

FINAL DRAINAGE REPORT

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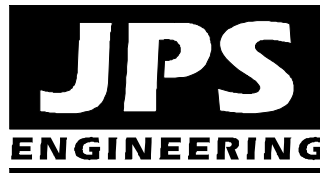
ARROWSWEST APARTMENTS
LOTS 1-8, SHOPS AT ARROWSWEST FILING NO. 1

Prepared for:

Arrowswest Apartments I LLC
9757 Juanita Drive NE, Suite 300
Kirkland, WA 98034

October 22, 2021
Revised September 16, 2022
Revised October 5, 2022

Prepared by:



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JPS Project No. 072002

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FINAL DRAINAGE REPORT
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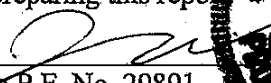
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**DRAINAGE REPORT STATEMENTS
ARROWSWEST APARTMENTS**

Engineer's Statement:

This report and plan for the final drainage design of Arrowswest Apartments was prepared by me (or under my direct supervision) and is correct to the best of my knowledge and belief. Said report and plan has been prepared in accordance with the City of Colorado Springs Drainage Criteria Manual and is in conformity with the map of the drainage basin. I understand that the City of Colorado Springs does not and will not assume liability for drainage facilities designed by others. I accept responsibility for negligent acts, errors or omissions on my part in preparing this report.


John P. Schwab, Colorado P.E. No. 29891

10/4/22
Date

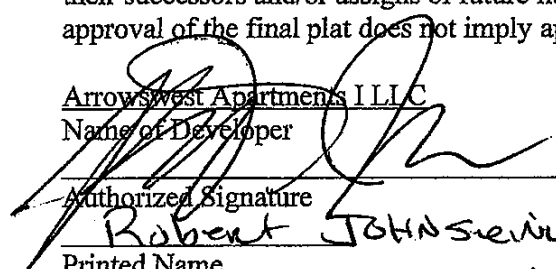


Developer's Statement:

Arrowswest Apartments I LLC hereby certifies that the drainage facilities for Arrowswest Apartments shall be constructed according to the design presented in this report. I understand that the City of Colorado Springs does not and will not assume liability for the drainage facilities designed and/or certified by my engineer and that are submitted to the City of Colorado Springs pursuant to Section 7.7.906 of the City Code; and cannot, on behalf of Arrowswest Apartments, guarantee that final drainage design review will absolve Arrowswest Apartments I LLC and/or their successors and/or assigns of future liability for improper design. I further understand that approval of the final plat does not imply approval of my engineer's drainage design.

Arrowswest Apartments I LLC

Name of Developer


Authorized Signature

10-4-2022
Date

Printed Name

VP of Construction, Design
Title

Address: 9757 Juanita Drive NE, Suite 300, Kirkland, WA 98034

City of Colorado Springs Statement:

Filed in accordance with Section 7.7.906 of the Code of the City of Colorado Springs, 2001, as amended.


For City Engineer

Heidi McMacken

10/18/22

Date

Conditions:

I. INTRODUCTION

A. Background

Arrowswest Apartments is a proposed residential apartment project located at the southwest corner of Garden of the Gods Road and Arrowswest Drive in Colorado Springs (see Vicinity Map in Appendix E). The 9.47-acre project site is comprised of eight platted lots described as Lots 1-8, Shops at Arrowswest Filing No. 1. The property will be replatted to eliminate the previously platted interior lot lines. The site is currently zoned PBC (Planned Business Center), and a conditional use permit will be processed for the proposed apartment use.

The proposed area of disturbance associated with this project is approximately 7.6 acres.

The proposed Site Development Plan consists of approximately 359 one-two bedroom apartment units in seven buildings (Buildings A-F), along with a club house building, with associated site grading, parking, and utility improvements. Access to the proposed apartment buildings will be provided by private driveways circulating through the site, with connections to the existing shared private access drive bisecting the site between 30th Street and Arrowswest Drive.

