatological homogeneity and are generally combinations of river basins separated by prominent divides. Four of these geographic regions are partially within Colorado. For convenience and use as an overlay on the precipitation-frequency maps, these regions are outlined on figure 19. The first Colorado region is part of the region that lies to the east of the Continental Divide and the crest of the Sangre de Cristo and Sacramento Mountains and is south of the divide separating the drainage basins of the North and South Platte Rivers. It consists of that portion of Colorado drained by the South Platte, Republican, Arkansas, and Cimarron Rivers (Region 1, fig. 19). The second region consists of the area drained by the San Juan, Upper Rio Grande, Upper Colorado, and Gunnison Rivers and by the Green River below its confluence with the Yampa River (Region 2, fig 19) This is part of a larger region that extends from southwestern Colorado, westward to the Wasatch Mountains of Utah, and southward through Arizona and the western half of New Mexico The third region is the mountainous portion of the area between the Continental Divide and the crest of the Cascade Range. The portion that lies within Colorado is the northwestern portion of the State that is drained by the Yampa River and the Green River above its confluence with the Yampa (Region 3, fig. 19). A small portion of Colorado drained by the North Platte is Region 4, figure 19 The larger region of which this is a part includes that portion of Wyoming and Montana east of the Continental Divide. Equations to provide estimates for the 1-hr duration for 2- and 100-yr return periods are shown in table 11 Also listed are the statistical parameters associated with each equation In these equations, the variable $[(X_1)(X_1/X_2)]$ or

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$\{(X_3)(X_4/X_3)\}$ can be regarded as the 6-hr value times the slope of the line connecting the 6- and 24-hr values for the appropriate return period

As with any separation into regions, the boundary can only be regarded as the sharpest portion of a zone of transition between regions. These equations have been tested for boundary discontinuities by computing values using equations from both sides of the boundary. Differences were found to be mostly under 15 percent. However, it is suggested that when computing estimates along or within a few miles of a regional boundary computations be made using equations applicable to each region and that the average of such computations be adopted.

Estimates of 1-hr precipitation-frequency values for return periods between 2 and 100 yrs. The 1-hr values for the 2- and 100-yr return periods can be plotted on the nomogram of figure 6 to obtain values for return periods greater than 2 yrs or less than 100 yrs. Draw a straight line connecting the 2- and 100-yr values and read the desired return-period value from the nomogram.

Estimates for 2- and 3-hr (120- and 180-min) precipitation-frequency values. To obtain estimates of precipitation-frequency values for 2 or 3 hrs, plot the 1- and 6-hr values from the Atlas on the appropriate nomogram of figure 16. Draw a straight line connecting the 1- and 6-hr values, and read the 2- and 3-hr values from the nomogram. This nomogram is independent of return period. It was developed using data from the same regions used to develop the 1-hr equations.

The mathematical solution from the data used to develop figure 16 gives the following equations for estimating the 2- and 3-hr values:

For Region 1,	2-hr = 0.342 (6-hr) + 0.658 (1-hr)	(3)
figure 19	3-hr = 0.597 (6-hr) + 0.403 (1-hr)	(4)
For Region 2,	2-hr = 0.341 (6-hr) + 0.659 (1-hr)	(5)
figure 19	3-hr = 0.569 (6-hr) + 0.431 (1-hr)	(6)
For Regions 3	2-hr = 0.250 (6-hr) + 0.750 (1-hr)	(7)
and 4, figure 19	3-hr = 0.467 (6-hr) + 0.533 (1-hr)	(8)

Estimates for 12-hr (720-min) precipitation-frequency values. To obtain estimates for the 12-hr duration, plot values from the 6- and 24-hr maps on figure 17. Read the 12-hr estimates at the intersection of the line connecting these points with the 12-hr duration line of the nomogram.

Estimates for less than 1 hr. To obtain estimates for durations of less than 1 hr, apply the values in table 12 to the 1-hr value for the return period of interest.

	1-hr	2-hr	3-hr	6-hr	24-hr
2-yr	*0.71*	*0.83*	*0.91*	**1.05**	**1.58**
5-yr				1.38	1.99
10-yr				1.59	2.27
25-yr				1.90	2.65
50-yr				2.19	2.95
100-yr	*1.86*			**2.39**	**3.35**

Table 13. *Precipitation data for depth-frequency atlas computation point 106°00′ W., 39°00′ N.*

Illustration of Use of Precipitation-Frequency Maps, Diagrams, and Equations

To illustrate the use of these maps, values were read from figures 20 to 31 for the point at 39°00′ N. and 106°00′ W. These values are shown in boldface type in table 13. The values read from the maps should be plotted on the return-period diagram of figure 6 because (1) not all points are as easy to locate on a series of maps as are latitude-longitude intersections, (2) there may be some slight registration differences in printing, and (3) precise interpolation between isolines is difficult. This has been done for the 24-hr values in table 13 (fig. 18a) and a line of best fit has been drawn subjectively. On this nomogram, the line fits the data rather well. Had any points deviated noticeably from the line, the value would have been reread from the line and the new value substituted in table 13 and adopted in preference to the original readings.

The 2- and 100-yr 1-hr values for the point were computed from the equations applicable to Region 1, figure 19 (table 11), since the point is east of the Continental Divide. The 2-yr 1-hr value is estimated at 0.71 in. (2-yr 6- and 24-hr values from table 13), the estimated 100-yr 1-hr value is 1.86 in. (100-yr 6- and 24-hr values from table 13 and elevation of 9,500 ft). By plotting these 1-hr values on figure 6 and connecting them with a straight line, one can obtain estimates for return periods of 5, 10, 25, and 50 yrs.

The 2- and 3-hr values can be estimated by using the nomogram of figure 16 or equations (3) and (4). The 1- and 6-hr values for the desired return period are obtained as above. Plot these points on the nomogram of figure 16 and connect them with a straight line. Read the estimates for 2 or 3 hrs at the intersections of the connecting line and the 2- and 3-hr vertical lines. An example is shown in figure 18b for the 2-yr return period. The 2-yr 2-hr (0.83 in.) and 2-yr 3-hr (0.91 in.) values are in italics on table 13.

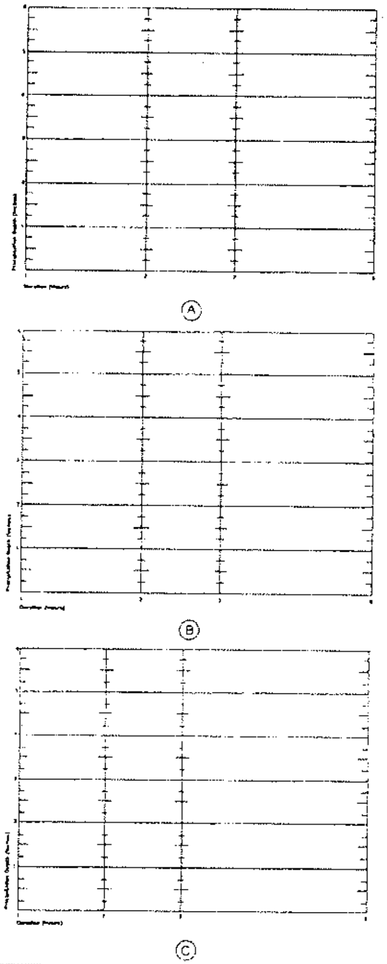
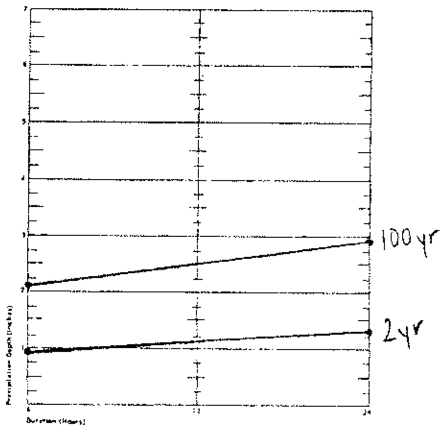


Figure 18. *Precipitation depth-duration diagram (1- to 6-hr)*
a. South Platte, Republican, Arkansas, and Cimarron River Basins (Region 1, fig. 19).
b. San Juan, Upper Rio Grande, Upper Colorado, and Gunnison River Basins and Green River Basin below its confluence with the Yampa River (Region 2, fig. 19).
c. Yampo and Green River Basins above confluence of Green and Yampo Rivers (Region 3, fig. 19) and North Platte Drainage (Region 4, fig. 19).

Figure 17. *Precipitation depth-duration diagram (6- to 24-hr)*



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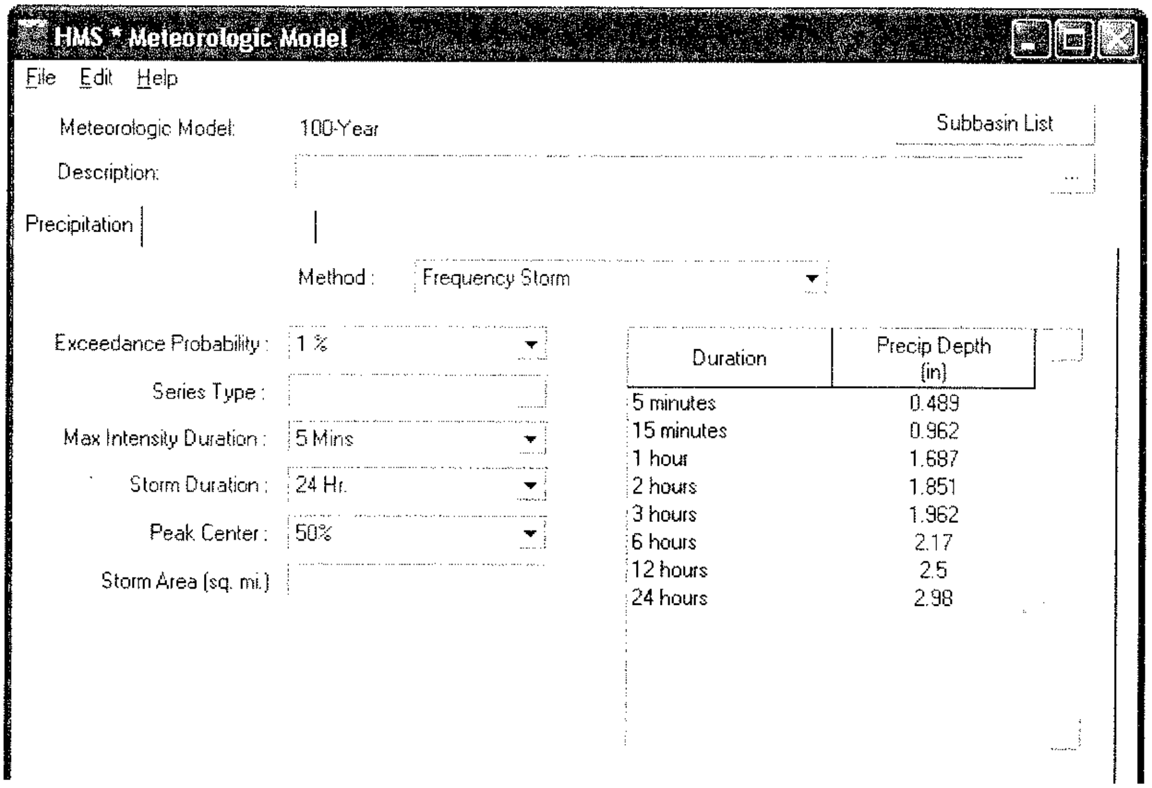
100-Year Rainfall Data



Meteorologic Model: 100-Year

Description:

Method : Frequency Storm

Exceedance Probability : 1 %

Series Type :

Max Intensity Duration : 5 Mins

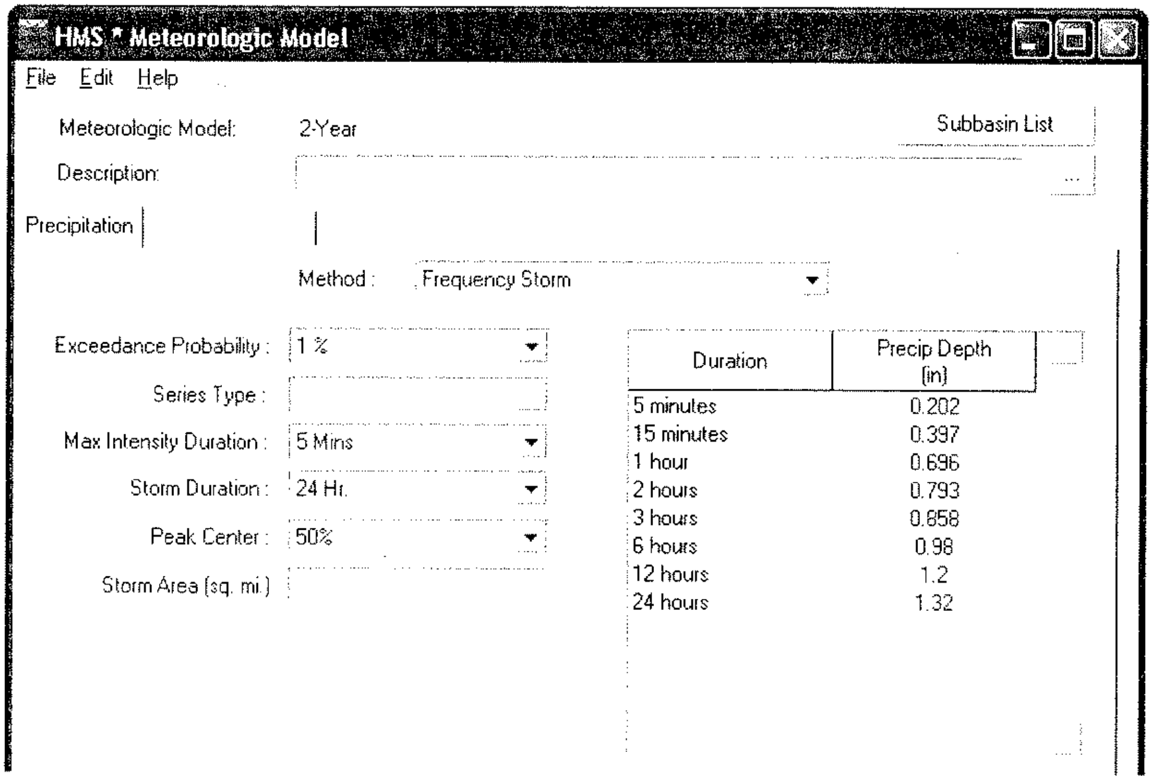
Storm Duration : 24 Hr.

Peak Center : 50%

Storm Area (sq. mi.)

Duration	Precip Depth (in)
5 minutes	0.489
15 minutes	0.962
1 hour	1.687
2 hours	1.851
3 hours	1.962
6 hours	2.17
12 hours	2.5
24 hours	2.98

2-Year Rainfall Data



Meteorologic Model: 2-Year

Description:

Method : Frequency Storm

Exceedance Probability : 1 %

Series Type :

Max Intensity Duration : 5 Mins

Storm Duration : 24 Hr.

Peak Center : 50%

Storm Area (sq. mi.)

Duration	Precip Depth (in)
5 minutes	0.202
15 minutes	0.397
1 hour	0.696
2 hours	0.793
3 hours	0.858
6 hours	0.98
12 hours	1.2
24 hours	1.32

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Drainage Report for Town Center at Grand Park

Grand Park - Existing Conditions
HCE Project No. 2052014.00
Soils Classification for Runoff Coefficient

Basin	Total Area	Total Area	Type B	Type C or D	Type A	Type B	Type C or D	Type A	% Imperv.	$C_{5 - \text{Type B}}$	$C_{100 - \text{Type B}}$	$C_{5 - \text{Type C/D}}$	$C_{100 - \text{Type C/D}}$	$C_{5 - \text{Type A}}$	$C_{100 - \text{Type A}}$	C_5	C_{100}
	(ac)	(mi^2)	Area (ac)	Area (ac)	Area (ac)	(%)	(%)	(%)	(Runoff Co.)	(Table RO-5)	(Table RO-5)	(Table RO-5)	(Table RO-5)	(Table RO-5)	(Table RO-5)	composite	composite
E1	70.5	0.110	70.5	0.0	0.0	100%	0%	0%	2%	0.088	0.362	0.162	0.508	0.008	0.216	0.088	0.362
E2	190.7	0.297	190.7	0.0	0.0	100%	0%	0%	2%	0.088	0.362	0.162	0.508	0.008	0.216	0.088	0.362
E3	24.1	0.038	24.1	0.0	0.0	100%	0%	0%	2%	0.088	0.362	0.162	0.508	0.008	0.216	0.088	0.362
E4	156.6	0.244	122.9	33.7	0.0	78%	22%	0%	2%	0.088	0.362	0.162	0.508	0.008	0.216	0.104	0.393
E5	221.0	0.345	57.3	163.7	0.0	26%	74%	0%	2%	0.088	0.362	0.162	0.508	0.008	0.216	0.143	0.470
E6	41.0	0.064	15.7	25.3	0.0	38%	62%	0%	2%	0.088	0.362	0.162	0.508	0.008	0.216	0.134	0.452
E7	184.0	0.287	31.2	98.6	54.2	17%	54%	29%	2%	0.088	0.362	0.162	0.508	0.008	0.216	0.104	0.397
E8	49.5	0.077	11.8	36.5	1.1	24%	74%	2%	2%	0.088	0.362	0.162	0.508	0.008	0.216	0.141	0.466
L1	624.8	0.975	468.2	156.5	0.0	75%	25%	0%	2%	0.088	0.362	0.162	0.508	0.008	0.216	0.107	0.399
L2	107.7	0.168	107.5	0.6	0.0	100%	1%	0%	2%	0.088	0.362	0.162	0.508	0.008	0.216	0.089	0.364
L3	59.4	0.093	24 2	34.1	1.0	41%	58%	2%	2%	0.088	0.362	0.162	0.508	0.008	0.216	0.129	0.444

Grand Park - Developed Conditions
HCE Project No. 2052014.00
Soils Classification for Runoff Coefficient

Basin	Total Area	Total Area	Type B	Type C or D	Type A	Type B	Type C or D	Type A	% Imperv.	$C_{5 - \text{Type B}}$	$C_{100 - \text{Type B}}$	$C_{5 - \text{Type C/D}}$	$C_{100 - \text{Type C/D}}$	$C_{5 - \text{Type A}}$	$C_{100 - \text{Type A}}$	C_5	C_{100}
	(ac)	(mi^2)	Area (ac)	Area (ac)	Area (ac)	(%)	(%)	(%)	(Runoff Co)	(Table RO-5)	(Table RO-5)	(Table RO-5)	(Table RO-5)	(Table RO-5)	(Table RO-5)	composite	composite
E1	70.5	0.110	70.5	0.0	0.0	100%	0%	0%	15%	0.170	0.420	0.240	0.540	0.100	0.280	0.170	0.420
E2	190.7	0 297	190.7	0.0	0.0	100%	0%	0%	15%	0.170	0.420	0.240	0.540	0.100	0.260	0.170	0.420
E3	24.1	0.038	24.1	0.0	0.0	100%	0%	0%	14%	0.165	0.415	0.235	0.545	0.095	0.275	0.165	0.415
E4	156.6	0.244	122.9	33.7	0.0	78%	22%	0%	26%	0.225	0.465	0.280	0.560	0.165	0.352	0.237	0.485
E5	221 0	0.345	57.3	163.7	0.0	26%	74%	0%	36%	0.275	0.485	0.335	0.570	0.225	0.390	0.319	0.548
E6	41.0	0.064	15.7	25.3	0.0	38%	62%	0%	41%	0.305	0.505	0 355	0.580	0.255	0.410	0.336	0.551
E7	184.0	0.287	31.2	98.6	54.2	17%	54%	29%	73%	0.525	0.640	0.555	0.695	0.475	0.585	0.526	0.653
E8	49.5	0.077	11 8	36.5	1.1	24%	74%	2%	32%	0.260	0.470	0 315	0.570	0.200	0.375	0.299	0.541
L1	624.8	0.975	468 2	156 5	0.0	75%	25%	0%	15%	0.170	0.420	0.240	0.540	0.100	0.280	0.188	0.450
L2	107.7	0.168	107.5	0 6	0.0	100%	1%	0%	2%	0.088	0.365	0 160	0 510	0.010	0.220	0.089	0.367
L3	59.4	0 093	24.2	34.1	1.0	41%	58%	2%	47%	0.340	0.513	0 380	0.595	0 285	0.455	0.362	0.559

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Soil Types by Basin			Cowdrey loam	Cumulic Cryaquolls	Frisco-Peeler Gravelly sandy loam	Frisco-Peeler Gravelly sandy loam	Frisco-Peeler Gravelly sandy loam	Scout cobbly Sandy loam	Tine Gravelly sandy loam	Outside Soil Study
Areas in Acres			15-45% Slope	nearly level	2-6%	6-25%	25-65%	15-65%	0-3%	
Basin	Basin_Area	Location	21	25	31	32	33	76	81	(blank)
E1	12.469	Offsite				0.525	0.067			11.843
	57.985	Onsite				48.938	9.044			
E1 Total	**70.454**					49.463	9.110			11.843
E2	190.678	Onsite			40.509	125.723	24.435			
E3	24.086	Onsite				19.076	4.999			
E4	156.640	Onsite	31.052	2.731	12.512	71.293	39.051			
E5	220.972	Onsite	145.454	18.265	18.729	38.518				
E6	41.025	Onsite	25.238	0.039	0.138	15.610				
E7	183.955	Onsite	2.184	96.375	31.168				54.228	
E8	49.483	Onsite	5.948	30.576	2.374	9.442			1.132	
L1	299.307	Offsite		29.642		47.194	90.185			132.257
	325.489	Onsite	113.384	13.492	0.065	198.542				
L1 Total	**624.797**		113.384	43.135	0.065	245.736	90.185			132.257
L2	107.729	Offsite		0.260	25.132	77.017	1.136	4.184		
L3	59.356	Onsite	0.951	33.190	12.712	2.490		9.024	0.988	

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

PARCELS BY BASIN

Area in Acres			Parcels/Land Use																									
			10W	11W	12W	13Wa	13Wb	14W	15W	16W	17W	18W	19W	1Wb	20W	21W	4W	6W	7W	8Wa	8Wb	9W	Cozans Meadow Neighborhood	Elk Creek 5W	Mixed Use Site	Stone Bench Townhomes	The Willows	T Ce
BASIN	BASIN_AREA	LOCATION	34.644	13.593	22.419	17.970	33.154	60.281	22.600	96.556	110.109	18.181	40.055	4.208	40.049	9.914	7.491	3.197	32.200	52.410	6.553	19.145	9.696	13.578	10.073	6.554	29.668	2
E1	12.469	Offsite																										
	57.985	Onsite									52.075																	
E1 Total	70.454										52.075																	
E2	190.678	Onsite					11.445	43.033	4.170	62.149	15.755																	
E3	24.086	Onsite							17.784	2.153																		
E4	156.640	Onsite			5.963	16.924	21.711	10.243										3.182	26.182	3.323								
E5	220.972	Onsite		4.758	16.457	1.047		7.016		0.922			14.705			6.070			6.020	49.084	1.019	12.525						
E6	41.025	Onsite	8.111	0.886																	5.535	6.621						
E7	183.955	Onsite															3.662						127.334		10.074	4.597	28.600	
E8	49.483	Onsite															3.858							13.579		1.954		
L1	299.307	Offsite													0.019													
	325.489	Onsite	26.536	7.950						31.399	42.348	18.182	25.353		40.033	3.845												
L1 Total	624.797		26.536	7.950						31.399	42.348	18.182	25.353		40.052	3.845												
L2	107.729	Offsite																										
L3	59.356	Onsite												4.208													1.070	2

Excerpt from High Country Engineering Final
Drainage Report for Town Center at Grand Park

Table 2-2a.—Runoff curve numbers for urban areas[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type and hydrologic condition	Average percent impervious area[2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

---

[1] Average runoff condition, and $I_a = 0.2S$.

[2] The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.

[3] CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.

[4] Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.

[5] Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4, based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

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Table 2-2c.—Runoff curve numbers for other agricultural lands[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type	Hydrologic condition	A	B	C	D
Pasture, grassland, or range—continuous forage for grazing.[2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element.[3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	[4]30	48	65	73
Woods—grass combination (orchard or tree farm).[5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods.[6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	[4]30	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

[1] Average runoff condition, and $I_a = 0.2S$.

[2] *Poor:* <50% ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: >75% ground cover and lightly or only occasionally grazed.

[3] *Poor:* <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.

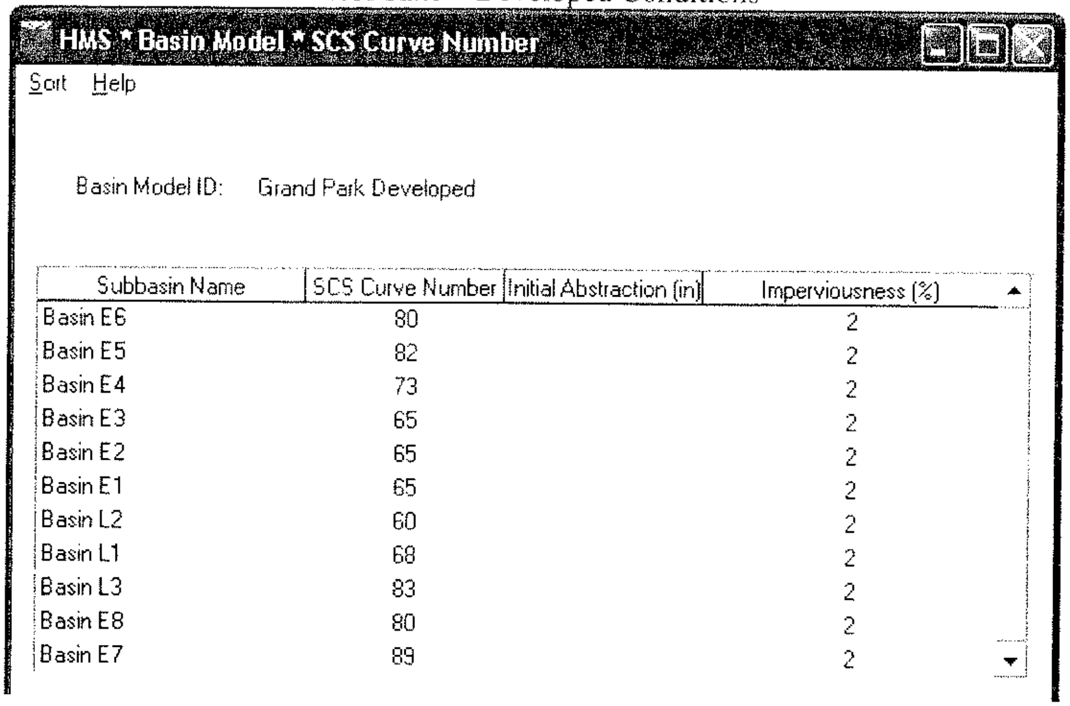
[4] Actual curve number is less than 30; use CN = 30 for runoff computations.

[5] CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.

[6] *Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

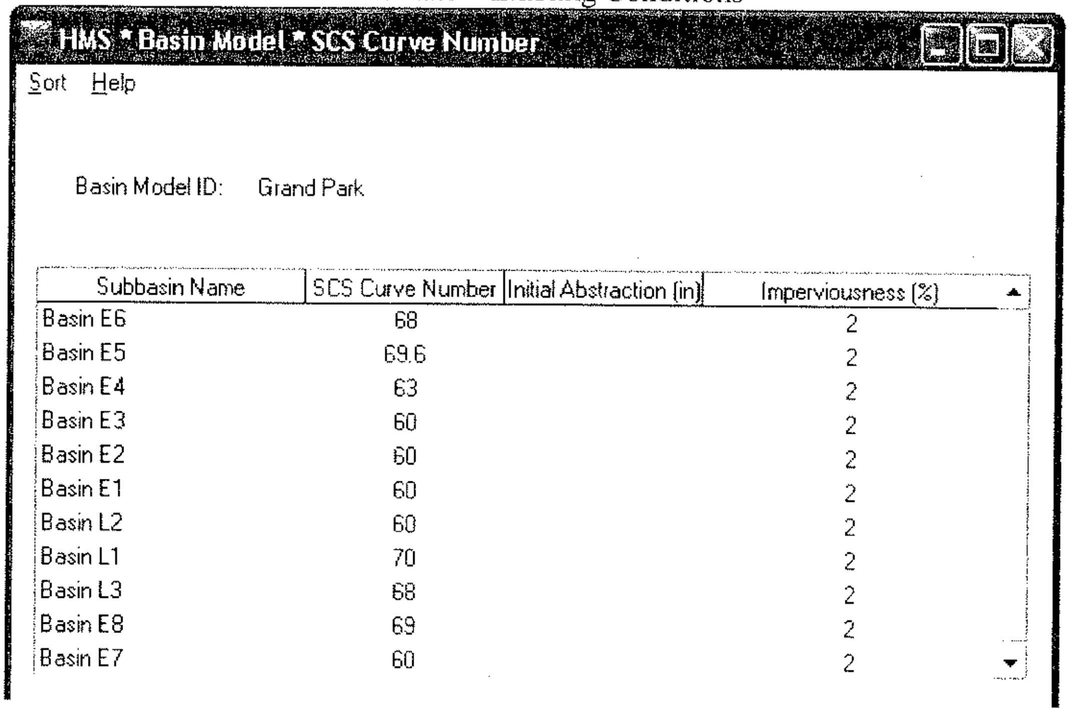
Loss Rate – Developed Conditions



Basin Model ID: Grand Park Developed

Subbasin Name	SCS Curve Number	Initial Abstraction (in)	Imperviousness (%)
Basin E6	80		2
Basin E5	82		2
Basin E4	73		2
Basin E3	65		2
Basin E2	65		2
Basin E1	65		2
Basin L2	60		2
Basin L1	68		2
Basin L3	83		2
Basin E8	80		2
Basin E7	89		2

Loss Rate – Existing Conditions



Basin Model ID: Grand Park

Subbasin Name	SCS Curve Number	Initial Abstraction (in)	Imperviousness (%)
Basin E6	68		2
Basin E5	69.6		2
Basin E4	63		2
Basin E3	60		2
Basin E2	60		2
Basin E1	60		2
Basin L2	60		2
Basin L1	70		2
Basin L3	68		2
Basin E8	69		2
Basin E7	60		2

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

Grand Park - Developed Conditions
HCE Project No. 2052014.00
% Imperviousness & Curve Number

Basin	Total Area (ac)	Composite % Imp.	Type B (%)	Type C or D (%)	Type A (%)	Type B CN	Type C or D CN	Type A CN	Composite CN
E1	70.5	15%	100%	0%	0%	65	78	50	65
E2	190.7	15%	100%	0%	0%	65	78	50	65
E3	24.1	14%	100%	0%	0%	65	78	50	65
E4	156.6	26%	78%	22%	0%	70	82	54	73
E5	221.0	36%	26%	74%	0%	74	85	60	82
E6	41.0	41%	38%	62%	0%	76	83	62	80
E7	184.0	73%	17%	54%	29%	89	92	82	89
E8	49.5	32%	24%	74%	2%	72	83	57	80
L1	624.8	15%	75%	25%	0%	65	78	50	68
L2	107.7	2%	100%	1%	0%	60	75	36	60
L3	59.4	47%	41%	58%	2%	80	85	72	83

Planning Area	Average % Imperv	Type B CN	Type C or D CN	Type A CN
10W	80	90	93	87
11W	65	85	91	77
12W	80	90	93	87
13Wa	30	72	83	57
13Wb	25	70	82	54
14W	25	70	82	54
15W	17	67	80	50
16W	15	65	78	50
17W	20	68	83	51
18W	25	70	82	54
19W	60	81	85	72
1Wb	75	89	92	82
20W	65	85	91	77
21W	65	85	91	77
4W	90	94	95	90
6W	90	94	95	90
7W	65	85	91	77
8Wa	65	85	91	77
8Wb	70	87	90	80
9W	80	90	93	87

Excerpt from High Country Engineering Final
Drainage Report for Town Center at Grand Park

Grand Park - Existing Conditions
HCE Project No. 2052014.00
Time of Concentration

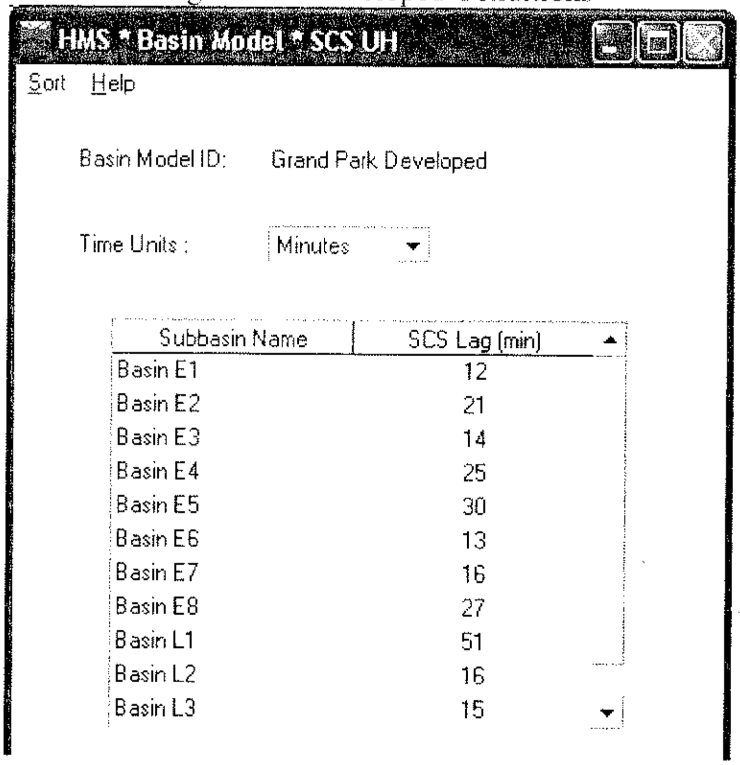
Sub-Basin Data			Overland Flow (t_i)					Travel Time (t_t)					Time of Concentration	
Designation	Area (acres)	C_5	Length (ft)	Δelev.	Slope (ft/ft)	Velocity (ft/s)	t_i (min)	Length (ft)	Δelev.	Slope (ft/ft)	Velocity (ft/s)	t_t (min)	t_c (min)	Lag Time(min)
E1	70.5	0.088	500	40	0.0800	2.8284	20.57	1800	380	0.2111	4.5947	6.53	27.10	16.26
E2	190.7	0.088	500	50	0.1000	3.1623	19.11	4800	650	0.1354	3.6799	21.74	40.85	24.51
E3	24.1	0.088	500	45	0.0900	3.0000	19.79	2000	160	0.0800	2.8284	11.79	31.57	18.94
E4	156.6	0.104	500	25	0.0500	2.2361	23.64	5300	480	0.0906	3.0094	29.35	53.00	31.80
E5	221.0	0.143	500	45	0.0900	3.0000	18.71	6800	550	0.0809	2.8440	39.85	58.56	35.14
E6	41.0	0.134	500	10	0.0200	1.4142	31.04	1600	160	0.1000	3.1623	8.43	39.47	23.68
E7	184.0	0.104	500	31	0.0620	2.4900	22.02	2400	40	0.0167	1.2910	30.98	53.00	31.80
E8	49.5	0.141	500	40	0.0800	2.8284	19.50	5700	110	0.0193	1.3892	68.39	87.88	52.73
L1	624.8	0.107	500	15	0.0300	1.7321	27.91	13000	1000	0.0769	2.7735	78.12	106.03	63.62
L2	107.7	0.089	500	15	0.0300	1.7321	28.41	2600	225	0.0865	2.9417	14.73	43.14	25.89
L3	59.4	0.129	500	40	0.0800	2.8284	19.73	2120	54	0.0255	1.5960	22.14	41.87	25.12

Grand Park - Developed Conditions
HCE Project No. 2052014.00
Time of Concentration

Sub-Basin Data			Overland Flow (t_i)					Travel Time (t_t)					Time of Concentration			
Designation	Area (acres)	C_5	Length (ft)	Δelev.	Slope (ft/ft)	Velocity (ft/s)	t_i (min)	Length (ft)	Δelev.	Slope (ft/ft)	Velocity (ft/s)	t_t (min)	t_c (min)	Urban Check	Lower t_c	Lag Time
E1	70.5	0.170	300	35	0.1167	3.4157	12.93	2000	385	0.1925	4.3875	7.60	20.53	22.78	20.53	12.32
E2	190.7	0.170	300	35	0.1167	3.4157	12.93	5000	665	0.1330	3.6469	22.85	35.78	39.44	35.78	21.47
E3	24.1	0.165	300	20	0.0667	2.5820	15.63	2200	185	0.0841	2.8998	12.64	28.28	23.89	23.89	14.33
E4	156.6	0.237	300	15	0.0500	2.2361	15.87	5500	490	0.0891	2.9848	30.71	46.58	42.22	42.22	25.33
E5	221.0	0.319	300	25	0.0833	2.8868	12.12	7000	570	0.0814	2.8536	40.88	53.01	50.56	50.56	30.33
E6	41.0	0.336	300	5	0.0167	1.2910	20.19	1800	165	0.0917	3.0277	9.91	30.10	21.67	21.67	13.00
E7	184.0	0.526	300	10	0.0333	1.8257	12.06	2600	61	0.0235	1.5317	28.29	40.35	26.11	26.11	15.67
E8	49.5	0.299	300	40	0.1333	3.6515	10.65	5900	110	0.0186	1.3654	72.02	82.67	44.44	44.44	26.67
L1	624.8	0.188	300	10	0.0333	1.8257	19.18	13200	1005	0.0761	2.7593	79.73	98.91	85.00	85.00	51.00
L2	107.7	0.089	300	9	0.0300	1.7321	22.01	2800	231	0.0825	2.8723	16.25	38.26	27.22	27.22	16.33
L3	59.4	0.362	300	24	0.0800	2.8284	11.62	2320	70	0.0302	1.7370	22.26	33.88	24.56	24.56	14.73

Excerpt from High Country Engineering Final
Drainage Report for Town Center at Grand Park

Lag Time – Developed Conditions

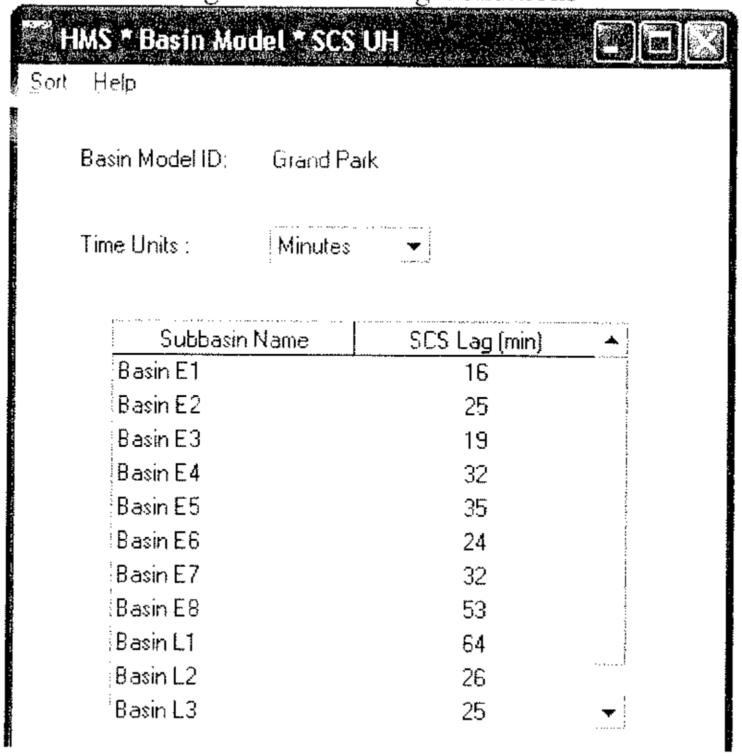


Basin Model ID: Grand Park Developed

Time Units : Minutes

Subbasin Name	SCS Lag (min)
Basin E1	12
Basin E2	21
Basin E3	14
Basin E4	25
Basin E5	30
Basin E6	13
Basin E7	16
Basin E8	27
Basin L1	51
Basin L2	16
Basin L3	15

Lag Time – Existing Conditions



Basin Model ID: Grand Park

Time Units : Minutes

Subbasin Name	SCS Lag (min)
Basin E1	16
Basin E2	25
Basin E3	19
Basin E4	32
Basin E5	35
Basin E6	24
Basin E7	32
Basin E8	53
Basin L1	64
Basin L2	26
Basin L3	25

No Baseflow for All Basins

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TABLE RO-3

Recommended Percentage Imperviousness Values

Land Use or Surface Characteristics	Percentage Imperviousness
Business:	
Commercial areas	95
Neighborhood areas	85
Residential:	
Single-family	*
Multi-unit (detached)	60
Multi-unit (attached)	75
Half-acre lot or larger	*
Apartments	80
Industrial:	
Light areas	80
Heavy areas	90
Parks, cemeteries	5
Playgrounds	10
Schools	50
Railroad yard areas	15
Undeveloped Areas:	
Historic flow analysis	2
Greenbelts, agricultural	2
Off-site flow analysis (when land use not defined)	45
Streets:	
Paved	100
Gravel (packed)	40
Drive and walks	90
Roofs	90
Lawns, sandy soil	0
Lawns, clayey soil	0

* See Figures RO-3 through RO-5 for percentage imperviousness.

Based in part on the data collected by the District since 1969, an empirical relationship between *C* and the percentage imperviousness for various storm return periods was developed. Thus, values for *C* can be determined using the following equations (Urbonas, Guo and Tucker 1990).

$$C_A = K_A + \left(1.31i^3 - 1.44i^2 + 1.135i - 0.12\right) \text{ for } C_A \geq 0\text{, otherwise } C_A = 0 \tag{RO-6}$$

$$C_{CD} = K_{CD} + \left(0.858i^3 - 0.786i^2 + 0.774i + 0.04\right) \tag{RO-7}$$

$$C_B = (C_A + C_{CD})/2$$

in which:

i = % imperviousness/100 expressed as a decimal (see Table RO-3)

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TABLE RO-5

Runoff Coefficients, *C*

Percentage Imperviousness	Type C and D NRCS Hydrologic Soil Groups					
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
0%	0.04	0.15	0.25	0.37	0.44	0.50
5%	0.08	0.18	0.28	0.39	0.46	0.52
10%	0.11	0.21	0.30	0.41	0.47	0.53
15%	0.14	0.24	0.32	0.43	0.49	0.54
20%	0.17	0.26	0.34	0.44	0.50	0.55
25%	0.20	0.28	0.36	0.46	0.51	0.56
30%	0.22	0.30	0.38	0.47	0.52	0.57
35%	0.25	0.33	0.40	0.48	0.53	0.57
40%	0.28	0.35	0.42	0.50	0.54	0.58
45%	0.31	0.37	0.44	0.51	0.55	0.59
50%	0.34	0.40	0.46	0.53	0.57	0.60
55%	0.37	0.43	0.48	0.55	0.58	0.62
60%	0.41	0.46	0.51	0.57	0.60	0.63
65%	0.45	0.49	0.54	0.59	0.62	0.65
70%	0.49	0.53	0.57	0.62	0.65	0.68
75%	0.54	0.58	0.62	0.66	0.68	0.71
80%	0.60	0.63	0.66	0.70	0.72	0.74
85%	0.66	0.68	0.71	0.75	0.77	0.79
90%	0.73	0.75	0.77	0.80	0.82	0.83
95%	0.80	0.82	0.84	0.87	0.88	0.89
100%	0.89	0.90	0.92	0.94	0.95	0.96
	Type B NRCS Hydrologic Soils Group					
0%	0.02	0.08	0.15	0.25	0.30	0.35
5%	0.04	0.10	0.19	0.28	0.33	0.38
10%	0.06	0.14	0.22	0.31	0.36	0.40
15%	0.08	0.17	0.25	0.33	0.38	0.42
20%	0.12	0.20	0.27	0.35	0.40	0.44
25%	0.15	0.22	0.30	0.37	0.41	0.46
30%	0.18	0.25	0.32	0.39	0.43	0.47
35%	0.20	0.27	0.34	0.41	0.44	0.48
40%	0.23	0.30	0.36	0.42	0.46	0.50
45%	0.26	0.32	0.38	0.44	0.48	0.51
50%	0.29	0.35	0.40	0.46	0.49	0.52
55%	0.33	0.38	0.43	0.48	0.51	0.54
60%	0.37	0.41	0.46	0.51	0.54	0.56
65%	0.41	0.45	0.49	0.54	0.57	0.59
70%	0.45	0.49	0.53	0.58	0.60	0.62
75%	0.51	0.54	0.58	0.62	0.64	0.66
80%	0.57	0.59	0.63	0.66	0.68	0.70
85%	0.63	0.66	0.69	0.72	0.73	0.75
90%	0.71	0.73	0.75	0.78	0.80	0.81
95%	0.79	0.81	0.83	0.85	0.87	0.88
100%	0.89	0.90	0.92	0.94	0.95	0.96

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

TABLE RO-5 (CONTINUED)