B. Purpose

This Final Drainage Report has been prepared in support of the site development plan and subdivision plat for the proposed Arrowswest Apartments project. The report is intended to meet the requirements of a Final Drainage Report in accordance with City of Colorado Springs drainage criteria.

C. General Description

The subject property (El Paso County Assessor's Parcel #73224-00-002, -004, and -005, and 73271-01-004, -005, -006, -007, and -008) is currently platted as Lots 1-8, Shops at Arrowswest Filing No. 1, and the property is located in the Southwest Quarter of Section 22 and the Northwest Quarter of Section 27, Township 13 South, Range 67 West of the 6th P.M.

The site is bounded by developed commercial and residential properties to the north and northeast. Garden of the Gods Road (fully improved arterial public street) adjoins the northeast boundary of the site, and 30th Street (fully improved arterial public street) adjoins the northwest property boundary.

An existing Loaf 'N Jug convenience store has been developed on the 1.1-acre site along the northwest boundary of the property (Lot 9, Shops at Arrowswest Filing No. 1). An existing shared private drive provides access to the convenience store and circulation between Arrowswest Drive and 30th Street.

The southeast boundary of the site adjoins a vacant 9-acre industrial lot owned by Verizon Wireless (platted as Lot 1, Block 1, Arrowswest Filing No. 7).

Arrowswest Drive (fully improved local public street) adjoins the east boundary of the property, and the recently constructed Red Leg Brewing Company has been developed on the 2.5-acre site across Arrowswest Drive to the east (Lot 9, Arrowswest Filing No. 8).

Ground elevations within the site range from 6,462 to 6,545 feet above mean sea level.

The terrain is gently rolling, with southwest to northeast slopes ranging from 2-8 percent for most of the property. The southwest edge of the property is an existing embankment rising southwesterly to an open space tract in the adjoining Kissing Camels neighborhood, with slopes in the 2:1-3:1 range. Historic drainage patterns from the site are conveyed overland towards the northeast boundaries of the site. The site is currently vegetated with native grasses.

Surface drainage within the site area generally flows northeast towards the existing public storm sewer system at the corner of Garden of the Gods Road and Arrowswest Drive, which flows southeasterly into the Douglas Creek Drainage Channel, ultimately flowing to Monument Creek.

The proposed development will consist of multi-family residential apartment project, with seven 3-story apartment buildings, a clubhouse and associated parking and landscaping areas. Site improvements will include overlot grading, parking improvements, site utilities, and commercial site development.

Stormwater quality and detention will be provided for all proposed site improvements.

D. Soil Conditions

According to the Soil Survey of El Paso County prepared by the Natural Resources Conservation Service (NRCS), on-site soils are comprised of the following soil types (see Appendix B):

- “Midway clay loam” soils (Type 54). These soils have a very slow infiltration rate (high runoff potential), and are classified as hydrologic soils group D.

E. References

City of Colorado Springs “Drainage Criteria Manual, Volumes 1 and 2,” May, 2014.

Classic Consulting Engineers & Surveyors, “Final Drainage Report for Shops at Arrowswest Filing No. 1,” April 2002 (approved by City 8/27/02).

Drexel, Barrell & Co., “Addendum No. 2 to Drainage Report for Arrowswest,” revised December 17, 1987 (approved by City 12/22/87).

Drexel, Barrell & Co., “Drainage Report for Arrowswest Filing #1,” revised February 22, 1984 (approved by City 3/14/84).

Elevation Consulting Group, Ltd., “Preliminary / Final Drainage Report for Red Leg Brewery,” January 29, 2020 (approved by City 1/30/20).