Runoff Coefficients, *C*

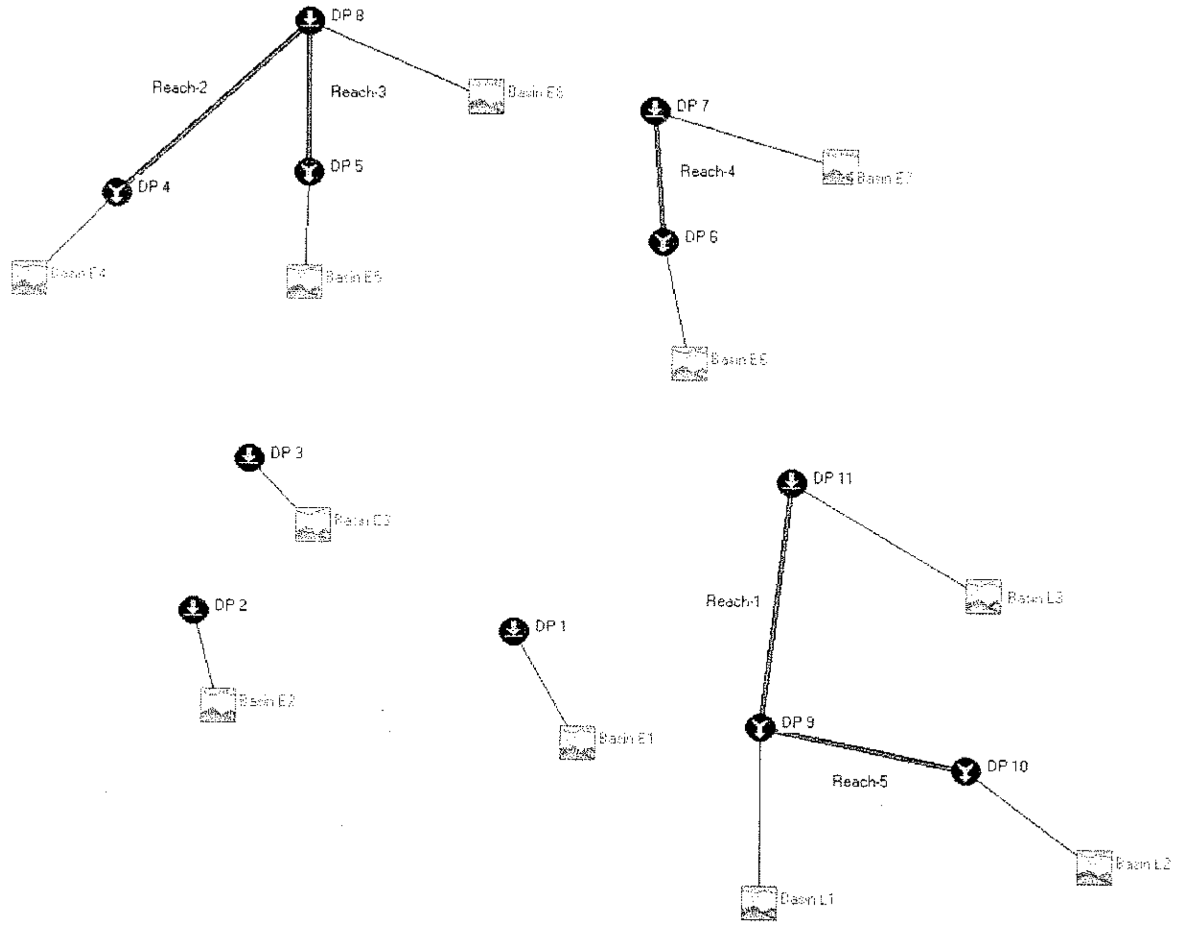
Percentage Imperviousness	Type A NRCS Hydrologic Soils Group					
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
0%	0.00	0.00	0.05	0.12	0.16	0.20
5%	0.00	0.02	0.10	0.16	0.20	0.24
10%	0.00	0.06	0.14	0.20	0.24	0.28
15%	0.02	0.10	0.17	0.23	0.27	0.30
20%	0.06	0.13	0.20	0.26	0.30	0.33
25%	0.09	0.16	0.23	0.29	0.32	0.35
30%	0.13	0.19	0.25	0.31	0.34	0.37
35%	0.16	0.22	0.28	0.33	0.36	0.39
40%	0.19	0.25	0.30	0.35	0.38	0.41
45%	0.22	0.27	0.33	0.37	0.40	0.43
50%	0.25	0.30	0.35	0.40	0.42	0.45
55%	0.29	0.33	0.38	0.42	0.45	0.47
60%	0.33	0.37	0.41	0.45	0.47	0.50
65%	0.37	0.41	0.45	0.49	0.51	0.53
70%	0.42	0.45	0.49	0.53	0.54	0.56
75%	0.47	0.50	0.54	0.57	0.59	0.61
80%	0.54	0.56	0.60	0.63	0.64	0.66
85%	0.61	0.63	0.66	0.69	0.70	0.72
90%	0.69	0.71	0.73	0.76	0.77	0.79
95%	0.78	0.80	0.82	0.84	0.85	0.86
100%	0.89	0.90	0.92	0.94	0.95	0.96

Excerpt from High Country Engineering Final
Drainage Report for Town Center at Grand Park

APPENDIX B– HYDROLOGIC OUTPUT

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

Grand Park Master Drainage Plan



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Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

ummary of Results

100-yr Existing Conditions

Hydrologic Element	Discharge Peak	Time of Peak	Volume (ac	Drainage Area
Basin E6	19.324		2.2342	0.064
DP 6	19.324		2.2342	0.064
Reach-4	19.148		2.1672	0.064
Basin E7	33.958		5.6703	0.287
DP 7	50.463		7.8376	0.351
Basin E4	39.604		6.0580	0.244
DP 4	39.604		6.0580	0.244
Reach-2	39.456		5.9452	0.244
Basin E5	93.513		13.188	0.345
DP 5	93.513		13.188	0.345
Reach-3	93.055		13.103	0.345
Basin E8	14.739		2.8117	0.077
DP 8	144.80		21.860	0.666
Basin E3	5.9553		0.75839	0.038
DP 3	5.9553		0.75839	0.038
Basin E2	40.212		5.8967	0.297
DP 2	40.212		5.8967	0.297
Basin E1	18.510		2.1992	0.110
DP 1	18.510		2.1992	0.110
Basin L2	22.406		3.3349	0.168
DP 10	22.406		3.3349	0.168
Reach-5	22.211		3.3140	0.168
Basin L1	172.59		37.471	0.975
DP 9	182.22		40.785	1.143
Reach-1	182.13		40.424	1.143
Basin L3	27.551		3.2445	0.093
DP 11	189.24		43.668	1.236

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

mmary of Results

2-yr Existing Conditions

Hydrologic Element	Discharge Peak	Time of Peak	Volume (ac	Drainage Area
Basin E6	0.74542		0.18222	0.064
DP 6	0.74542		0.18222	0.064
Reach-4	0.73971		0.17154	0.064
Basin E7	2.8198		0.40225	0.287
DP 7	2.8510		0.57379	0.351
Basin E4	2.3979		0.38328	0.244
DP 4	2.3979		0.38328	0.244
Reach-2	2.3772		0.37110	0.244
Basin E5	3.9164		1.2088	0.345
DP 5	3.9164		1.2088	0.345
Reach-3	3.9070		1.1925	0.345
Basin E8	0.65430		0.24698	0.077
DP 8	6.9324		1.8106	0.666
Basin E3	0.49955			0.038
DP 3	0.49955			0.038
Basin E2	3.3527		0.41665	0.297
DP 2	3.3527		0.41665	0.297
Basin E1	1.5772		0.15453	0.110
DP 1	1.5772		0.15453	0.110
Basin L2	1.8632		0.23569	0.168
DP 10	1.8632		0.23569	0.168
Reach-5	1.8544		0.23475	0.168
Basin L1	8.6585		3.5367	0.975
DP 9	9.1755		3.7714	1.143
Reach-1	9.1722		3.7080	1.143
Basin L3	1.0660		0.26461	0.093
DP 11	9.5213		3.9726	1.236

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

mmary of Results

Project : Grand Park   Run Name : Run 2

100-year Developed Conditions

Hydrologic Element	Discharge Peak	Time of Peak	Volume (ac	Drainage Area
Basin E6	58.514		4.3100	0.064
DP 6	58.514		4.3100	0.064
Reach-4	58.266		4.1881	0.064
Basin E7	369.67		28.966	0.287
DP 7	389.07		33.154	0.351
Basin E4	104.03		11.402	0.244
DP 4	104.03		11.402	0.244
Reach-2	103.96		11.289	0.244
Basin E5	224.62		25.350	0.345
DP 5	224.62		25.350	0.345
Reach-3	222.28		25.248	0.345
Basin E8	48.024		5.1549	0.077
DP 8	371.66		41.692	0.666
Basin E3	11.596		1.0982	0.038
DP 3	11.596		1.0982	0.038
Basin E2	74.579		8.5401	0.297
DP 2	74.579		8.5401	0.297
Basin E1	36.219		3.1821	0.110
DP 1	36.219		3.1821	0.110
Basin L2	28.249		3.3581	0.168
DP 10	28.249		3.3581	0.168
Reach-5	27.823		3.3345	0.168
Basin L1	176.12		33.408	0.975
DP 9	186.02		36.743	1.143
Reach-1	185.60		36.398	1.143
Basin L3	94.340		7.2045	0.093
DP 11	196.72		43.602	1.236

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

mmary of Results

Project : Grand Park   Run Name : Run 4

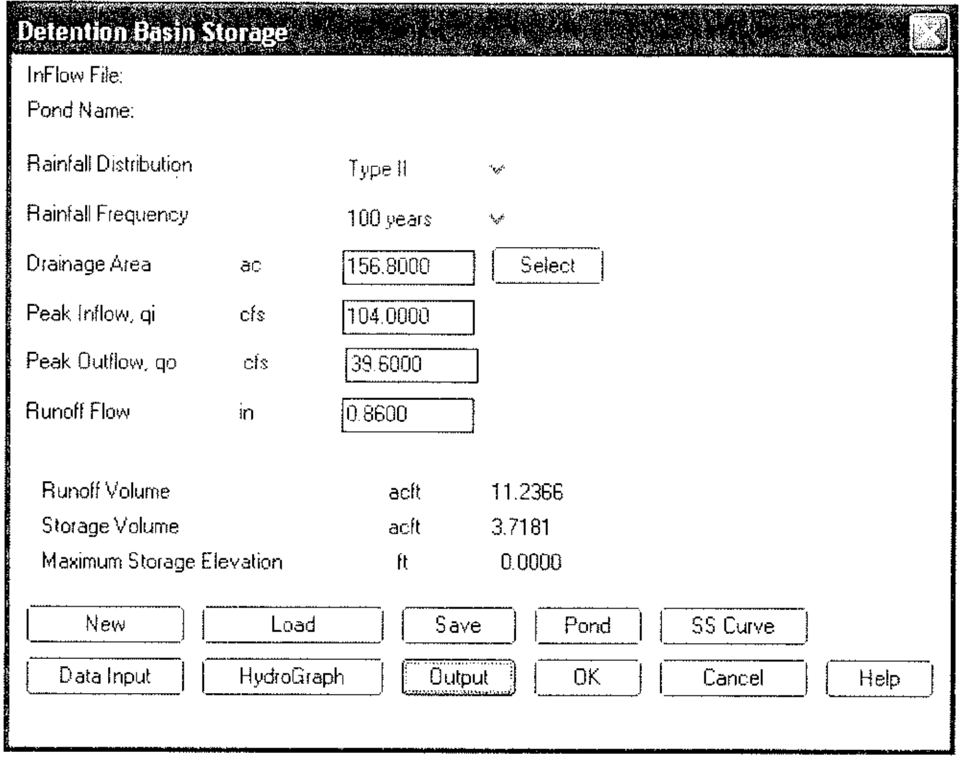
2-year Developed Conditions

Hydrologic Element	Discharge Peak	Time of Peak	Volume (ac	Drainage Area
Basin E6	7.4256		0.76401	0.064
DP 6	7.4256		0.76401	0.064
Reach-4	7.2605		0.78619	0.064
Basin E7	90.356		7.8460	0.287
DP 7	90.390		8.6321	0.351
Basin E4	6.2238		1.3307	0.244
DP 4	6.2238		1.3307	0.244
Reach-2	6.1836		1.2996	0.244
Basin E5	34.032		4.9823	0.345
DP 5	34.032		4.9823	0.345
Reach-3	33.888		4.9611	0.345
Basin E8	6.1455		0.91482	0.077
DP 8	44.126		7.1755	0.666
Basin E3	0.57987			0.038
DP 3	0.57987			0.038
Basin E2	3.7038		0.57448	0.297
DP 2	3.7038		0.57448	0.297
Basin E1	1.8115		0.21388	0.110
DP 1	1.8115		0.21388	0.110
Basin L2	2.4079		0.23600	0.168
DP 10	2.4079		0.23600	0.168
Reach-5	2.3886		0.23524	0.168
Basin L1	7.4891		2.7233	0.975
DP 9	8.2402		2.9585	1.143
Reach-1	8.2230		2.9043	1.143
Basin L3	15.280		1.4853	0.093
DP 11	16.616		4.3897	1.236

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

Detention Calculations – AutoCAD Hydrology Method

Design Point 4 – Elk Creek at Railroad

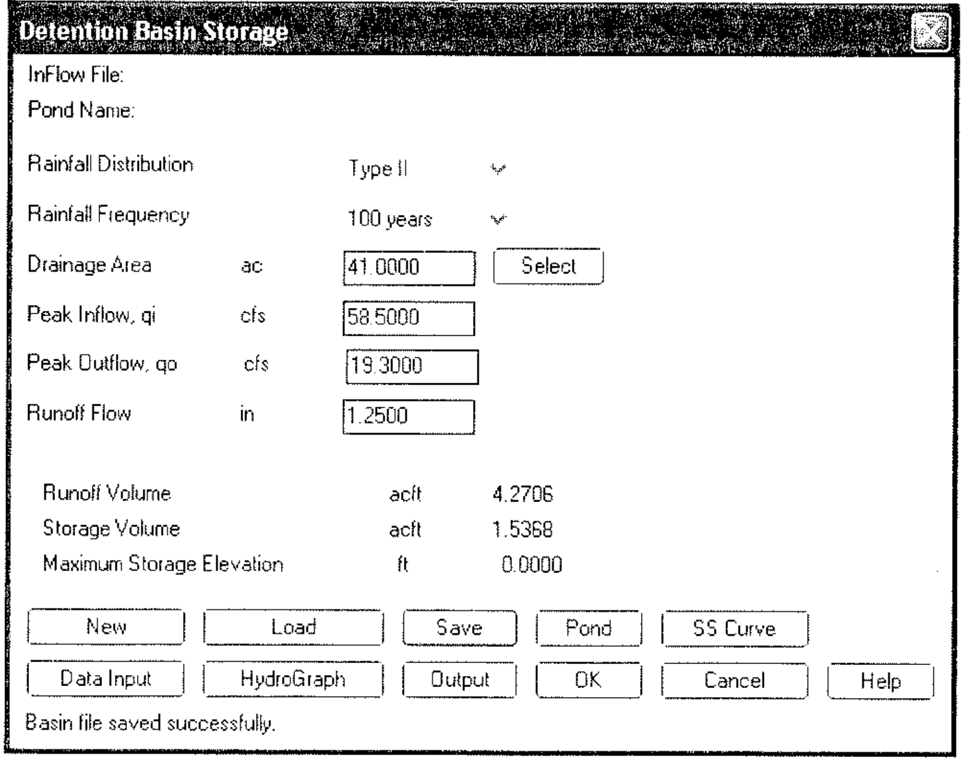


InFlow File:
Pond Name:

Rainfall Distribution Type II
Rainfall Frequency 100 years
Drainage Area ac 156.8000
Peak Inflow, qi cfs 104.0000
Peak Outflow, qo cfs 39.6000
Runoff Flow in 0.8600

Runoff Volume acft 11.2366
Storage Volume acft 3.7181
Maximum Storage Elevation ft 0.0000

Design Point 6 – Unknown Drainage Culvert at Railroad



InFlow File:
Pond Name:

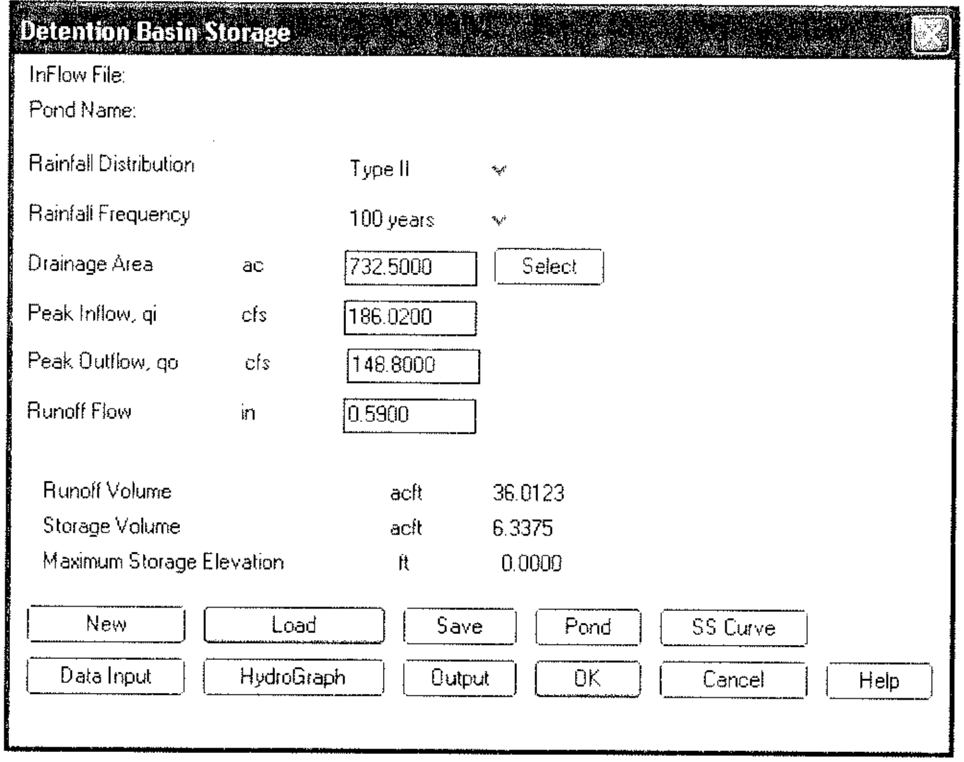
Rainfall Distribution Type II
Rainfall Frequency 100 years
Drainage Area ac 41.0000
Peak Inflow, qi cfs 58.5000
Peak Outflow, qo cfs 19.3000
Runoff Flow in 1.2500

Runoff Volume acft 4.2706
Storage Volume acft 1.5368
Maximum Storage Elevation ft 0.0000

Basin file saved successfully.

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

Design Point 9 – Leland Creek at Railroad



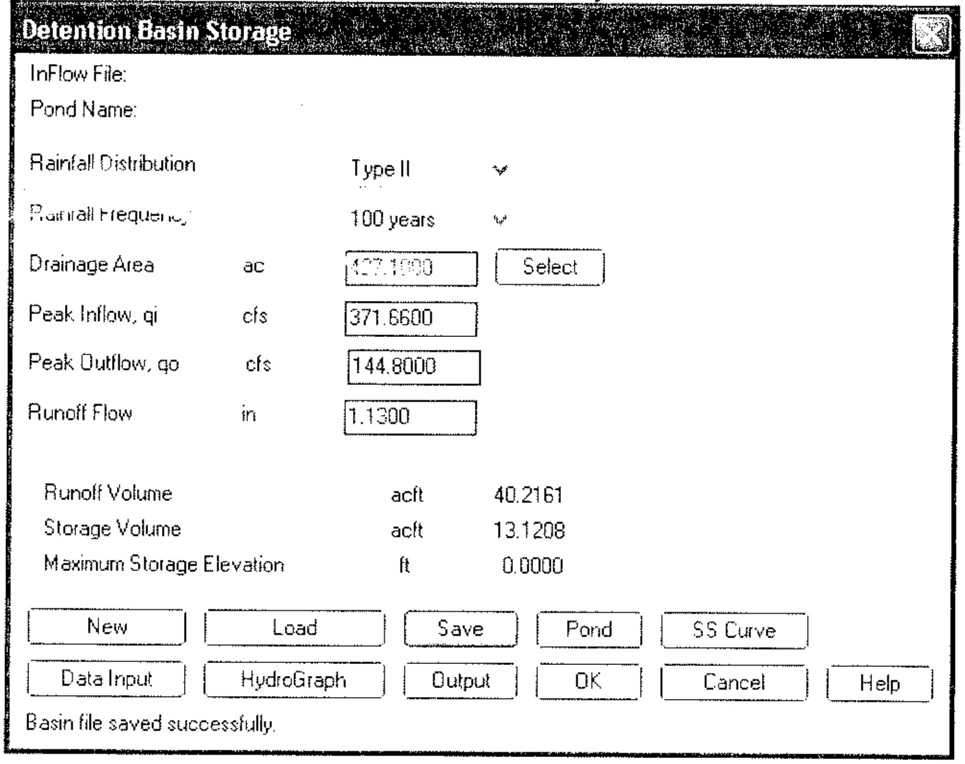
InFlow File:

Pond Name:

Rainfall Distribution		Type II
Rainfall Frequency		100 years
Drainage Area	ac	732.5000
Peak Inflow, qi	cfs	186.0200
Peak Outflow, qo	cfs	148.8000
Runoff Flow	in	0.5900

Runoff Volume	acft	36.0123
Storage Volume	acft	6.3375
Maximum Storage Elevation	ft	0.0000

Design Point 8 – Elk Creek at US 40 Boundary



InFlow File:

Pond Name:

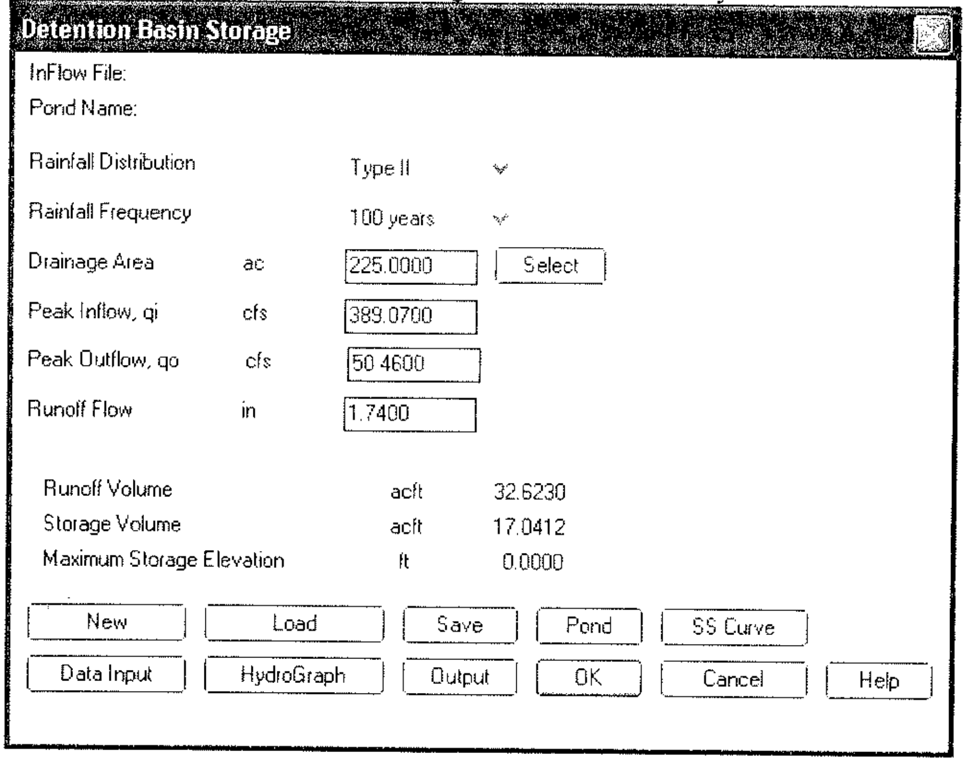
Rainfall Distribution		Type II
Rainfall Frequency		100 years
Drainage Area	ac	427.1000
Peak Inflow, qi	cfs	371.6600
Peak Outflow, qo	cfs	144.8000
Runoff Flow	in	1.1300

Runoff Volume	acft	40.2161
Storage Volume	acft	13.1208
Maximum Storage Elevation	ft	0.0000

Basin file saved successfully.

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

Design Point 7 – Unknown Drainage at US 40 Boundary



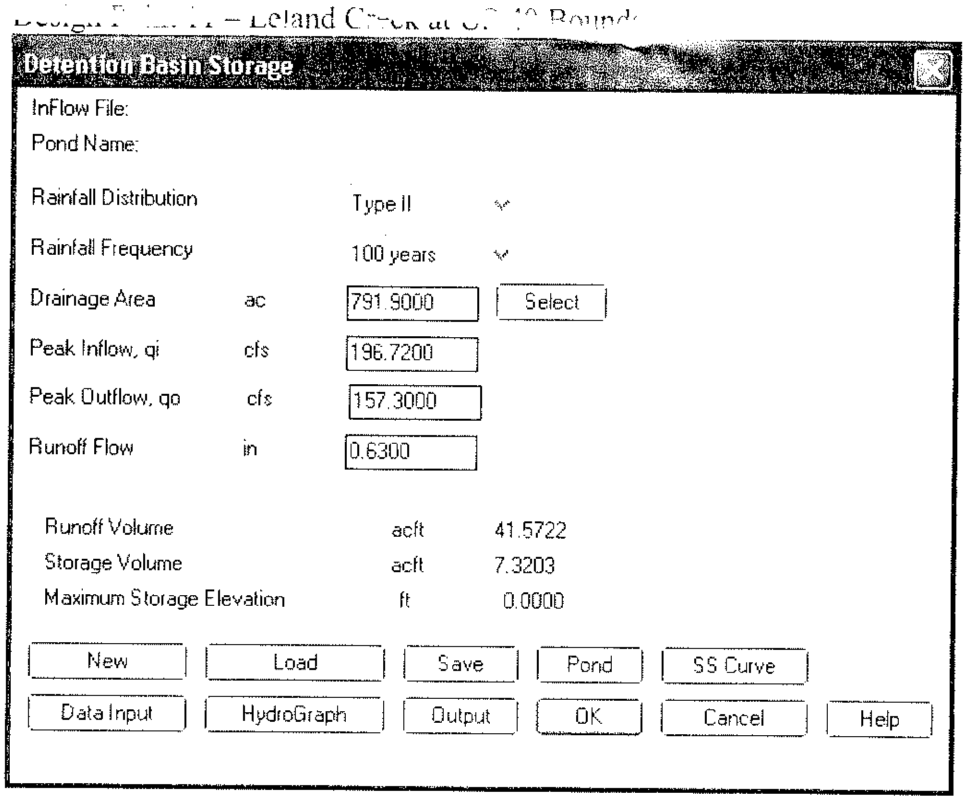
Detention Basin Storage

InFlow File:

Pond Name:

Rainfall Distribution		Type II
Rainfall Frequency		100 years
Drainage Area	ac	225.0000
Peak Inflow, qi	cfs	389.0700
Peak Outflow, qo	cfs	50.4600
Runoff Flow	in	1.7400
Runoff Volume	acft	32.6230
Storage Volume	acft	17.0412
Maximum Storage Elevation	ft	0.0000

Design Point 11 – Leland Creek at US 40 Bound



Detention Basin Storage

InFlow File:

Pond Name:

Rainfall Distribution		Type II
Rainfall Frequency		100 years
Drainage Area	ac	791.9000
Peak Inflow, qi	cfs	196.7200
Peak Outflow, qo	cfs	157.3000
Runoff Flow	in	0.6300
Runoff Volume	acft	41.5722
Storage Volume	acft	7.3203
Maximum Storage Elevation	ft	0.0000

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

Grand Park - Existing Conditions
HCE Project No. 2052014.00
Detention Volumes and Release Rates

Design Point 4 - Elk Creek at Railroad

Basin	Area (acres)	% Imperviousness	Type B	Type C
E4	156.6	26%	78%	22%

UDCFD Volume 2, Section3.2.2 Empirical Equations for Sizing On-site Detention Storage Volumes

$$V_i = K_i{*}A$$

$$K_{100} = \frac{(1.78I - 0.002I^2 - 3.56)}{900}$$

$$K_{10} = \frac{(0.95I - 1.90)}{1000}$$

I =	26.00	total ratio
Area =	156.6	acres

K_{100} = 0.046
K_{10} = 0.023

V_{100} = 7.198 acre-feet
V_{10} = 3.570 acre-feet

UDCFD Volume 2, Section 3.2.1 Allowable Release Rates

From Table SO-1 Maximum Allowable Unit Flow Release Rates:

	Soil Group B	C & D
10 year Flow	0.305	0.365
100 year Flow	0.460	0.560

10 yr Release Rate = 49.83 cfs
100 yr Release Rate = 75.48 cfs

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

Grand Park - Existing Conditions
HCE Project No. 2052014.00
Detention Volumes and Release Rates

Design Point 6 - Unknown Drainage Culvert

Basin	Area (acres)	% Imperviousness	Type B	Type C
E6	41	41%	38%	62%

UDCFD Volume 2, Section3.2.2 Empirical Equations for Sizing On-site Detention Storage Volumes

$$V_i = K_i{*}A$$

$$K_{100} = \frac{(1.78I - 0.002I^2 - 3.56)}{900}$$

$$K_{10} = \frac{(0.95I - 1.90)}{1000}$$

I =	41.00	total ratio
Area =	41	acres

$K_{100} =$ 0.073
$K_{10} =$ 0.037

$V_{100} =$ 3.009 acre-feet
$V_{10} =$ 1.519 acre-feet

UDCFD Volume 2, Section 3.2.1 Allowable Release Rates

From Table SO-1 Maximum Allowable Unit Flow Release Rates:

	Soil Group B	C & D
10 year Flow	0.365	0.425
100 year Flow	0.500	0.580

10 yr Release Rate = 16.49 cfs
100 yr Release Rate = 22.53 cfs

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

Grand Park - Existing Conditions
HCE Project No. 2052014.00
Detention Volumes and Release Rates

Design Point 9 - Leland Creek at Railroad

Basin	Area (acres)	% Imperviousness	A*I	(A*I)/ΣA	Type B	Type C
L1	624.8	15%	93.72	12.79%	75%	25%
L2	107.7	2%	2.1546	0.29%	100%	0%
Total	732.5			13.09%		

UDCFD Volume 2, Section3.2.2 Empirical Equations for Sizing On-site Detention Storage Volumes

$V_i = K_i{*}A$

$$K_{100} = \frac{(1.78I - 0.002I^2 - 3.56)}{900}$$

$$K_{10} = \frac{(0.95I - 1.90)}{1000}$$

I = 13.09 total ratio
Area = 732.5 acres

K_{100} = 0.022
K_{10} = 0.011

V_{100} = **15.785** **acre-feet**
V_{10} = **7.716** **acre-feet**

UDCFD Volume 2, Section 3.2.1 Allowable Release Rates

From Table SO-1 Maximum Allowable Unit Flow Release Rates:

	Soil Group B	C & D
10 year Flow	0.230	0.310
100 year Flow	0.410	0.535

10 yr Release Rate = 180.94 cfs
100 yr Release Rate = 319.78 cfs

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

Grand Park - Existing Conditions
HCE Project No. 2052014.00
Detention Volumes and Release Rates

Design Point 8 - Elk Creek at US 40 Boundary

Basin	Area (acres)	% Imperviousness	A*I	(A*I)/ΣA	Type B	Type C	Type A
E4	156.6	26%	40.7264	9.54%	78%	22%	0.00%
E5	221.0	36%	79.5492	18.62%	26%	74%	0.00%
E8	49.5	32%	15.84	3.71%	24%	74%	2%
Total	427.1			28.16%			

UDCFD Volume 2, Section3.2.2 Empirical Equations for Sizing On-site Detention Storage Volumes

$V_i = K_i{*}A$

$$K_{100} = \frac{(1.78I - 0.002I^2 - 3.56)}{900}$$

$$K_{10} = \frac{(0.95I - 1.90)}{1000}$$

I = 28.16 total ratio
Area = 427.1 acres

$K_{100} =$ 0.050
$K_{10} =$ 0.025

$V_{100} =$ 21.346 acre-feet
$V_{10} =$ 10.615 acre-feet

UDCFD Volume 2, Section 3.2.1 Allowable Release Rates

From Table SO-1 Maximum Allowable Unit Flow Release Rates:

	Soil Group B	C & D	A
10 year Flow	0.325	0.385	0.260
100 year Flow	0.475	0.570	0.375

10 yr Release Rate = 152.75 cfs
100 yr Release Rate = 224.96 cfs

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

Grand Park - Existing Conditions
HCE Project No. 2052014.00
Detention Volumes and Release Rates

Design Point 7 - Unknown Drainage at US 40 Boundary

Basin	Area (acres)	% Imperviousness	A*I	(A*I)/ΣA	Type B	Type C	Type A
E6	41.0	41%	16.8182	7.48%	38%	62%	0%
E7	184.0	73%	134.2835	59.69%	17%	54%	29%
Total	225.0			67.17%			

UDCFD Volume 2, Section3.2.2 Empirical Equations for Sizing On-site Detention Storage Volumes

$V_i = K_i * A$

$$K_{100} = \frac{(1.78I - 0.002I^2 - 3.56)}{900}$$

$$K_{10} = \frac{(0.95I - 1.90)}{1000}$$

I = 67.17 total ratio
Area = 225.0 acres

$K_{100} =$ 0.119
$K_{10} =$ 0.062

$V_{100} =$ 26.739 acre-feet
$V_{10} =$ 13.927 acre-feet

UDCFD Volume 2, Section 3.2.1 Allowable Release Rates

From Table SO-1 Maximum Allowable Unit Flow Release Rates:

	Soil Group B	C & D	A
10 year Flow	0.510	0.555	0.470
100 year Flow	0.605	0.665	0.545

10 yr Release Rate = 118.15 cfs
100 yr Release Rate = 140.30 cfs

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

Grand Park - Existing Conditions
HCE Project No. 2052014.00
Detention Volumes and Release Rates

Design Point 11 - Leland Creek at US 40 Boundary

Basin	Area (acres)	% Imperviousness	A*I	(A*I)/ΣA	Type B	Type C	Type A
L1	624.8	15%	93.72	11.84%	75%	25%	0.00%
L2	107.7	2%	2.1546	0.27%	100%	0%	0.00%
L3	59.4	47%	27.89727	3.52%	41%	58%	2%
Total	791.9			15.63%			

UDCFD Volume 2, Section3.2.2 Empirical Equations for Sizing On-site Detention Storage Volumes

$$V_i = K_i{*}A$$

$$K_{100} = \frac{(1.78I - 0.002I^2 - 3.56)}{900}$$

$$K_{10} = \frac{(0.95I - 1.90)}{1000}$$

I = 15.63 total ratio
Area = 791.9 acres

$K_{100} =$ 0.026
$K_{10} =$ 0.013

$V_{100} =$ 20.917 acre-feet
$V_{10} =$ 10.254 acre-feet

UDCFD Volume 2, Section 3.2.1 Allowable Release Rates

From Table SO-1 Maximum Allowable Unit Flow Release Rates:

	Soil Group B	C & D	A
10 year Flow	0.250	0.240	0.170
100 year Flow	0.420	0.540	0.300

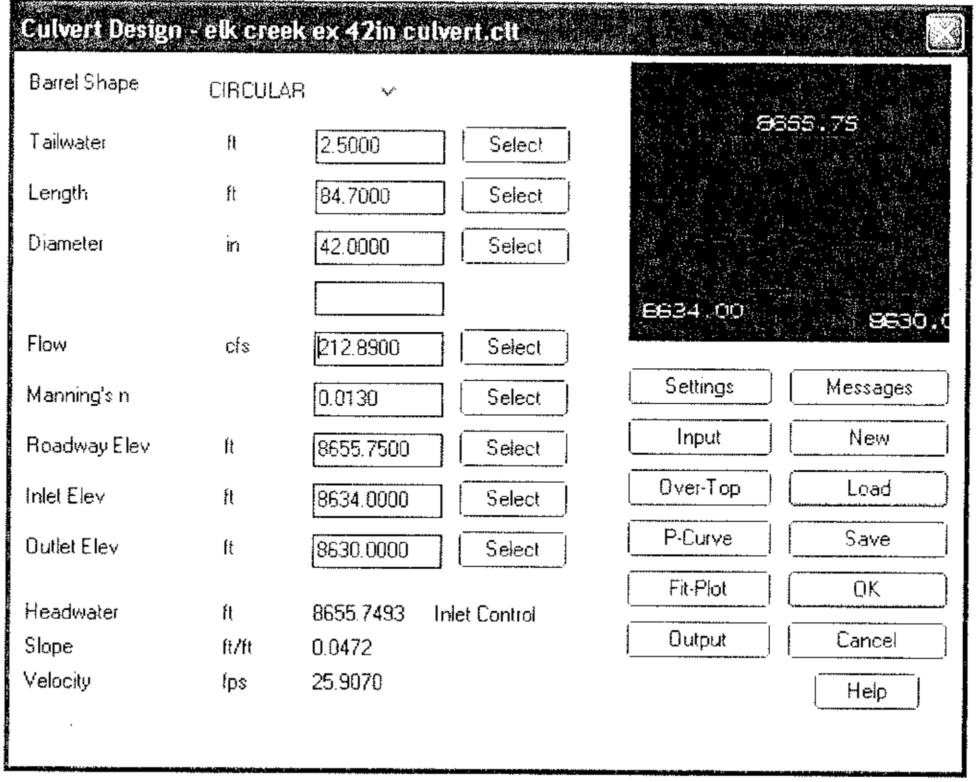
10 yr Release Rate = 195.91 cfs
100 yr Release Rate = 355.23 cfs

Excerpt from High Country Engineering Final
Drainage Report for Town Center at Grand Park

APPENDIX C – CULVERT CALCULATIONS

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

Elk Creek Capacity – Flow at Railroad Elevation



Culvert Design - elk creek ex 42in culvert.clt

Barrel Shape CIRCULAR

Tailwater ft 2.5000

Length ft 84.7000

Diameter in 42.0000

Flow cfs 212.8900

Manning's n 0.0130

Roadway Elev ft 8655.7500

Inlet Elev ft 8634.0000

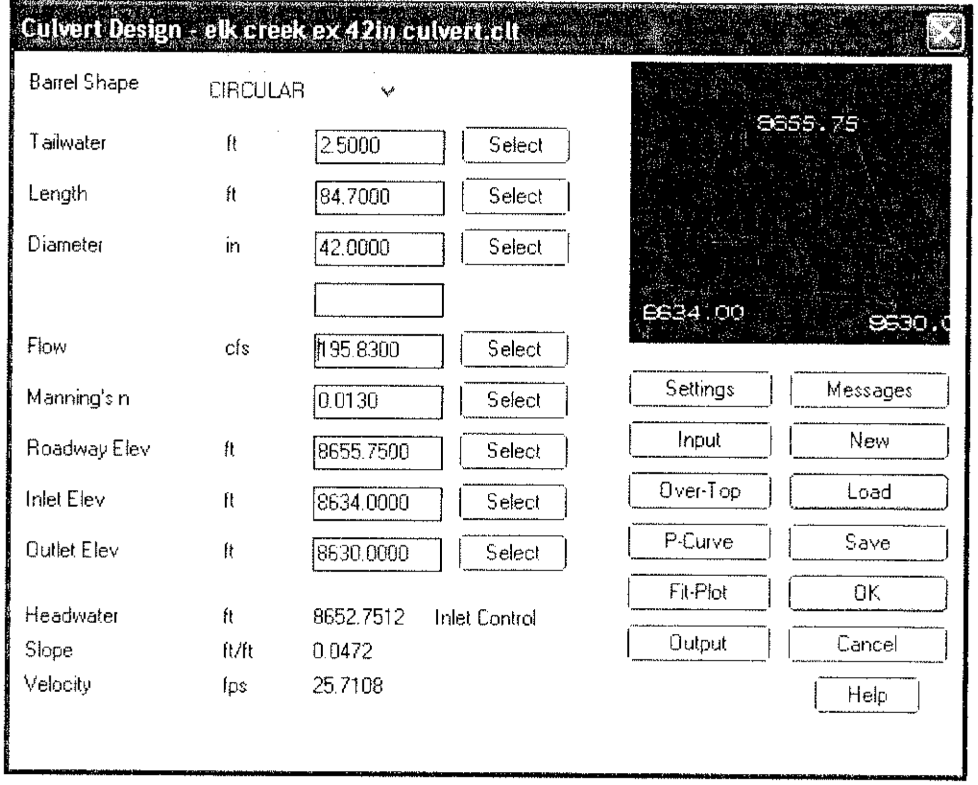
Outlet Elev ft 8630.0000

Headwater ft 8655.7493 Inlet Control

Slope ft/ft 0.0472

Velocity fps 25.9070

Elk Creek Capacity – Flow at 3' below Railroad Elevation



Culvert Design - elk creek ex 42in culvert.clt

Barrel Shape CIRCULAR

Tailwater ft 2.5000

Length ft 84.7000

Diameter in 42.0000

Flow cfs 195.8300

Manning's n 0.0130

Roadway Elev ft 8655.7500

Inlet Elev ft 8634.0000

Outlet Elev ft 8630.0000

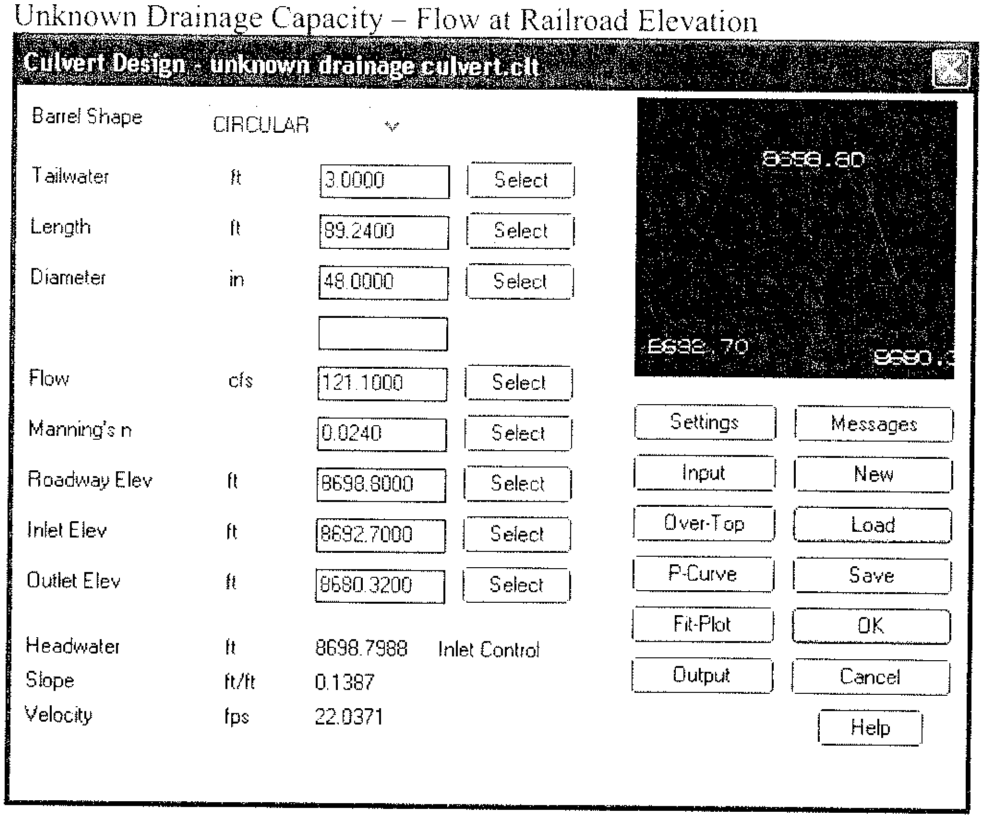
Headwater ft 8652.7512 Inlet Control

Slope ft/ft 0.0472

Velocity fps 25.7108

Excerpt from High Country Engineering Final Drainage Report for Town Center at Grand Park

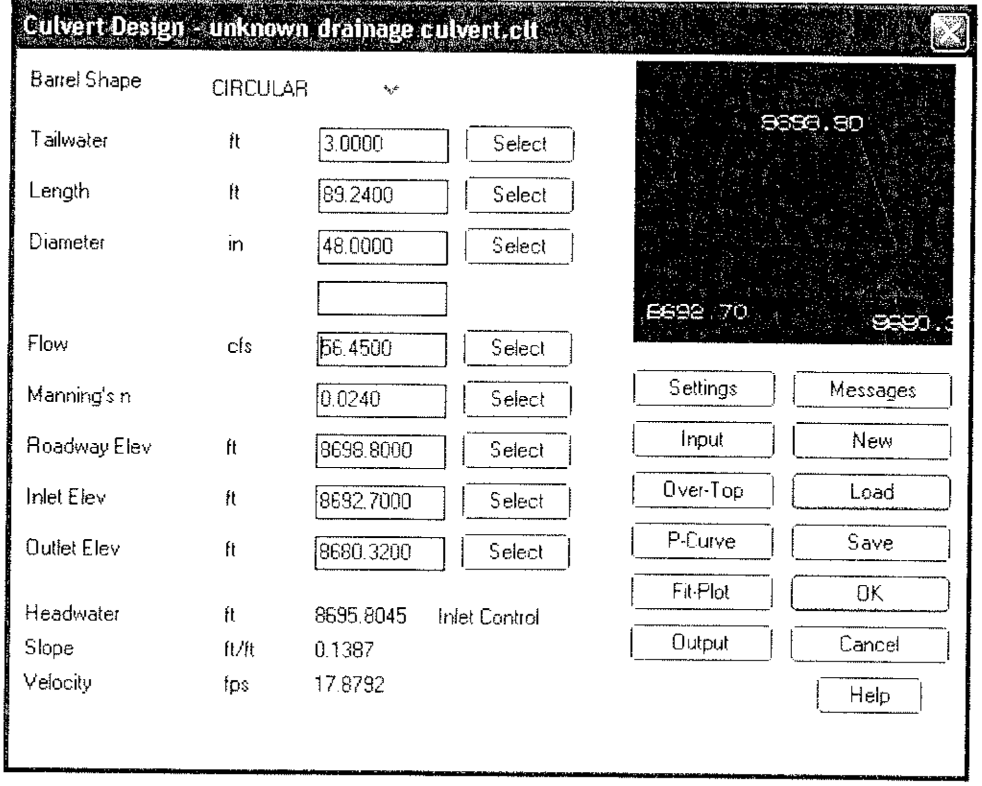
Unknown Drainage Capacity – Flow at Railroad Elevation