II. DRAINAGE CRITERIA

A. Hydrologic Criteria

Tributary drainage areas impacting the on-site drainage analysis are all less than 100-acres, so Rational Method procedures were utilized for calculation of peak flows within the on-site drainage basins. In accordance with City of Colorado Springs Drainage Criteria Manual Volume 1 (DCM 1), Rational Method hydrologic calculations were based on the following assumptions:

- Design storm (minor): 5-year
- Design storm (major): 100-year

$$Q = CiA$$

Q = Peak Flow (cubic feet per second, cfs)
C = Runoff Coefficient
i = Rainfall Intensity (inches per hour, in/hr)
A = Tributary Drainage Area (acres, ac)

Runoff times of concentration were calculated based on guidance in DCM 1. Rainfall intensities were derived from City of Colorado Springs Intensity-Duration-Frequency (IDF) curves. Runoff coefficients were selected based on the existing and proposed land uses according to DCM 1 Table 6-6. Hydrologic calculations are enclosed in Appendix B, and peak design flows are identified on the drainage basin drawings.

B. Hydraulic Criteria

Hydraulic design criteria are based on guidelines delineated in the City of Colorado Springs Drainage Criteria Manual (DCM).

Storm inlet design and related gutter flow calculations have been performed using the “UD-Inlet_v4.05” design software published by the Mile High Flood District (MHFD).

Storm sewer design calculations have been performed using the FHWA “Hydraulic Toolbox 4.2” software. Storm sewer hydraulic grade line (HGL) calculations for the private storm sewers within the site are generally based on 100-year pipe capacity, with appropriate surface overflow paths provided.

Stormwater detention facilities have been designed using the “MHFD-Detention_v4.04” software package published by MHFD. Stormwater quality facilities have been designed using the “UD-BMP_v3.07” software package published by MHFD.

Final storm sewer hydraulic grade line (HGL) calculations will be performed using the “UD-Sewer-2009” software package published by MHFD.

As required for storm sewer lines larger than 12” diameter, a separate Final Drainage Report Addendum will be submitted providing HGL calculations (using “UD-Sewer”) along with submittal of the Storm Sewer Plan and Profile drawings. The Drainage Report Addendum will include confirmation that storm sewer design meets DCM criteria for both 5-year and 100-year design conditions.

III. EXISTING DRAINAGE CONDITIONS

The project site is located within the Douglas Creek Drainage Basin.

The development site generally slopes downward to the northeast, with average grades of 2-8 percent. The property is currently vacant and unimproved, with the exception of the existing convenience store adjoining the west side of the property and the existing shared private drive bisecting the site between Arrowswest Drive and 30th Street.

Drainage planning for this subdivision was previously studied in the April, 2002 “Final Drainage Report for Shops at Arrowswest Filing No. 1” by Classic Consulting Engineers & Surveyors (CCES). Existing drainage conditions are depicted on the enclosed “Shops at Arrowswest Filing No. 1 Drainage Plan” by CCES. The previously approved subdivision drainage report identifies site drainage flowing northeasterly to an existing public storm sewer system at the intersection of Arrowswest Drive and Garden of the Gods Road. An existing 24” RCP public storm sewer extends northeasterly from this intersection across Garden of the Gods Road into an existing 42” RCP public storm sewer which flows southeasterly to the Douglas Creek channel. Two existing 18” RCP storm sewer stubs have been extended southwesterly upstream of the existing public storm inlet at the intersection to serve this property.

As depicted on the CCES Drainage Plan, one existing 18” RCP Storm Sewer stub enters the northeast corner of the property. Based on the slope of 5.45% identified on the CCES Drainage Plan, the northerly 18” RCP stub provides a full-pipe capacity of 23.6 cfs.

The second existing 18” RCP Storm Sewer stub extends to the southwest corner of the intersection of Arrowswest Drive and the shared private access drive entering this site. Based on the slope of 3.82% identified on the CCES Drainage Plan, the southerly 18” RCP stub provides a full-pipe capacity of 22 cfs.

Final HGL calculations (to be provided in a future addendum to this report) will be based upon the tailwater condition at the connection to each existing pipe during each storm event.