Culvert Design - unknown drainage culvert.clt

Barrel Shape		CIRCULAR
Tailwater	ft	3.0000
Length	ft	89.2400
Diameter	in	48.0000
Flow	cfs	121.1000
Manning's n		0.0240
Roadway Elev	ft	8698.8000
Inlet Elev	ft	8692.7000
Outlet Elev	ft	8680.3200
Headwater	ft	8698.7988 Inlet Control
Slope	ft/ft	0.1387
Velocity	fps	22.0371

Unknown Drainage Capacity – Flow at 3' below Railroad Elevation

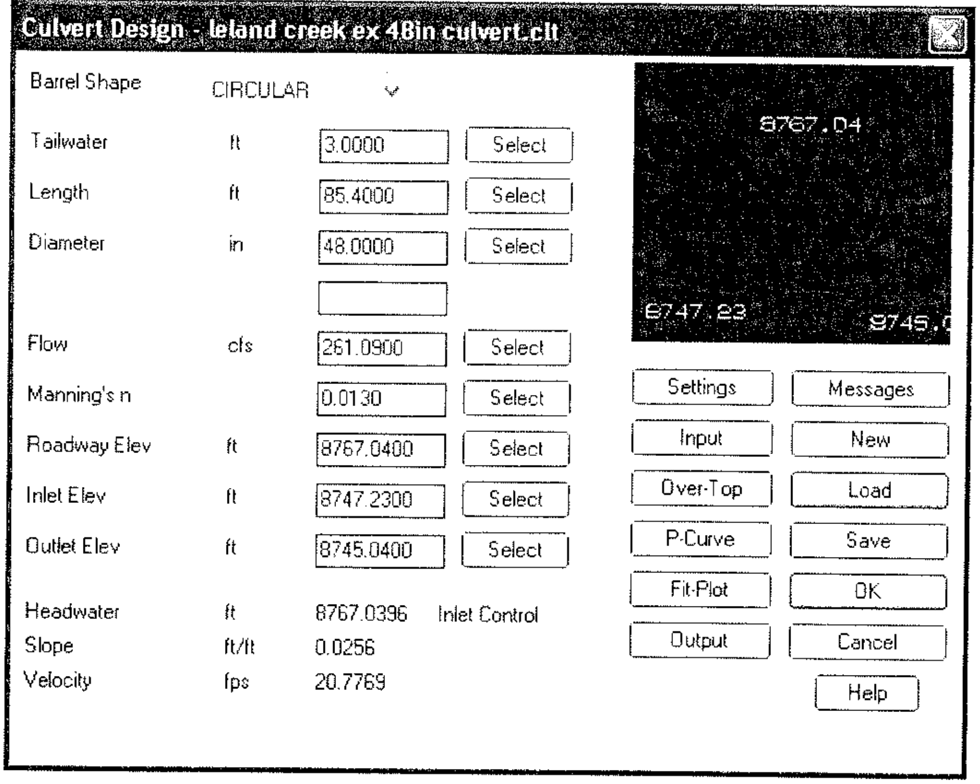


Culvert Design - unknown drainage culvert.clt

Barrel Shape		CIRCULAR
Tailwater	ft	3.0000
Length	ft	89.2400
Diameter	in	48.0000
Flow	cfs	56.4500
Manning's n		0.0240
Roadway Elev	ft	8698.8000
Inlet Elev	ft	8692.7000
Outlet Elev	ft	8680.3200
Headwater	ft	8695.8045 Inlet Control
Slope	ft/ft	0.1387
Velocity	fps	17.8792

Excerpt from High Country Engineering Final
Drainage Report for Town Center at Grand Park

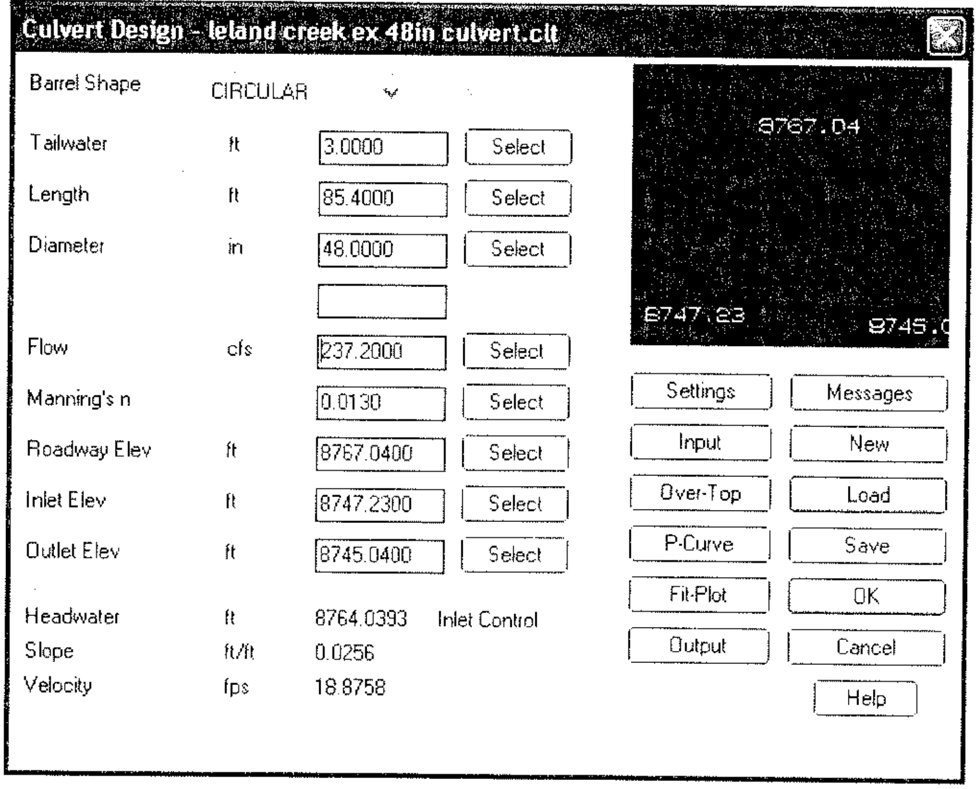
Leland Creek Capacity – Flow at Railroad Elevation



Culvert Design - leland creek ex 48in culvert.clt

Barrel Shape		CIRCULAR	
Tailwater	ft	3.0000	
Length	ft	85.4000	
Diameter	in	48.0000	
Flow	cfs	261.0900	
Manning's n		0.0130	
Roadway Elev	ft	8767.0400	
Inlet Elev	ft	8747.2300	
Outlet Elev	ft	8745.0400	
Headwater	ft	8767.0396	Inlet Control
Slope	ft/ft	0.0256	
Velocity	fps	20.7769	

Leland Creek Capacity – Flow at 3' below Railroad Elevation



Culvert Design - leland creek ex 48in culvert.clt

Barrel Shape		CIRCULAR	
Tailwater	ft	3.0000	
Length	ft	85.4000	
Diameter	in	48.0000	
Flow	cfs	237.2000	
Manning's n		0.0130	
Roadway Elev	ft	8767.0400	
Inlet Elev	ft	8747.2300	
Outlet Elev	ft	8745.0400	
Headwater	ft	8764.0393	Inlet Control
Slope	ft/ft	0.0256	
Velocity	fps	18.8758	

water

MDPI

Article

A Pragmatic Slope-Adjusted Curve Number Model to Reduce Uncertainty in Predicting Flood Runoff from Steep Watersheds

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Abstract: The applicability of the curve number (CN) model to estimate runoff has been a conundrum for years, among other reasons, because it presumes an uncertain fixed initial abstraction coefficient ($\lambda = 0.2$), and because choosing the most suitable watershed CN values is still debated across the globe. Furthermore, the model is widely applied beyond its originally intended purpose. Accordingly, there is a need for more case-specific adjustments of the CN values, especially in steep-slope watersheds with diverse natural environments. This study scrutinized the λ and watershed slope factor effect in estimating runoff. Our proposed slope-adjusted CN ($CN_{II\alpha}$) model used data from 1779 rainstorm–runoff events from 39 watersheds on the Korean Peninsula (1402 for calibration and 377 for validation), with an average slope varying between 7.50% and 53.53%. To capture the agreement between the observed and estimated runoff, the original CN model and its seven variants were evaluated using the root mean square error (RMSE), Nash–Sutcliffe efficiency (NSE), percent bias (PB), and 1:1 plot. The overall lower RMSE, higher NSE, better PB values, and encouraging 1:1 plot demonstrated good agreement between the observed and estimated runoff by one of the proposed variants of the CN model. This plausible goodness-of-fit was possibly due to setting $\lambda = 0.01$ instead of 0.2 or 0.05 and practically sound slope-adjusted CN values to our proposed modifications. For more realistic results, the effects of rainfall and other runoff-producing factors must be incorporated in CN value estimation to accurately reflect the watershed conditions.

Keywords: initial abstraction coefficient; slope-adjusted curve number; rainfall; precise runoff; model accuracy

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1. Introduction

There is plethora of process-based hydrological models, but they require extensive data, which is a limitation in ungauged watersheds. These process-based models are broadly used to estimate and/or predict hydrologic processes across landscapes and to assess the corresponding impacts of land use/cover changes [1]. Rainfall-runoff modeling is among the most fundamental concepts in hydrology, providing a starting point to estimate flood peaks and design structures. The rainfall-runoff process is a dynamic and complex hydrological phenomenon affected by different physical factors and their interactions [2]. Due to the non-linear relationship between rainfall and runoff, the development of a robust model to predict runoff in ungauged watersheds is difficult and time-consuming [3]. The least complex model that reliably meets the anticipated application is often preferable [4]. The advantages of the Natural Resources Conservation Service (NRCS) curve number (CN) [1] model are its simplicity, predictability, and dependence on only one parameter. The CN model has well-documented data, has been globally tested, and has a rich literature. The CN is a function of soil permeability/infiltration capacity, land use/cover, and other runoff-producing conditions of a watershed; it quantifies direct runoff, requiring only the cumulative rainfall depth and the watershed's CN [5]. The initial abstraction coefficient (λ) and the CN in the CN model are vital to accurately estimate runoff from a watershed [6].

1.1. The CN Model Framework

The CN model is structured to quantify runoff depth (Q) using the cumulative rainstorm depth (P) and maximum potential water retention amount (S), a measure of the ability of a watershed to abstract and retain storm precipitation. Here, P, S, and Q are measured in millimeters.

$$Q = \frac{(P - \lambda S)^2}{P + (1 - \lambda)S} \text{ for } P \geq \lambda S Q = \ 0 \text{ otherwise} \tag{1}$$

The initial abstraction is the rainstorm depth required before runoff begins. Originally, it was taken as $I_a = \lambda S = 0.2S$; here, S (mm) is related to CN via

$$CN = 100\left(\frac{x}{x + S}\right) \text{ or } S = x\left(\frac{100}{CN} - 1\right) \text{ for } x = 254 \text{ mm } (\text{or } 10 \text{ in}) \tag{2}$$

The dimensionless CN varies from 0 to 100 [5]. Handbook tables for CN selection are based on soil types and land use/land cover. The threshold of λ = 0.2 is being actively debated across the globe for its inconsistent watershed runoff estimation because λ = 0.05 has been found to be much more representative [2]. Nevertheless, essentially all handbook CN table values correspond to λ = 0.2. The corresponding *S* for λ = 0.05 is different from that for λ= 0.2 and, hence, the resulted runoff values are different. The adjustment of CN from λ = 0.2 to λ = 0.05 has recently been adopted by the Task Group on Curve Number Hydrology [5], which recommends a new relation as $S_{0.05} = 1.42S_{0.2}$, and leads to

$$CN_{0.05} = \frac{100}{1.42 - 0.0042CN_{0.2}} \tag{3}$$

Several studies have shown considerable differences between handbook-tabulated CN values based on land cover/use and those estimated from watershed observations of rainfall–runoff events [2,5,7–10]. The differences are more prominent with smaller CN values and land types not clearly described in the CN tables [5]. Different studies have evidenced runoff prediction from different biomes using λ < 0.2 values [2,10–16], suggesting λ in the range of 0.01 to 0.05.

1.2. Effect of Slope on CN and Runoff Estimation

There is no handbook convention but, intuitively, higher-sloped watersheds should have higher CN values. Several CN-based models have documented positive slope-adjustment techniques [10,17–24]. However, some mild negative relationships for limited data are also available [5]. Steep slopes generally give a higher potential for runoff [25], but the impact of slope steepness on runoff generation is a debatable topic. Researchers from different biomes have reported increases in runoff that were attributed to a decrease in infiltration, less detention storage and ponding depth, and high flow velocity [10,19–22,25,26]. Some researchers have captured reduced runoff generation per unit of slope length from steep-slope watersheds with pronounced decreasing storm duration, which might be due to thinning and/or disruption of the crust, differential soil cracking, formation of rills, and more ponding depth [27–33]. However, other studies [34,35] found insignificant effects of slope steepness on runoff. These discrepancies are possibly due to contradiction in experimental settings, as well as land cover and use differences.

To accurately estimate runoff, the CN values found in handbook tables are more effective for rain-fed agricultural watersheds, are less efficient for semi-arid watersheds, and are least successful for forested watersheds [36]. The CN model has a spotty and inconsistent performance history for some forested watersheds (i.e., those in which infiltration potential usually exceeds the rainfall intensities), and for frequent, low-volume, and low-intensity rainfalls. Some researchers found notable problems associated with the tabulated CN values for heavy land cover and humid, forested watersheds, suggesting that the model is inapplicable for runoff estimation in such watersheds [2,9]. For many years, the CN values obtained from handbook tables have been problematic and may need case-specific adjustment when applied in regions with more complex natural environments. The accuracy of the CN value is vital in runoff estimation [37]. The objective of this study was to frame a practically sound slope-adjusted CN equation that could follow the CN theoretical limits (0, 100) and enhance the runoff prediction capability of the CN model from rainstorm events in steep-sloped watersheds.

2. Materials and Methods

2.1. Study Area Description and Climate

South Korea is typical of regions largely influenced by complicated geographical features. Its precipitation patterns have diverse seasonal and regional variability [38]. The elevation (area) of the watersheds included in this study vary from 26 m (42.32 km^2) to 911 m (879.10 km^2) above mean sea level. The average slope of the watershed ranges between 7.50% and 53.53%. The majority of the land cover (about 70.50%) is upland forests, followed by 20.26% agricultural land, urban areas (5.22%), grassland (1.56%), and other land cover distribution (2.45%). The dominant soil types are loam and sandy loam, with some fractions of silt loam. The location of watersheds is shown in Figure 1, and other details can be found in [10].

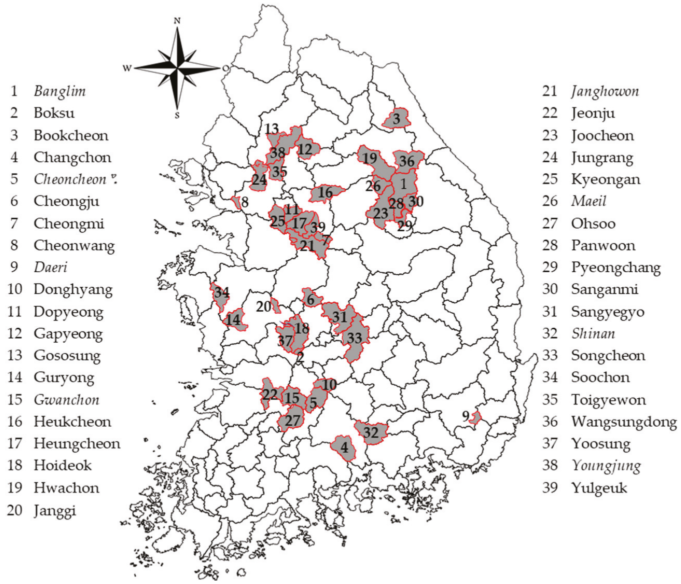


Figure 1. Location of watersheds in the study area. The watersheds in italics were used for validation.

The climatic patterns over the study area are quite variable due to the Asian monsoon. Winter is extremely dry and cold, and summer is warm and moist with frequent heavy rainstorms [38]. The mean annual precipitation (from 1970 to 2000) ranged between 1000 and 1800 mm from the central to the southern regions. Approximately 50% to 60% of this precipitation falls at a high intensity and short duration from July to September [10].

2.2. Data Collection and Interpretation

Continuous rainfall and discharge data (from 2005 to 2012) for this study were collected from the Hydrological Survey Center (HSC) of South Korea. The straight-line hydrograph approach was used to separate direct runoff from the total discharge [10]. For any rain event, the prior five days' cumulative rainfall (P_5) was used to identify the watershed antecedent moisture [10,20,22,39]. The watershed weighted curve number (CN_{II}) corresponding to the normal conditions were derived from the documented tables on the basis of land use/cover and soil types. The CN_I (CN_{III}) for dry (wet) conditions were adjusted as recommended by Mishra et al. [40].

2.3. Slope-Adjusted Curve Number Considerations and Development

Although the CN model is extensively used for predicting runoff from ungauged watersheds, one study found considerable uncertainties when tabulated CN values were applied to estimate runoff from 10 mountainous, forested watersheds in the eastern United States [9]. Similarly, another study [41] observed substantial change in the watershed CN values, ranging from 55 to 70. Moreover, the use of hydrologic soil group D (and its corresponding CN) for forested, mountainous watersheds is incompatible with the National Engineering Handbook [42] guidelines. Although very limited attention has been given to incorporate slope factors in the existing CN models [43], one study reported that adjusting handbook CN values for slope factors significantly enhanced the predicted runoff [26]. To better capture the watershed response in runoff prediction, a slope-adjusted CN is required for steep-slope, mountainous watersheds [10].

Assuming that the handbook CN value is appropriate for a 5% slope [10,17,19,20,22,23], it needs to be adjusted for steep-slope watersheds. To improve the runoff prediction capability of the CN model, the slope-adjusted CN suggested by Sharpley and Williams [17] is generally expressed as

$$CN_{II\alpha} = a(CN_{III} - CN_{II})(1 - be^{-c\times\alpha}) + CN_{II} \tag{4}$$

where $CN_{II\alpha}$ is the slope-adjusted CN for the antecedent runoff condition representing the watershed normal moisture (ARC-II), CN_{II} and CN_{III} are the handbook CN values obtained from watershed characteristics for ARC-II and ARC-III (wet condition), and α is the watershed average soil slope (m/m). The approach of Sharpley and Williams [17] has three empirical parameters—a, b, and c—with optimized values of 1/3, 2, and 13.86, respectively. Their adjusted relationship leads to

$$CN_{II\alpha} = \left(\frac{CN_{III} - CN_{II}}{3}\right)(1 - 2e^{-13.86\alpha}) + CN_{II} \tag{5}$$

Retaining the assumption of Sharpley and Williams [17] for CN_{II} values applicable to a 5% average slope, another study [23] developed the following relationship to adjust CN values for other slopes:

$$S_{II\alpha} = S_{II}\left(1.1 - \frac{\alpha}{\alpha + e^{(3.7+0.02117\alpha)}}\right) \tag{6}$$

where S_{II} and $S_{II\alpha}$ are the S values for normal moisture condition and slope-adjusted normal moisture conditions, respectively, and α is the watershed mean slope in percentage. The slope-adjusted CN can be obtained from the above equation using the general S and CN interrelationship as it is found in Equation (2). According to Huang et al. [19], the approach in Sharpley and Williams [17] has not been intensively verified in the field. Hence, they adopted a simplified approach for the $CN_{II\alpha}$ determination on the basis of their experiments for soil slopes ranging between 0.14 and 1.40, and proposed the following relationship:

$$\mathrm{CN}_{\mathrm{II}\alpha} = \mathrm{CN}_{\mathrm{II}}\left(\frac{322.79+15.63\alpha}{\alpha+323.52}\right) \tag{7}$$

However, this relationship is unstable because it does not follow the CN theoretical limits.

An investigation by Garg et al. [26] showed that the differences between the tabulated CN values and those calculated from the approach in Huang et al. [19] were very small when compared to that of Sharpley and Williams [17]. This is why the approach in Huang et al. [19] depicted modest improvement in estimating large as well as small runoff events and produced results very close to the original CN model with handbook CN values. Any underestimation of the runoff events using the approach in Huang et al. [19] can be attributed to the empirically selected numerical constants of Equation (7), and needs validation using the measured rainfall-runoff data.

In another study, Ajmal et al. [10] developed a slope-adjusted average CN relationship using data from 39 mountainous watersheds. They calibrated the $\mathrm{CN}_{\mathrm{II}\alpha}$ using 1402 measured rainfall-runoff events from 31 watersheds and validated this with 377 rainfall–runoff events from the remaining eight watersheds. This is represented as

$$\mathrm{CN}_{\mathrm{II}\alpha} = \mathrm{CN}_{\mathrm{II}}\left[\frac{1.9274\alpha+2.13273}{\alpha+2.1791}\right] \tag{8}$$

The above relationship was derived on the basis of data from watersheds with an average slope between 7.50% and 53.53%, where, besides other typical watershed geophysical characteristics, most of the area (approximately 70.50%) was covered with upland forests. However, their approach was also inconsistent with the CN theoretical limits on the basis of the presumption that the CN tables were originally developed with a 5% average slope in their experimental plots [10,17,19]. Knowing $\mathrm{CN}_{\mathrm{II}}$, $\mathrm{CN}_{\mathrm{III}}$, and α as the mean slope of a watershed, the proposed slope-adjusted CN ($\mathrm{CN}_{\mathrm{II}\alpha}$) in its general form is presented as

$$\mathrm{CN}_{\mathrm{II}\alpha} = \left(\frac{\mathrm{CN}_{\mathrm{III}} - \mathrm{CN}_{\mathrm{II}}}{2}\right)\left[1 - e^{-b\times(\alpha-0.05)}\right]+\mathrm{CN}_{\mathrm{II}} \tag{9}$$

2.4. Steps of Slope-Adjusted CN Parameter Optimization

1. Data pertaining to 39 watersheds in which 1779 rainstorms events occurred provided the known values of the rainstorm events, P; the observed runoff, Q_o; and the optimized CNs for each watershed. The least squares nonlinear orthogonal distance regression objective function in Origin Pro 9.6 software produced the optimized CN values from the following equation.

$$\sum_{i=1}^{n}(Q_o - Q_e)^2 = \sum\left\{Q_o - \left[\frac{\left(P - 0.2\times\left(\frac{25400}{CN} - 254\right)\right)^2}{P+0.8\times\left(\frac{25400}{CN} - 254\right)}\right]\right\}^2 = \text{Minimum} \tag{10}$$

2. To optimize parameter b in Equation (9), the CNs obtained for the 39 watersheds from Equation (10) were divided into two sets, those of 31 watersheds (1402 rainstorm–runoff events) for calibration and those of 8 watersheds (377 rainstorm-runoff events) for validation. For calibration, the optimized CNs in step 1 were set as the target values challenging the right side of Equation (9) using the nonlinear regression least squares Levenberg–Marquardt algorithm in SPSS v.25 software. To take into account the individual watersheds' effects on parameter b optimization, the leave-one-out (LOOV) technique was adopted. The average of 31 calibrations repetitions was the value of b = 7.125. This led to recasting the proposed $\mathrm{CN}_{\mathrm{II}\alpha}$ as

$$\mathrm{CN}_{\mathrm{II}\alpha} = \left(\frac{\mathrm{CN}_{\mathrm{III}} - \mathrm{CN}_{\mathrm{II}}}{2}\right)\left[1 - e^{-7.125\times(\alpha-0.05)}\right]+\mathrm{CN}_{\mathrm{II}} \tag{11}$$

This can also be represented as

$$\mathrm{CN}_{\mathrm{II}\alpha}= (0.5 - 0.714\mathrm{e}^{-7.125\alpha})(\mathrm{CN}_{\mathrm{III}} - \mathrm{CN}_{\mathrm{II}}) + \mathrm{CN}_{\mathrm{II}} \tag{12}$$

Introducing the $\mathrm{CN}_{\mathrm{III}}$ conversion from $\mathrm{CN}_{\mathrm{II}}$ after a suggestion in Mishra et al. [40] gives

$$\mathrm{CN}_{\mathrm{III}} = \frac{\mathrm{CN}_{\mathrm{II}}}{0.430+0.0057\mathrm{CN}_{\mathrm{II}}} \tag{13}$$

Imputing Equation (13) into Equation (11) and simplifying it, the proposed relationship can be recast as

$$\mathrm{CN}_{\mathrm{II}\alpha} = \left[\frac{\mathrm{CN}_{\mathrm{II}}(50 - 0.5\mathrm{CN}_{\mathrm{II}})}{\mathrm{CN}_{\mathrm{II}} + 75.43}\right] \times \left[1 - \mathrm{e}^{-7.125(\alpha-0.05)}\right]+\mathrm{CN}_{\mathrm{II}} \tag{14}$$

This proposed $\mathrm{CN}_{\mathrm{II}\alpha}$ relationship has twofold advantages over the previous three suggested relationships. The proposed model has only one parameter to be optimized compared to three in Sharpley and Williams [17] and Williams and Izaurralde [23], and two in Huang et al. [19], if the suggested parameter values are not applicable. Our proposed $\mathrm{CN}_{\mathrm{II}\alpha}$ works within the theoretical limits (i.e., 0 to 100), unlike that in Huang et al. [19], which loses its effectiveness after $\mathrm{CN}_{\mathrm{II}}$ = 94.27 using the highest average slope of their watersheds. Similarly, the adjustment in Williams and Izaurralde [23] and Ajmal et al. [10] also fails to follow the CN theoretical limits. The different variants of the CN model are shown in Table 1.

Table 1. Models and their descriptions.

	Parameters		
Model Identity	**λ**	**CN ($\mathrm{CN}_{\mathrm{II}\alpha}$)**	**Model Expression**
M1	0.20	*NEH-4 Tables	Equations (1) and (2)
M2	0.05	NEH-4 Tables	Equations (1)–(3)
M3	0.20	Sharpley and Williams [17]	Equations (1), (2) and (5)
M4	0.20	Huang et al. [19]	Equations (1), (2) and (7)
M5	0.20	Ajmal et al. [10]	Equations (1), (2) and (8)
M6	0.20	Proposed	Equations (1), (2) and (12)
M7	0.05	Proposed	Equations (1)–(3) and (12)
M8	0.01	Proposed	Equations (1), (2) and (12)

*NEH-4: National Engineering Handbook Section-4 [42].

3. Statistical Analysis for Model Performance Evaluation

This study estimated the agreement between a series of observed and estimated runoffs using the root mean square error (RMSE), Nash–Sutcliffe efficiency (NSE), percent bias (PB) [34], and/or graphical assessments augmented with model performance ratings [44]. Mathematically, these indicators are

$$\mathrm{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(Q_{oi} - Q_{ei})^2} \tag{15}$$

$$\mathrm{NSE} = 1 - \left[\frac{\sum_{I=1}^{n}(Q_{oi} - Q_{ei})^2}{\sum_{I=1}^{n}(Q_{oi} - \bar{Q}_{o})^2}\right] \tag{16}$$

$$\mathrm{PB} = \left[\frac{\sum_{I=1}^{n}(Q_{oi} - Q_{ei})}{\sum_{I=1}^{n} Q_{oi}}\right] \times 100 \tag{17}$$

where Q_{oi} and Q_{ei} are the observed and estimated runoff values for rainstorm events 1 to n, and $\overline{Q_O}$ is the mean observed runoff in each watershed. The RMSE (0 to ∞) values closer to zero depict more appropriateness of the model to estimate runoff. The NSE (−∞ to 1) illustrates how well a plot of observed vs. estimated runoff fits a 1:1 line (i.e., a perfect fit) [39]. The PB (optimum = 0) describes the average tendency of estimated values to be larger or smaller than their observed ones. Positive (negative) values indicate underestimation (overestimation) bias [44]. It is notable that perfect agreement of the estimated vs. observed data does not essentially indicate a perfect model, because observed data could have uncertainties [39]. However, we are confident about the good quality of the data used in this study. Performance evaluation of different statistical indicators and their suggested ratings [44,45] are given Table 2.

Table 2. Statistical indicators and associated performance ratings [44,45].

Performance Rating	NSE [44]	NSE [45]	PB (%)
Very good	$0.75 < NSE \leq 1.00$	$0.90 < NSE \leq 1.00$	$-10 < PB < +10$
Good	$0.65 < NSE \leq 0.75$	$0.80 \leq NSE \leq 0.90$	$\pm10 \leq PB < \pm15$
Satisfactory	$0.50 < NSE \leq 0.65$	$0.65 \leq NSE < 0.80$	$\pm15 \leq PB < \pm25$
Unsatisfactory	$NSE \leq 0.50$	$NSE \leq 0.65$	$PB \geq \pm25$

4. Results and Discussion

The performance evaluation of the existing models (M1–M5) and our proposed approach (M6–M8) was accomplished in two steps. First, the basic statistics of the observed runoff were compared to the models' estimated runoff both for the calibration and validation watersheds. In the second step, commonly used statistical indicators were used to check the model's predictive credibility [20,34,44] in conjunction with a 1:1 plot graphical judgement between the observed and modeled runoff values [46].

4.1. Models' Analysis Based on Descriptive Statistics

The basic descriptive statistics (Table 3) favor the M8 model using the $CN_{II\alpha}$ and lower $\lambda = 0.01$ followed by the M6 and M5 models. However, the M6 model was preferred over the M5 due to its practically sound $CN_{II\alpha}$ to follow the CN theoretical bounds (0–100). In estimating runoff, the M2 model was not plausibly different from the M1 model. Therefore, lowering λ from 0.2 to 0.05, along with its corresponding CN adjustment using Equation (3), produced only modest changes in the estimated runoff values. Nonetheless, using $\lambda = 0.05$ and retaining handbook CN values without adjustment can improve the model's runoff predictive capability, which is not shown in the assessment but is reflected in the comparison of the M6 and M7 models. The majority of the existing CN model variants underestimated the runoff in different watersheds. Nevertheless, it can be inferred that the watershed CN was not the only important parameter; selecting the proper λ also played a crucial role in estimating accurate runoff. Additionally, the prominent response of CNs to the rainstorm depth was vital in runoff depth estimation [1].

Table 3. Summary statistic of rainfall (P), observed runoff (Q_o), and modeled runoff (M1–M8) in the calibration and validation watersheds.

Calibration Watersheds (1402 Rainstorm–Runoff Events)						
Parameter/Model	**Mean**	**Minimum**	**First Quartile (Q1)**	**Median**	**Third Quartile (Q3)**	**Maximum**
P	80.96	12.10	39.92	59.09	98.27	519.68
Q_o	**38.60**	**0.17**	**8.23**	**19.61**	**49.04**	**348.46**
M1	25.57	0.00	1.49	6.13	27.03	415.63
M2	23.56	0.00	1.14	7.26	25.79	**383.27**
M3	28.79	0.00	1.30	7.95	32.94	436.28
M4	26.06	0.00	1.52	6.31	28.33	419.65
M5	30.06	0.00	1.35	8.83	35.39	443.28
M6	30.26	0.00	1.23	9.38	35.34	445.73
M7	28.98	0.00	2.54	10.77	34.57	417.11
M8	**39.67**	**0.53**	**7.93**	**20.13**	**49.30**	458.55

Table 3. *Cont.*

Validation Watersheds (377 Rainstorm–Runoff Events)						
P	75.22	20.52	40.97	57.05	86.95	376.86
Q_o	**35.03**	**0.24**	**8.30**	**19.10**	**43.20**	**364.38**
M1	22.04	0.00	1.48	6.35	20.35	294.27
M2	19.85	0.00	0.85	5.55	19.93	265.59
M3	24.75	0.00	1.52	6.27	25.99	309.31
M4	22.49	0.00	1.39	6.63	21.48	296.26
M5	26.48	0.00	2.03	7.87	30.12	309.72
M6	26.07	0.00	1.71	6.66	29.04	314.48
M7	24.98	0.00	2.10	9.43	26.71	293.91
M8	**34.77**	**0.87**	**7.70**	**17.91**	**40.12**	**325.07**

Note: The highlighted values show the good agreement between the observed and the estimated runoff.

4.2. Model Performance Evaluation in Watersheds Used for Calibration

We evaluated the runoff predictability performance of the existing CN models (M1 to M5) and the proposed variants (M6 to M8) for the calibration watersheds (Figure 2). Because of minimal difference in the $CN_{II\alpha}$ values proposed by Williams and Izaurralde [23] and Sharpley and Williams [17], we compared only the latter with the other approaches. As mentioned earlier, the RMSE can vary from 0 to ∞, and a value close to zero indicates a nearly perfect fit [15,20,34]. On the basis of the RMSE (mean, median) values, the M2 (23.90, 21.91) and M3 (24.30, 21.90) models exhibited similar but improved runoff estimation compared to the M1 (26.49, 24.02) model. The mean value for all of the statistical indicators is shown on each box plot through connected lines. The M2 model's enhanced runoff estimation could be attributed to the lower $\lambda = 0.05$ [2], whereas the M3 model's improved predictability could be ascribed to $CN_{Ii\alpha}$, which was comparatively higher than the tabulated CN [17]. The M4 model (26.08, 23.78) showed almost no improvement compared to the M1 model. Comparatively better runoff prediction was found for the M5 model (23.53, 21.15), and that of the M6 model (23.23, 20.79) was almost equal in the calibration watersheds. However, the runoff predictive capabilities of the M7 model (21.06, 19.29) and M8 model (18.59, 16.87) were better, as was also evident from their overall RMSE values (Figure 2a). It can be inferred that setting a lower λ and a comparatively higher $CN_{Ii\alpha}$, as was the case in model M8, possibly reduces the infiltration and surface water retention capacity.

Following the model performance ratings shown in Table 2 and the box plot statistics (Figure 2b), the NSE (mean, median) for the M1 model (0.58, 0.63) and the M4 model (0.59, 0.64) were the smallest among the eight variants of the CN model. It must be kept in mind that the Gusosung watershed statistics were excluded, meaning the mean and median values were calculated for the remaining 30 calibration watersheds. In that particular watershed, only the M8 model showed a reasonable runoff prediction, whereas the rest of the models' performance indicators ratings were unsatisfactory. The M3 model (0.64, 0.68) results showed modest improvement, followed by the M2 (0.66, 0.71) and M5 (0.66, 0.71) models. However, the M6 (0.67, 0.72) and M7 (0.74, 0.77) models exhibited significantly improved results compared to the M1 model. In addition, the M8 model (0.80, 0.82) outperformed all the other models in the majority of the watersheds. The best performance of the M8 model is also evident from Figure 2b, followed by the M7 and M6 models, in that order. The lack of effectiveness of the M1 and M4 models could be attributed to the fixed and higher $\lambda = 0.2$ and inconsistent watershed tabulated CN values [10,15]. Similarly, on the basis of the PB performance ratings (Table 2), the accuracy runoff predictability of the different CN model variants is shown in Figure 2c. Using PB (mean, median), the order for accurately estimating runoff was M8 (−2.43, 0.67) > M7 (19.47, 18.06) > M6 (22.37, 22.51) > M5 (23.22, 21.93) > M3 (25.93, 24.46) > M2 (31.86, 31.26) > M4 (32.93, 32.41) > M1 (34.19, 33.14). In addition, Figure 2c shows that the PB values obtained from the M8 model in estimating runoff in the study area, except for two watersheds, were rated either very good, good, or at least satisfactory.

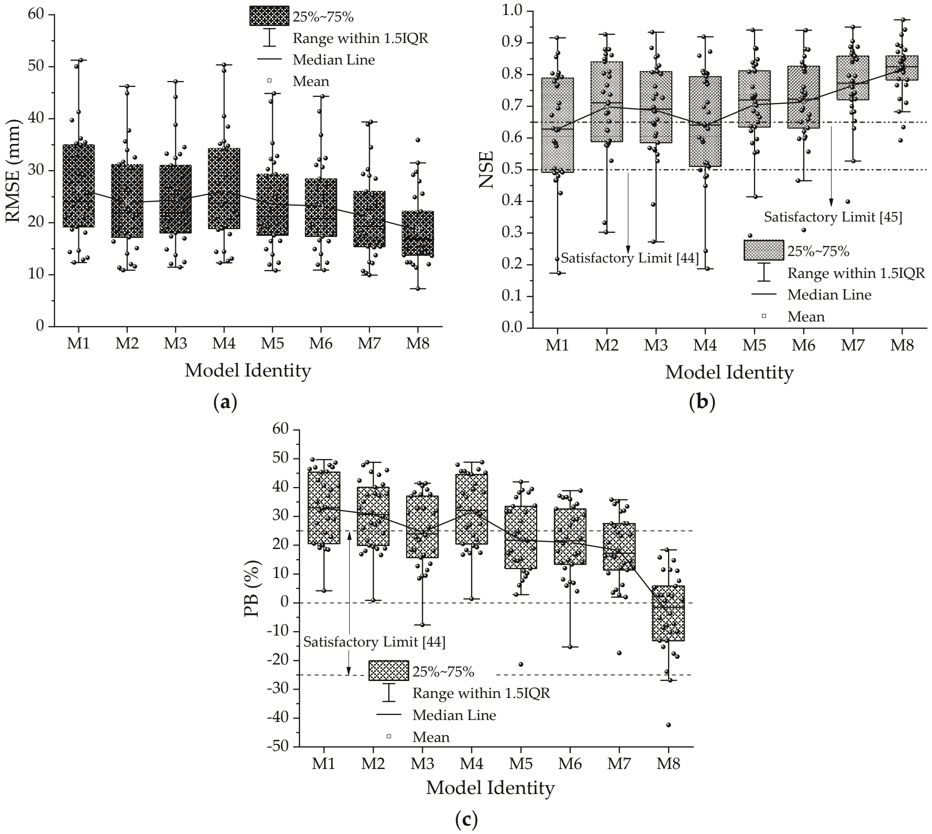
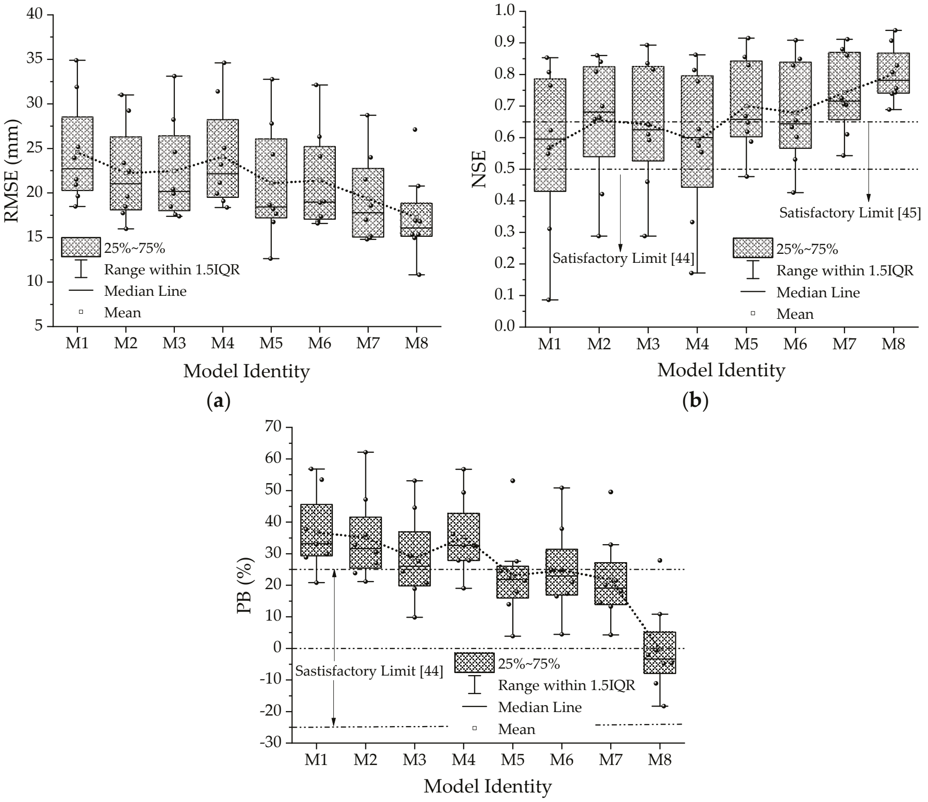


Figure 2. (**a**) Root mean square error (RMSE), (**b**) Nash–Sutcliffe efficiency (NSE), and (**c**) percent bias (PB) for eight variants of the CN model using data of 30 out of 31 calibration watersheds.

4.3. Models' Performance Evaluation in Watersheds Used for Validation

The performance of the CN model variants in the validation watersheds using the RMSE, NSE, and PB is shown in Figure 3. The superior performance of the M8 model is evident, whereas the least efficient was the M1 model with its RMSE, NSE, and PB (mean, median) values of (24.56, 22.73), (0.57, 0.60), and (36.73, 33.18), respectively. The corresponding best runoff prediction by the M8 model was recorded with RMSE (17.25, 16.07), NSE (0.80, 0.78), and PB (−0.35, −3.35). Similarly, the higher PB positive values by the M1 model in the majority of the watersheds indicated underestimation and were in the unsatisfactory range, as found by other researchers [10,20,34,44]. Nevertheless, the M8 model overestimated runoff in the majority of the watersheds, but, was within the acceptable performance range. In addition, among the remaining six variants of the CN model, the M7 model predicted more accurate runoff, followed by the M5, M6, M2, M3, and M4 models, in that order. On the basis of the PB values (Figure 3), the M8 model predicted runoff well in all the watersheds except one.



(**a**) (**b**) (**c**)

Figure 3. (**a**) RMSE, (**b**) NSE, and (**c**) PB for eight variants of the CN model using data of eight validation watersheds.

4.4. Overall Performance of Models and Comparison Based on 1:1 Plot

Table 4 summarizes the credibility of the eight variants of the CN model in estimating runoff from rainstorm events in different watersheds. It is obvious that the M8 model exhibited more accurate results for a very good performance rating based on NSE (PB) in 30 (19) out of 39 watersheds. The corresponding goodness-of-fit ratting for the M1 model was found only in 14 (1) watershed(s). Applying the model evaluation criteria recommended by Ritter and Muñoz-Carpena [45], the M1 and M4 model predictions were “satisfactorily” to “very good” in only 43.6% of the watersheds, followed by the M3, M5, M2, M6, and M7 models with their corresponding values of 53.9%, 61.5%, 64.1%, 66.7%, and 84.6% of the watersheds, respectively. The more plausible model for efficiently predicting runoff was M8 in 92.3% (36 out of 39) watersheds. It is notable that the majority of the runoff was underestimated by the M1 model, as has also been reported for rangeland and cropland in Montana and Wyoming [47], Mississippi [48], the Loess Plateau of China [19], India [20,22,26,43], South Korea [10,15], and Poland [49]. After M8, the M7 and M6 models predicted runoff more coincident with the observed values. The M4 model’s inferior performance could possibly be linked to very little difference in the $CN_{II\alpha}$ and the handbook CN values ($CN_{II\alpha}$–CN), which varied in the range of 0.73 to 1.46. The corresponding CN differences for the M3, M5, and M6 models were in the range of 1.37 to 6.52, 0.73 to 11.28, and 1.15 to 9.48, respectively. It is notable that the M6 and M8 models used the same $CN_{II\alpha}$ values. The M8 model’s outperformance in predicting runoff was probably because of its lower λ = 0.01, as suggested for Korean steep-slope watersheds [10], and its comparatively higher $CN_{II\alpha}$ values.

Table 4. Performance of the CN model and its variants in 39 watersheds in the study area.

	M1	M2	M3	M4	M5	M6	M7	M8
Performance Criteria	**NSE [44]**							
0.75 < NSE ≤ 1.00	14	15	14	14	14	14	20	30
0.65 < NSE ≤ 0.75	3	10	7	3	10	12	13	6
0.50 < NSE ≤ 0.65	10	9	13	13	11	9	4	2
NSE ≤ 0.50	12	5	5	9	4	4	2	1
	NSE [45]							
0.90 < NSE ≤ 1.00	1	1	1	1	2	2	3	5
0.80 ≤ NSE ≤ 0.90	6	12	12	8	11	11	11	20
0.65 ≤ NSE < 0.80	10	12	8	8	11	13	19	11
NSE ≤ 0.65	22	14	18	22	15	13	6	3
	PB (%)							
−10 < PB < +10	1	1	5	1	5	6	6	19
±10 ≤ PB < ±15	0	0	3	0	6	5	8	9
±15 ≤ PB < ±25	10	11	12	10	13	12	12	7
PB ≥ ±25	28	27	19	28	15	16	13	4

We further compared the different CN model variants on the basis of cumulative observed and estimated runoff from the 39 watersheds using the 1:1 plot and the coefficient of determination, R^2. The moderately high R^2 value supported better runoff prediction capability of the M2 model compared to the M1 model. However, deviation of the observed–estimated runoff best-fit-regression line from the 1:1 plot shows that both the M1 and M2 models underestimated the majority of the runoff events (Figure 4). Although the M2 model R^2 value was comparatively high, the runoff predictability of the M1, M2, and M4 models was almost indistinguishable. Nevertheless, the closeness of data points around the 1:1 plot and the higher R^2 values of the M5 through M8 models favored these models for comparatively better runoff prediction. The best agreement between the observed and estimated runoff was evidenced by applying the M8 model, as shown in Figure 4. It should be noted that the R^2 statistics used for model evaluation could mislead practitioners. These statistics are oversensitive to extremely high values and insensitive to additive and proportional differences between model predictions and measured data [44]. The overall promising results of the M8 model support its suitability for runoff prediction in the steep-slope watersheds. Therefore, the original CN model and the majority of its variants discussed here do not well represent complex watershed characteristics, and thus the abstraction coefficient, the CN values from watershed, and the CN model itself need to be revised for general application. A very recent and comprehensive review by the NRCS Task Group on Curve Number Hydrology [5] also suggested changes to update the handbook and its associated procedures on the basis of lessons learned from global experiences and additional data analyses. To avoid jumps in runoff estimation, the CN model could be made to be more robust by not fixing the initial abstraction coefficient and considering the effect of rainfall as well as the spatial and temporal variability while estimating the watershed CN values.