The CCES report identifies the total developed flow from the site entering the existing 24" RCP public storm sewer at the intersection of Arrowswest Drive and Garden of the Gods Road as $Q_5 = 11$ cfs and $Q_{100} = 24$ cfs (CCES Design Point 12), and states that "From the Garden of the Gods Road, Drainage Study, Widening Project, by Nolte Engineers, the 100-year conveyance is expected to be 34.9 cfs. Therefore, the proposed flows leaving the site are less than and have been accounted for downstream on Garden of the Gods" (see excerpt from CCES FDR in Appendix A).

As depicted on the "Existing Conditions Drainage Plan" (Sh. EX1, Appendix E), the on-site area has been delineated as Basin A (9.47 acres), which sheet flows northeasterly to Design Point #1 at the northeast corner of the site. Existing drainage from Basin A flows northeasterly by sheet flow and drainage swales, with existing peak flows calculated as $Q_5 = 5.1$ cfs and $Q_{100} = 28.3$ cfs.

The property is impacted by an off-site area consisting of the vegetated embankment adjoining the southwest boundary of the site. Off-site Basin OA1 (0.4 acres) comprises the southwest embankment area, which sheet flows to the northeast. Existing peak flows from Basin OA1 are calculated as $Q_5 = 0.2$ cfs and $Q_{100} = 1.4$ cfs. Off-site Basin OB1 (1.6 acres) comprises the southeast part of the embankment area, which sheet flows to the northeast. Existing peak flows from Basin OB1 are calculated as $Q_5 = 1.0$ cfs and $Q_{100} = 5.5$ cfs.

The property is also impacted by the developed off-site area delineated as Basin OA2 (1.04 acres) which is the existing convenience store and gas station platted as Lot 9, Shops at Arrowswest Filing No. 1, adjoining the west boundary of the site. Existing developed drainage from Basin OA2 sheet flows easterly across Lot 9, with existing peak flows calculated as $Q_5 = 4.0$ cfs and $Q_{100} = 7.8$ cfs.

Existing flows from Basins OA1, OA2, OB1, and A combine at Design Point #1, with existing peak flows calculated as $Q_5 = 8.9$ cfs and $Q_{100} = 39.6$ cfs.

IV. PROPOSED DRAINAGE CONDITIONS

As shown on the enclosed Drainage Plan (Sheet D1, Appendix F), developed runoff from the site will continue to follow historic drainage patterns to the northeast.

The proposed drainage plan for the new Arrowswest Apartments development will provide on-site extended detention and water quality facilities to meet current full-spectrum detention and water quality requirements before discharging into the existing downstream public storm sewer system.

Basin B1

The southwest area of the Arrowswest Apartments site has been delineated as Basin B1 (4.27 acres), and this basin will generally flow easterly to private storm inlets draining into Private Full-Spectrum Detention Basin B1.

Existing runoff from Off-site Basin OB1 (1.6 acres) will continue to drain northeasterly into the site, and Proposed Private Inlets OB1.1-OB1.4 are grated landscape inlets (18" Nyoplast or equal; sump condition) designed to intercept surface drainage from Basin OB1 along the southwest side of Building F. Proposed Private Storm Sewer OB1 (12" HDPE) will collect the flow from Inlets OB1.1-OB1.4, and extend to discharge in the parking area on the southeast side of Building F, where this flow will continue along the southeasterly curb and gutter to Private Inlet B1E near the southeast corner of Building C. In the event of clogging, overflows from Inlets OB1.1-OB1.4 would follow the drainage swale along the southwest side of Building F, flowing to the parking lot on the southeast side of Building F. Overflow Swale OB1 is a proposed 2-foot deep grass-lined ditch with 3:1 side slopes and a slope of 0.5 percent. As detailed in the hydraulic calculations in Appendix C, the swale has been designed to convey the design flow with stable velocities and a minimum of 1-foot freeboard.

Proposed Private Inlets B1A-B1C are grated landscape inlets (18" Nyoplast or equal; sump condition) collecting surface drainage between Buildings D and E, and these inlets will drain southeasterly through Private Storm Sewer B1C (12" HDPE) to Private Inlet B1D in the access drive between Buildings C and D. In the event of clogging, overflows from Inlets B1A-B1C would drain easterly between Buildings D and E, flowing into the parking lot on the east side of Buildings D-E.