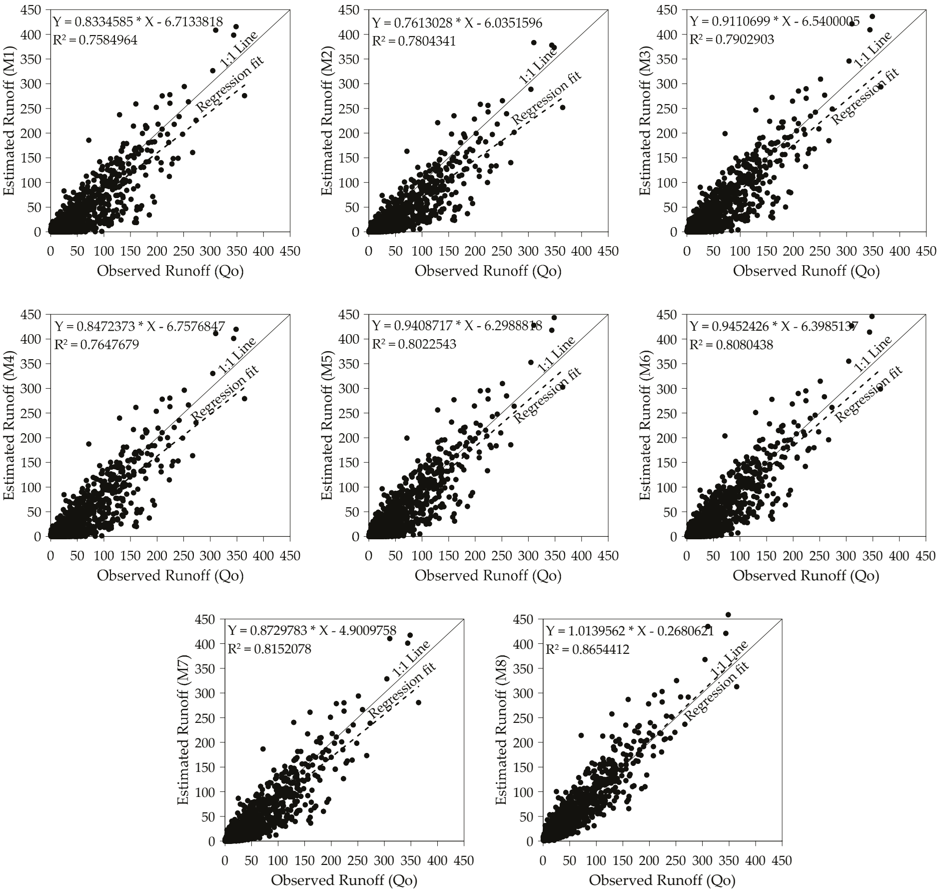


Figure 4. Observed and estimated runoff comparison for eight variants of the CN model using cumulative data of all 39 watersheds.

There is an evidence that the CN tables that were documented a few decades back that were based on soils and land use/cover are often wide of the mark and not supported by real ground data or by critical analyses [10,15,50]. The original CN model response demonstrated in different studies is very sensitive in selecting the watershed-representative CN. Moreover, the runoff response from some watersheds were found to be very erratic, leading to great discrepancies between the modeled data and reality [50]. Like our findings, various studies have reported underestimated runoff in the steep-slope watersheds using the original CN methodology [10,17–23], and slope adjustment for CN was proposed to capture the watershed response in predicting runoff [10,17–19,21–24]. Application of the suggested approach by Sharpley and Williams [17] was criticized for being tested with very limited data in the field [19]. To support the findings of Williams et al. [18], two other slope-adjusted CN approaches were developed by Ajmal et al. [10] and Sharpley and Williams [17], but they were not structurally sound due to incapability to follow the CN theoretical limits. Because of the plausible response in replicating the watershed runoff, the slope-adjusted CN approach proposed in this study was not only structurally sound in terms of following the theoretical bounds of the CN, but also in supporting its application for better runoff prediction. However, the model results could be further improved by introducing the effects of spatial variability in CN for the soil–cover complex along watersheds [51,52].

5. Conclusions and Practical Implications

The CN model is being updated continuously on the basis of new measured rainfall–runoff data and innovation in research. When handbook CN values are used, the inconsistent runoff prediction capability of this model has led researchers to adjust the CN values using the effect of rainfall magnitudes [2,5] and watershed slope [10,17–19,24,26]. However, some researchers agree that the handbook CN values are fit for runoff estimation from watersheds with a maximum 5% average slope. Hence, there is a room for further refinement in determining CN values. This study investigated and proposed a practically sound slope-adjusted CN ($CN_{II\alpha}$) approach to improve the runoff prediction capability of the CN model in steep-slope watersheds in order to reduce possible uncertainties. The proposed $CN_{II\alpha}$ not only followed the theoretical limits (0, 100) [17], but in addition, unlike other existing $CN_{II\alpha}$ approaches [10,19,23], it provided a promising runoff prediction capability in the study area. The use of $\lambda = 0.05$ in place of $\lambda = 0.2$ and their adjusted $CN_{0.05}$ values modestly improved the CN model runoff predictability, but not well enough for runoff estimation from steep-slope watersheds. On the basis of different performance indicators, we found that the proposed $CN_{II\alpha}$ had a positive impact on the CN model runoff prediction. Users of the CN model should know the limitations in its procedures and assumptions because the model produces diverse responses when applied to different land types and watersheds [5]. Assuming a fixed λ value and its associated three fixed values of initial abstraction for dry, normal, and wet conditions are among the major limitations of the original CN model and variants used in this study. The model needs an overhaul for various compelling reasons to circumvent the fixed λ value, as well as unjustified sudden jumps in CN values and its associated estimated runoff. In this era of cutting-edge technology, researchers of different biomes have introduced new parameters in the model to improve its runoff prediction capability. However, inculcating new parameters has increased the model complexity and restricted its application in ungauged watersheds. The CN methodology must be overhauled using experiences from the modern hydrologic engineering without losing the simplicity rule.

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Description

A sediment basin is a temporary pond built on a construction site to capture eroded or disturbed soil transported in storm runoff prior to discharge from the site. Sediment basins are designed to capture site runoff and slowly release it to allow time for settling of sediment prior to discharge. Sediment basins are often constructed in locations that will later be modified to serve as post-construction stormwater basins.

Photograph SB-1. Sediment basin at the toe of a slope. Photo courtesy of WWE.

Appropriate Uses

Most large construction sites (typically greater than 2 acres) will require one or more sediment basins for effective management of construction site runoff. On linear construction projects, sediment basins may be impractical; instead, sediment traps or other combinations of BMPs may be more appropriate.

Sediment basins should not be used as stand-alone sediment controls. Erosion and other sediment controls should also be implemented upstream.

When feasible, the sediment basin should be installed in the same location where a permanent post-construction detention pond will be located.

Design and Installation

The design procedure for a sediment basin includes these steps:

- **Basin Storage Volume**: Provide a storage volume of at least 3,600 cubic feet per acre of drainage area. To the extent practical, undisturbed and/or off-site areas should be diverted around sediment basins to prevent “clean” runoff from mixing with runoff from disturbed areas. For undisturbed areas (both on-site and off-site) that cannot be diverted around the sediment basin, provide a minimum of 500 ft^3/acre of storage for undeveloped (but stable) off-site areas in addition to the 3,600 ft^3/acre for disturbed areas. For stable, developed areas that cannot be diverted around the sediment basin, storage volume requirements are summarized in Table SB-1.

- **Basin Geometry:** Design basin with a minimum length-to-width ratio of 2:1 (L:W). If this cannot be achieved because of site space constraints, baffling may be required to extend the effective distance between the inflow point(s) and the outlet to minimize short-circuiting.

- **Dam Embankment**: It is recommended that embankment slopes be 4:1 (H:V) or flatter and no steeper than 3:1 (H:V) in any location.

Sediment Basins	
Functions	
Erosion Control	No
Sediment Control	Yes
Site/Material Management	No

- **Inflow Structure**: For concentrated flow entering the basin, provide energy dissipation at the point of inflow.

Table SB-1. Additional Volume Requirements for Undisturbed and Developed Tributary Areas Draining through Sediment Basins

Imperviousness (%)	Additional Storage Volume (ft^3) Per Acre of Tributary Area
Undeveloped	500
10	800
20	1230
30	1600
40	2030
50	2470
60	2980
70	3560
80	4360
90	5300
100	6460

- **Outlet Works**: The outlet pipe shall extend through the embankment at a minimum slope of 0.5 percent. Outlet works can be designed using one of the following approaches:
  - **Riser Pipe (Simplified Detail):** Detail SB-1 provides a simplified design for basins treating no more than 15 acres.
  - **Orifice Plate or Riser Pipe**: Follow the design criteria for Full Spectrum Detention outlets in the EDB Fact Sheet provided in Chapter 4 of this manual for sizing of outlet perforations with an emptying time of approximately 72 hours. In lieu of the trash rack, pack uniformly sized 1½ - to 2-inch gravel in front of the plate or surrounding the riser pipe. This gravel will need to be cleaned out frequently during the construction period as sediment accumulates within it. The gravel pack will need to be removed and disposed of following construction to reclaim the basin for use as a permanent detention facility. If the basin will be used as a permanent extended detention basin for the site, a trash rack will need to be installed once contributing drainage areas have been stabilized and the gravel pack and accumulated sediment have been removed.
  - **Floating Skimmer**: If a floating skimmer is used, install it using manufacturer's recommendations. Illustration SB-1 provides an illustration of a Faircloth Skimmer Floating Outlet™, one of the more commonly used floating skimmer outlets. A skimmer should be designed to release the design volume in no less than 48 hours. The use of a floating skimmer outlet can increase the sediment capture efficiency of a basin significantly. A floating outlet continually decants cleanest water off the surface of the pond and releases cleaner water than would discharge from a perforated riser pipe or plate.

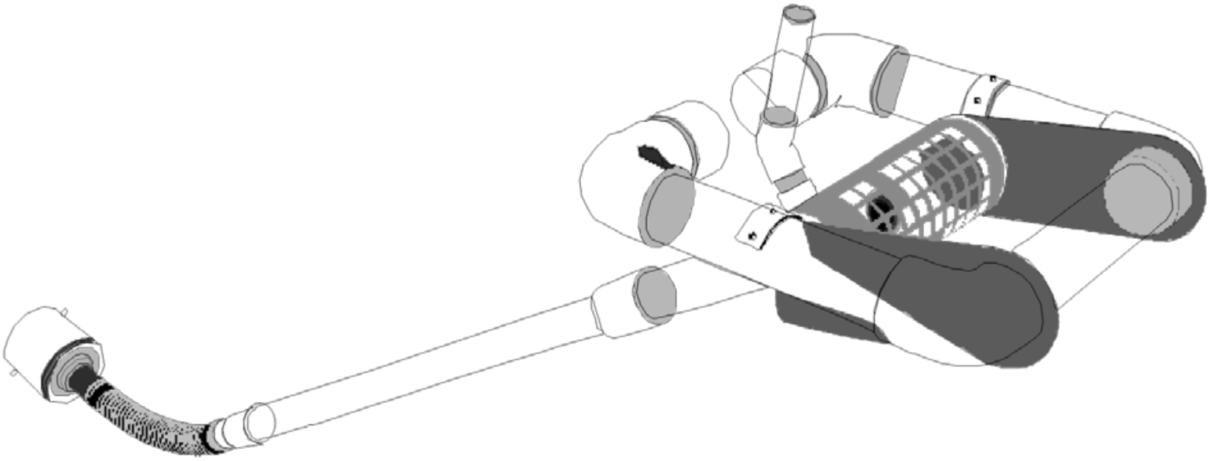


Illustration SB-1. Outlet structure for a temporary sediment basin - Faircloth Skimmer Floating Outlet. Illustration courtesy of J. W. Faircloth & Sons, Inc., FairclothSkimmer.com.

- **Outlet Protection and Spillway:** Consider all flow paths for runoff leaving the basin, including protection at the typical point of discharge as well as overtopping.
  - **Outlet Protection:** Outlet protection should be provided where the velocity of flow will exceed the maximum permissible velocity of the material of the waterway into which discharge occurs. This may require the use of a riprap apron at the outlet location and/or other measures to keep the waterway from eroding.
  - **Emergency Spillway:** Provide a stabilized emergency overflow spillway for rainstorms that exceed the capacity of the sediment basin volume and its outlet. Protect basin embankments from erosion and overtopping. If the sediment basin will be converted to a permanent detention basin, design and construct the emergency spillway(s) as required for the permanent facility. If the sediment basin will not become a permanent detention basin, it may be possible to substitute a heavy polyvinyl membrane or properly bedded rock cover to line the spillway and downstream embankment, depending on the height, slope, and width of the embankments.

Maintenance and Removal

Maintenance activities include the following:

- Dredge sediment from the basin, as needed to maintain BMP effectiveness, typically when the design storage volume is no more than one-third filled with sediment.
- Inspect the sediment basin embankments for stability and seepage.
- Inspect the inlet and outlet of the basin, repair damage, and remove debris. Remove, clean and replace the gravel around the outlet on a regular basis to remove the accumulated sediment within it and keep the outlet functioning.
- Be aware that removal of a sediment basin may require dewatering and associated permit requirements.
- Do not remove a sediment basin until the upstream area has been stabilized with vegetation.

Final disposition of the sediment basin depends on whether the basin will be converted to a permanent post-construction stormwater basin or whether the basin area will be returned to grade. For basins being converted to permanent detention basins, remove accumulated sediment and reconfigure the basin and outlet to meet the requirements of the final design for the detention facility. If the sediment basin is not to be used as a permanent detention facility, fill the excavated area with soil and stabilize with vegetation.

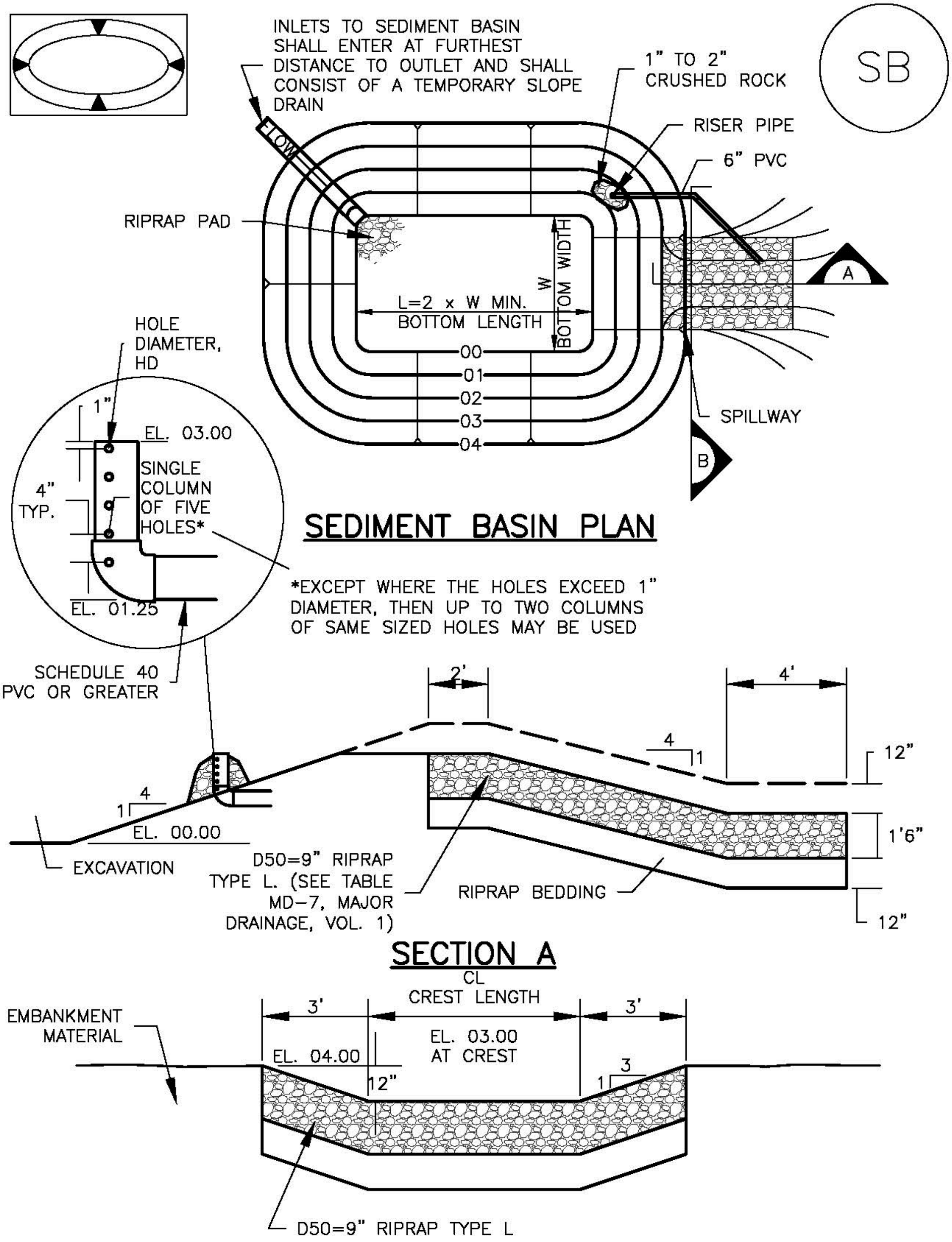

SB
INLETS TO SEDIMENT BASIN SHALL ENTER AT FURTHEST DISTANCE TO OUTLET AND SHALL CONSIST OF A TEMPORARY SLOPE DRAIN
1" TO 2" CRUSHED ROCK
RISER PIPE
6" PVC
FLOW
RIPRAP PAD
W BOTTOM WIDTH
L=2 x W MIN. BOTTOM LENGTH
00
01
02
03
04
A
B
SPILLWAY
HOLE DIAMETER, HD
1"
EL. 03.00
4" TYP.
SINGLE COLUMN OF FIVE HOLES*
EL. 01.25
SEDIMENT BASIN PLAN
*EXCEPT WHERE THE HOLES EXCEED 1" DIAMETER, THEN UP TO TWO COLUMNS OF SAME SIZED HOLES MAY BE USED
SCHEDULE 40 PVC OR GREATER
2'
4'
4
1
12"
1'6"
12"
EL. 00.00
EXCAVATION
D50=9" RIPRAP TYPE L. (SEE TABLE MD-7, MAJOR DRAINAGE, VOL. 1)
RIPRAP BEDDING
SECTION A
CL
CREST LENGTH
3'
3'
EMBANKMENT MATERIAL
EL. 04.00
EL. 03.00 AT CREST
12"
3
1
D50=9" RIPRAP TYPE L

TABLE SB–1. SIZING INFORMATION FOR STANDARD SEDIMENT BASIN

Upstream Drainage Area (rounded to nearest acre), (ac)	Basin Bottom Width (W), (ft)	Spillway Crest Length (CL), (ft)	Hole Diameter (HD), (in)
1	12 1/2	2	9/32
2	21	3	13/16
3	28	5	1/2
4	33 1/2	6	9/16
5	38 1/2	8	21/32
6	43	9	21/32
7	47 1/4	11	25/32
8	51	12	27/32
9	55	13	7/8
10	58 1/4	15	15/16
11	61	16	31/32
12	64	18	1
13	67 1/2	19	1 1/16
14	70 1/2	21	1 1/8
15	73 1/4	22	1 3/16

SEDIMENT BASIN INSTALLATION NOTES

1. SEE PLAN VIEW FOR:
   - –LOCATION OF SEDIMENT BASIN.
   - –TYPE OF BASIN (STANDARD BASIN OR NONSTANDARD BASIN).
   - –FOR STANDARD BASIN, BOTTOM WIDTH W, CREST LENGTH CL, AND HOLE DIAMETER, HD.
   - –FOR NONSTANDARD BASIN, SEE CONSTRUCTION DRAWINGS FOR DESIGN OF BASIN INCLUDING RISER HEIGHT H, NUMBER OF COLUMNS N, HOLE DIAMETER HD AND PIPE DIAMETER D.

2. FOR STANDARD BASIN, BOTTOM DIMENSION MAY BE MODIFIED AS LONG AS BOTTOM AREA IS NOT REDUCED.

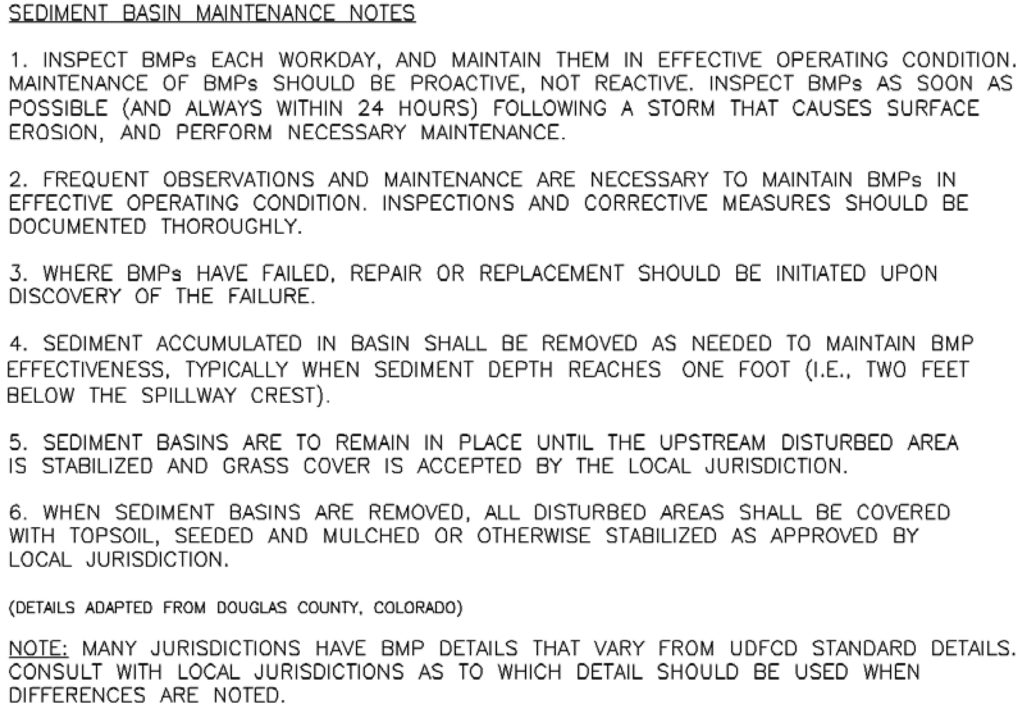
3. SEDIMENT BASINS SHALL BE INSTALLED PRIOR TO ANY OTHER LAND–DISTURBING ACTIVITY THAT RELIES ON ON BASINS AS AS A STORMWATER CONTROL.

4. EMBANKMENT MATERIAL SHALL CONSIST OF SOIL FREE OF DEBRIS, ORGANIC MATERIAL, AND ROCKS OR CONCRETE GREATER THAN 3 INCHES AND SHALL HAVE A MINIMUM OF 15 PERCENT BY WEIGHT PASSING THE NO. 200 SIEVE.

5. EMBANKMENT MATERIAL SHALL BE COMPACTED TO AT LEAST 95 PERCENT OF MAXIMUM DENSITY IN ACCORDANCE WITH ASTM D698.

6. PIPE SCH 40 OR GREATER SHALL BE USED.

7. THE DETAILS SHOWN ON THESE SHEETS PERTAIN TO STANDARD SEDIMENT BASIN(S) FOR DRAINAGE AREAS LESS THAN 15 ACRES. SEE CONSTRUCTION DRAWINGS FOR EMBANKMENT, STORAGE VOLUME, SPILLWAY, OUTLET, AND OUTLET PROTECTION DETAILS FOR ANY SEDIMENT BASIN(S) THAT HAVE BEEN INDIVIDUALLY DESIGNED FOR DRAINAGE AREAS LARGER THAN 15 ACRES.



SEDIMENT BASIN MAINTENANCE NOTES

1. INSPECT BMPs EACH WORKDAY, AND MAINTAIN THEM IN EFFECTIVE OPERATING CONDITION. MAINTENANCE OF BMPs SHOULD BE PROACTIVE, NOT REACTIVE. INSPECT BMPs AS SOON AS POSSIBLE (AND ALWAYS WITHIN 24 HOURS) FOLLOWING A STORM THAT CAUSES SURFACE EROSION, AND PERFORM NECESSARY MAINTENANCE.

2. FREQUENT OBSERVATIONS AND MAINTENANCE ARE NECESSARY TO MAINTAIN BMPs IN EFFECTIVE OPERATING CONDITION. INSPECTIONS AND CORRECTIVE MEASURES SHOULD BE DOCUMENTED THOROUGHLY.

3. WHERE BMPs HAVE FAILED, REPAIR OR REPLACEMENT SHOULD BE INITIATED UPON DISCOVERY OF THE FAILURE.

4. SEDIMENT ACCUMULATED IN BASIN SHALL BE REMOVED AS NEEDED TO MAINTAIN BMP EFFECTIVENESS, TYPICALLY WHEN SEDIMENT DEPTH REACHES ONE FOOT (I.E., TWO FEET BELOW THE SPILLWAY CREST).

5. SEDIMENT BASINS ARE TO REMAIN IN PLACE UNTIL THE UPSTREAM DISTURBED AREA IS STABILIZED AND GRASS COVER IS ACCEPTED BY THE LOCAL JURISDICTION.

6. WHEN SEDIMENT BASINS ARE REMOVED, ALL DISTURBED AREAS SHALL BE COVERED WITH TOPSOIL, SEEDED AND MULCHED OR OTHERWISE STABILIZED AS APPROVED BY LOCAL JURISDICTION.

(DETAILS ADAPTED FROM DOUGLAS COUNTY, COLORADO)

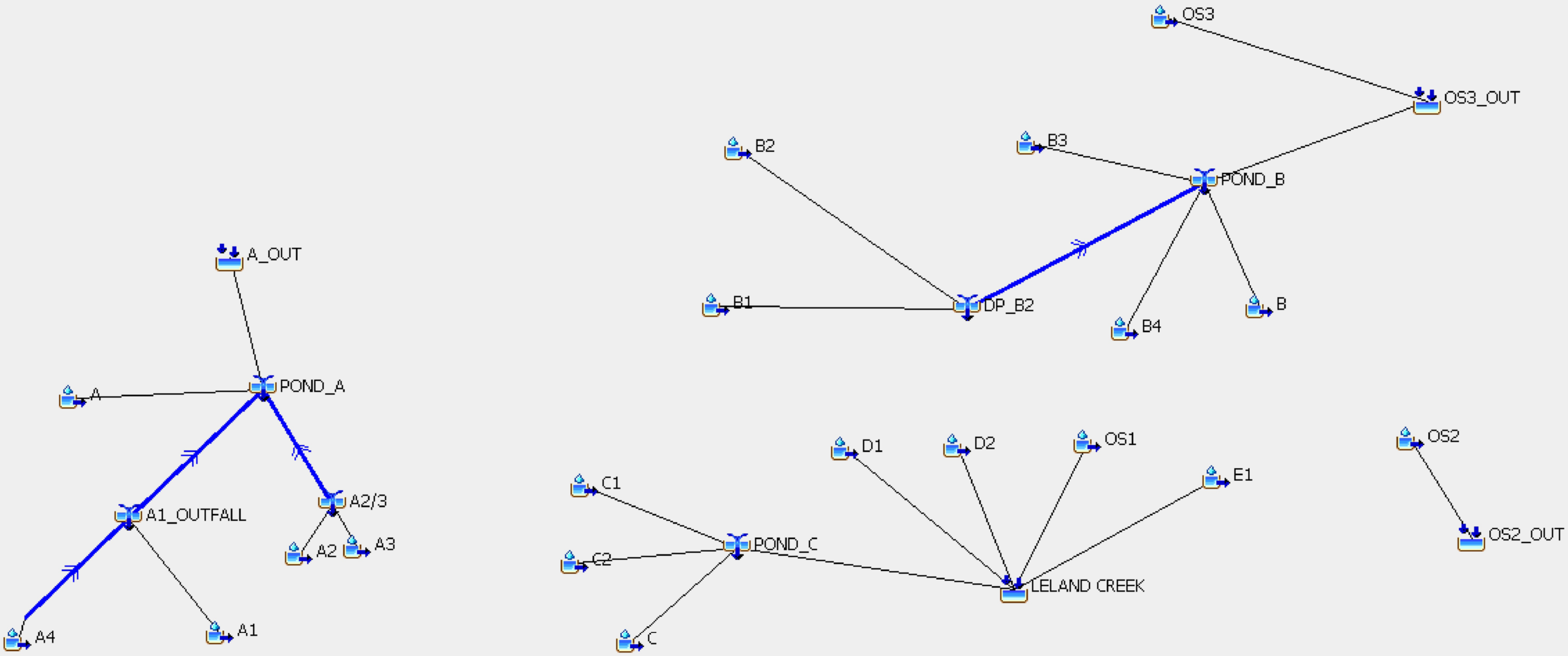
NOTE: MANY JURISDICTIONS HAVE BMP DETAILS THAT VARY FROM UDFCD STANDARD DETAILS. CONSULT WITH LOCAL JURISDICTIONS AS TO WHICH DETAIL SHOULD BE USED WHEN DIFFERENCES ARE NOTED.

APPENDIX E

DRAINAGE MAPS

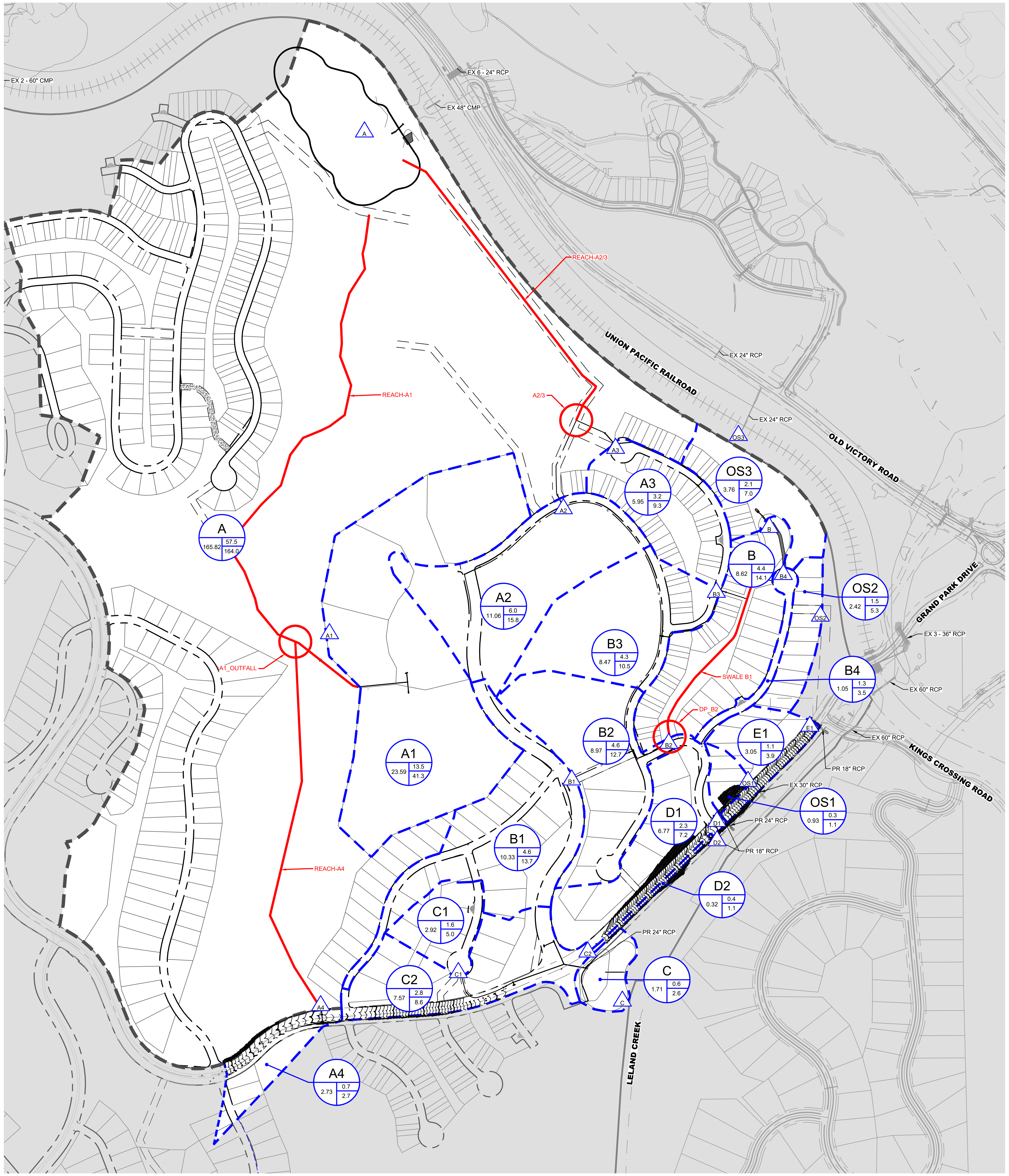
HEC-HMS Basin Model Map

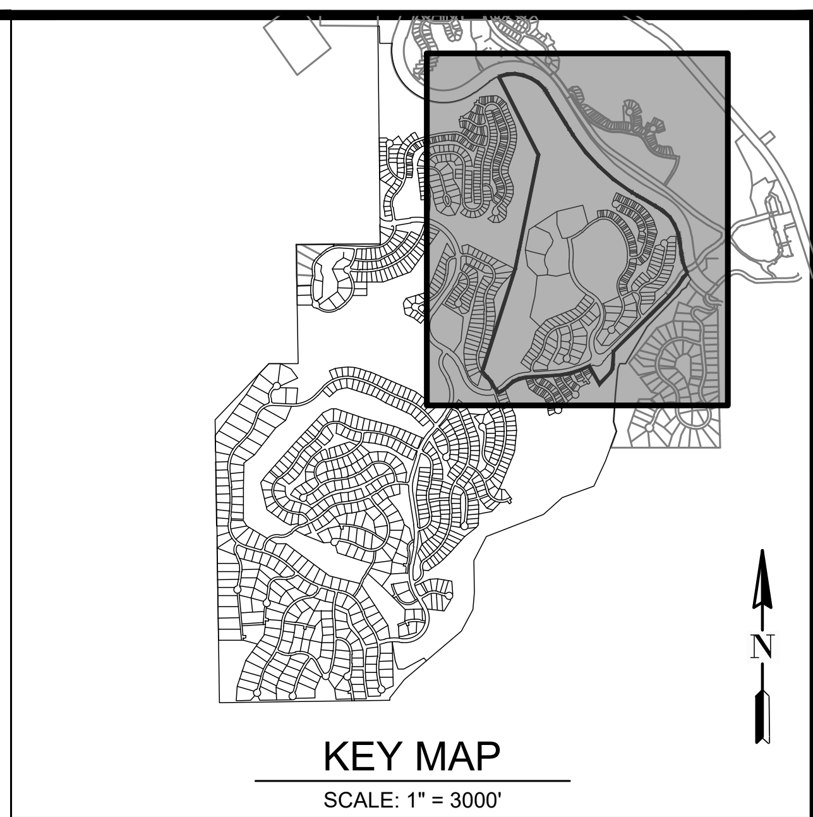
Proposed Drainage Map


OS3
OS3_OUT
B2
B3
POND_B
A_OUT
B1
DP_B2
B4
B
A
POND_A
D1
D2
OS1
OS2
E1
C1
A1_OUTFALL
A2/3
POND_C
OS2_OUT
C2
A2
A3
LELAND CREEK
A4
A1
C

Existing Conditions			
Element	Area (Ac)	Q5 (CFS)	Q100 (CFS)
A	165.82	47.7	143.8
A_OUT	-	58.7	183.0
A1	23.59	6.8	26.4
A1_OUTFALL	-	7.0	27.2
A2	11.06	2.5	9.4
A2/3	-	4.2	15.8
A3	5.95	1.8	6.4
A4	2.73	0.6	2.1
B	8.62	3.7	14.6
B1	10.33	2.7	9.1
B2	8.97	2.3	7.7
B3	8.47	2.5	9.1
B4	1.05	0.3	1.1
C	1.71	0.4	1.3
C1	2.92	0.8	2.8
C2	7.57	2.1	8.3
DP_B2	-	5.0	16.8
D1	6.77	1.3	4.2
D2	0.32	0.1	0.3
E1	3.05	0.9	3.7
LELAND CREEK	-	5.3	17.4
OS1	0.93	0.3	1.4
OS2	2.42	0.7	2.9
OS2_OUT	-	0.7	2.9
OS3	3.76	1.9	7.2
OS3_OUT	-	11.1	33.7
POND_A	-	58.7	183.0
POND_B	-	9.9	30.3
POND_C	-	3.1	11.7
REACH-A1	-	7.0	26.6
REACH-A2/3	-	4.2	15.5
REACH-A4	-	0.6	2.1
SWALE B	-	5.0	16.7

Proposed Conditions			
Element	Area (Ac)	Q5 (CFS)	Q100 (CFS)
A	165.82	57.5	164.0
A_OUT	-	4.0	49.0
A1	23.59	13.5	41.3
A1_OUTFALL	-	13.9	43.1
A2	11.06	6.0	15.8
A2/3	-	8.9	24.2
A3	5.95	3.2	9.3
A4	2.73	0.7	2.7
B	8.62	4.4	14.1
B1	10.33	4.6	13.7
B2	8.97	4.6	12.7
B3	8.47	4.3	10.5
B4	1.05	1.3	3.5
C	1.71	0.6	2.6
C1	2.92	1.6	5.0
C2	7.57	2.8	8.6
DP_B2	-	9.2	26.2
D1	6.77	2.3	7.2
D2	0.32	0.4	1.1
E1	3.05	1.1	3.9
LELAND CREEK	-	3.7	12.0
OS1	0.93	0.3	1.1
OS2	2.42	1.5	5.3
OS2_OUT	-	1.5	5.3
OS3	3.76	2.1	7.0
OS3_OUT	-	2.2	22.7
POND_A	-	4.0	49.0
POND_B	-	0.9	21.0
POND_C	-	0.1	1.7
REACH-A1	-	13.7	42.6
REACH-A2/3	-	8.9	24.1
REACH-A4	-	0.7	2.7
SWALE B	-	9.2	26.2





KEY MAP

SCALE: 1" = 3000'

N

0 250' 500'

1 inch = 250'

LEGEND

4900	PROPOSED MAJOR CONTOUR
4885	PROPOSED MINOR CONTOUR
4900	PROPOSED MAJOR CONTOUR
4885	PROPOSED MINOR CONTOUR
▬ ▬ ▬	PROPOSED DRAINAGE BASIN MAJOR
- - -	PROPOSED DRAINAGE BASIN MINOR
▬ ▬ ▬	EXISTING DRAINAGE BASIN MAJOR
- - -	EXISTING DRAINAGE BASIN MINOR
▭	NOT A PART
EXISTING PROPOSED	STORM (FES, MH, & INLET)
EX-1 AREA X.XX (AC) 0.XX 0.XX / PR-1 AREA X.XX (AC) 0.XX 0.XX	BASIN DESIGNATION MINOR RUNOFF (CFS) MAJOR RUNOFF (CFS)
→ →	DIRECTIONAL FLOW ARROW
△EX-1 △PR-1	DESIGN POINT
→	EMERGENCY OVERFLOW ROUTE
━	REACH
○	JUNCTION

terracina design

10200 E. Girard Ave, A-314
Denver, CO 80231
ph: 303.632.8867

#	REVISION DESCRIPTION	DATE	BY
1	1ST SUBMITTAL	04/11/2025	MJG
2	2ND SUBMITTAL	XX/XX/XXXX	MJG

NOT FOR CONSTRUCTION

GRAND PARK - 8WB, 9W, 10W.3, & 11W.2
TOWN OF FRASER, COLORADO

PHASE II DRAINAGE REPORT
HEC-HMS DRAINAGE MAP

Know what's **below.** **Call** before you dig.
811

12/15/2025 12:49 PM, X:\GRAND PARK\DOCUMENTS\REPORTS\DRAINAGE\16.1 - FILING 1 - 8WB, 9W, 10W, 11W\PHASE 2\E - DRAINAGE MAPS PROPOSED HEC-HMS MAP.DWG 1

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A1	23.59	6.8	26.4
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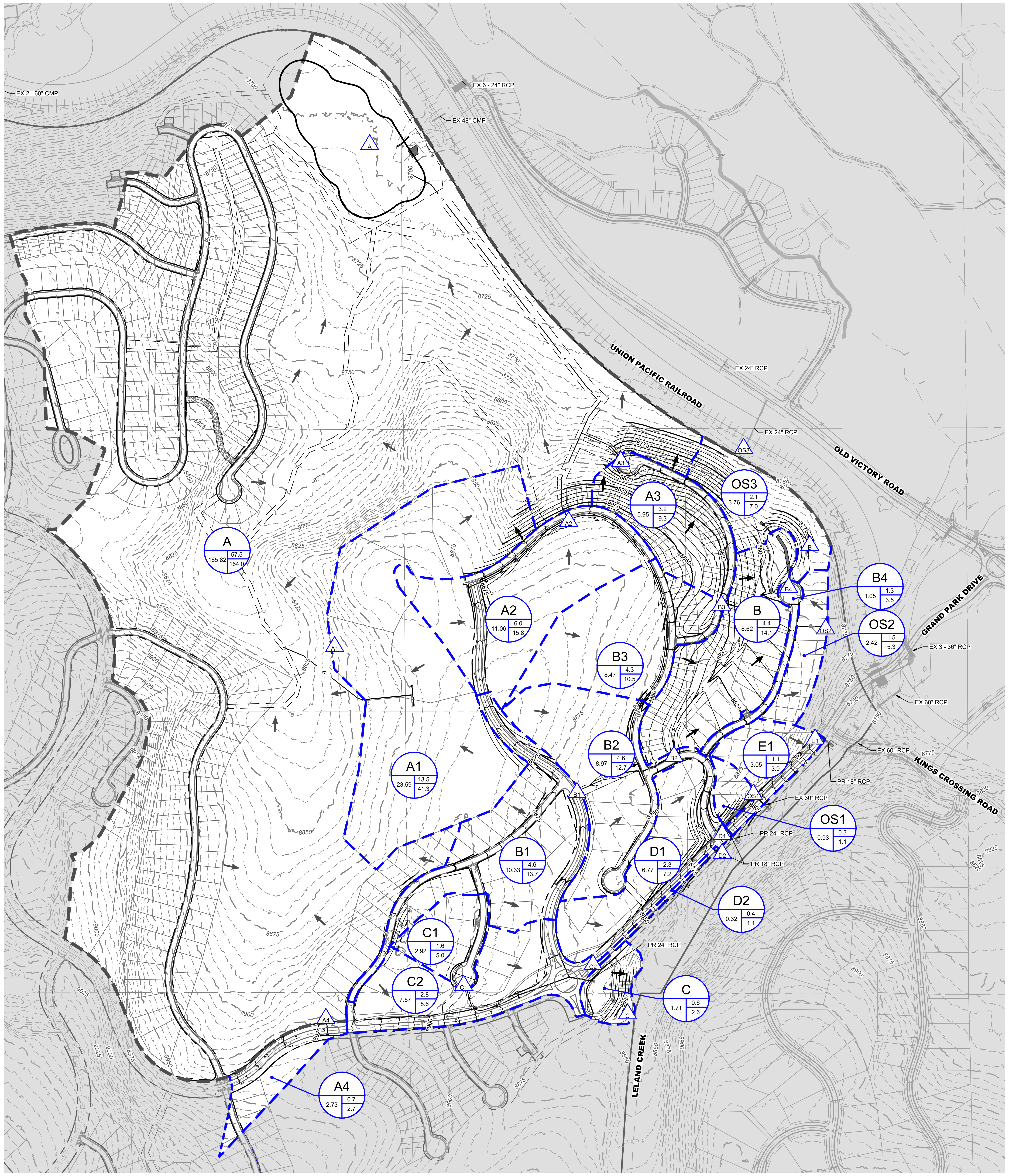

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4900	PROPOSED MAJOR CONTOUR
4885	PROPOSED MINOR CONTOUR
▬ ▬ ▬	PROPOSED DRAINAGE BASIN MAJOR
▬ ▬ ▬	PROPOSED DRAINAGE BASIN MINOR
▬ ▬ ▬	EXISTING DRAINAGE BASIN MAJOR
▬ ▬ ▬	EXISTING DRAINAGE BASIN MINOR
▨	NOT A PART
EXISTING / PROPOSED	STORM (FES, MH, & INLET)
EX-1 / PR-1	BASIN DESIGNATION
AREA X.XX (AC) 0.XX	MINOR RUNOFF (CFS)
0.XX	MAJOR RUNOFF (CFS)
→ →	DIRECTIONAL FLOW ARROW
EX-1 / PR-1	DESIGN POINT
→	EMERGENCY OVERFLOW ROUTE

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PHASE II DRAINAGE REPORT
PROPOSED DRAINAGE MAP

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