Private Inlet B1D (CDOT Type 13; sump condition) will intercept surface drainage from a part of the parking area, and Private Storm Sewer B1D (15" HDPE) will flow southeasterly to Private Storm Inlet B1E at the southeast corner of Building C. In the event of clogging, overflows from Inlet B1D would flow southeasterly in the concrete crossspan along the southwest side of Building C, flowing to Private Storm Inlet B1E.

Private Storm Inlet B1E (10-foot D10R; sump condition) will intercept surface drainage from the southeast part of the site, and Private Storm Sewer B1E (24" HDPE) will convey the combined flow northeasterly into Private Full-Spectrum Detention Basin B1. In the event of clogging, overflows from Inlet B1E would flow northeasterly into Detention Basin B1. The maximum ponding elevation of Inlet B1E is 12-inches, and based on the proposed grading plan, the adjoining Building C Floor Elevation (FF=6481.0) is well above the maximum ponding elevation (6480.1).

As depicted on the Developed Drainage Plan, an 8-inch PVC roof drain collection line (Private Storm Sewer B1F) will be provided along the northeast side of Building C to ensure that developed flows from the building roof are conveyed southeasterly into Full-Spectrum Detention Basin B1.

Developed peak flows for Basin B1 (4.27 acres) have been calculated as $Q_5 = 13.9$ cfs and $Q_{100} = 29.1$ cfs.

Private Full-Spectrum Detention Basin B1 will be constructed at the southeast corner of the site, and this detention basin has been sized for a volume of 0.52 acre-feet to provide stormwater detention and water quality treatment for Basins OB1 and B1. The discharge pipe from Full-Spectrum Detention Basin B1 (12" HDPE) will flow northwesterly parallel to Arrowswest Drive to a proposed Private Storm Sewer Manhole connecting to the existing 18" RCP storm sewer stubbed into the property on the south side of the existing shared access drive.

An emergency spillway will be provided in the northeast corner of Full-Spectrum Detention Basin B1, with a 6-foot wide concrete chase providing a stable emergency overflow path into the adjoining curb and gutter along Arrowswest Drive.

The undetained developed peak flows at Design Point B1.1 (combined Basins OB1 and B1) have been calculated as $Q_5 = 11.7$ cfs and $Q_{100} = 27.9$ cfs, which would exceed the capacity of the existing 18" RCP storm sewer stub into the property. The detained flow at Design Point B1.1d (accounting for detained outflows from Full-Spectrum Detention Basin B1) reduces the combined discharge to $Q_5 = 2.4$ cfs and $Q_{100} = 6.8$ cfs, which is well within the allowable capacity of the existing downstream public storm sewer system.

Basin A1

The west side of the proposed Arrowswest Apartments site has been delineated as Basin A1 (2.51 acres), and this basin will generally drain northeasterly to private storm inlets flowing into Detention Basin B3.

Existing runoff from Off-site Basin OA1 (0.4 acres) will continue to drain northeasterly into the site, and Proposed Swale A1 will intercept surface drainage from Basin OA1 and the southwest part of Basin A1, diverting this drainage to flow northeasterly along the west side of Building G. Swale A1 is a proposed 2-foot deep grass-lined ditch with 3:1 side slopes and a slope of 0.6 percent. As detailed in the hydraulic calculations in Appendix C, the swale has been designed to convey the design flow with stable velocities and a minimum of 1-foot freeboard.

Proposed Private Inlets A1A and A1B (5-foot D10R; sump condition) will intercept surface drainage on the south side of the existing shared access drive, and Storm Sewer A1A-A1B (18" HDPE) will flow northeasterly to Private Storm Manhole A1C, joining with flows from Inlet A1C. In the event of clogging, overflows from Inlets A1A and A1B would sheet flow northeasterly into the existing curb and gutter along the shared access drive.

Storm Inlet A1C (5-foot D10R; sump) will intercept surface drainage on the west edge of the site, including the off-site flow from the existing convenience store (Basin OA2; 1.04 acres), and convey this flow southeasterly through Private Storm Sewer A1C (18"

HDPE) to Private Storm Manhole B3B (Type I). In the event of clogging, overflows from Inlet A1C would sheet flow southeasterly across the parking lot on the south side of Building B, flowing into Detention Basin B3.

Private Storm Sewer B3B-B3C (24" HDPE) will convey the flow from Private Storm Manhole B3B northeasterly into Private Full-Spectrum Detention Basin B3.

Developed peak flows for Basin A1 have been calculated as $Q_5 = 7.9$ cfs and $Q_{100} = 17.0$ cfs.

Basin B3

The northeast part of the Arrowswest Apartments site has been delineated as Basin B3 (1.83 acres), which will generally drain northeasterly to private storm inlets flowing into Private Full-Spectrum Detention Basin B3. Proposed Private Inlet B3A (5-foot D10R; sump condition) will intercept surface drainage in the parking area between Buildings A and B, and Private Storm Sewer B3A (24" HDPE) will flow southeasterly into Storm Manhole B3B. Private Storm Sewer B3B (24" HDPE) will convey the combined flow from this junction manhole east to Private Inlet B3B. In the event of clogging, overflows from Inlet B3A would flow southeasterly along the curb and gutter, flowing around the south side of Building B and into Detention Basin B3. The maximum ponding elevation of Inlet B3A is 12-inches, and based on the proposed grading plan the adjoining Building B Floor Elevation (FF=6478.0) is above the maximum ponding elevation (6477.5).

Private Storm Inlet B3B (5-foot D10R; sump) will intercept surface drainage in the northeast corner of the parking lot on the south side of Building B, and Private Storm Sewer B3C (24" HDPE) will convey the combined flow from this inlet northeasterly into Private Full-Spectrum Detention Basin B3. In the event of clogging, overflows from Inlet B3B would sheet flow northeasterly into Detention Basin B3.

As depicted on the Developed Drainage Plan, an 8-inch PVC roof drain collection line (Private Storm Sewer B3D) will be provided along the northeast side of Building A to ensure that developed flows from the building roof are conveyed southeasterly into Full-Spectrum Detention Basin B3.

Developed peak flows for Basin B3 have been calculated as $Q_5 = 4.2$ cfs and $Q_{100} = 9.7$ cfs.

Private Full-Spectrum Detention Basin B3 will be constructed at the northeast corner of the site, and this detention basin has been sized for a volume of 0.65 acre-feet to provide stormwater detention and water quality treatment for Basins OA1, OA2, A1, and B3. The discharge pipe from Full-Spectrum Detention Basin B3 (18" HDPE) will flow northeasterly into a proposed Private Storm Sewer Manhole connecting to the existing 18" RCP storm sewer stubbed into the property at the northeast corner of the property.

An emergency spillway will be provided on the southeast side of Full-Spectrum Detention Basin B3, with an 8-foot wide concrete chase providing a stable emergency overflow path into the adjoining curb and gutter along Arrowswest Drive.

The undetained developed peak flows at Design Point B3.1 (combined Basins OA1, OA2, A1, and B3) have been calculated as $Q_5 = 12.5$ cfs and $Q_{100} = 27.6$ cfs, which would exceed the capacity of the existing 18" RCP storm sewer stub into the property. The detained flow at Design Point B3.1d (accounting for detained outflows from Full-Spectrum Detention Basin B3) reduces the combined discharge to $Q_5 = 0.2$ cfs and $Q_{100} = 5.5$ cfs, which is well within the allowable capacity of the existing downstream public storm sewer system.

Basin B2

Basin B2 (0.47 acres) consists of the easterly segment of the existing shared access drive connecting to Arrowswest Drive at the east edge of the site, and the landscaped area along the east side of Buildings B and C, which will sheet flow easterly into the existing curb and gutter along the west side of Arrowswest Drive.

No significant impervious area improvements are planned for Basin B2, and all of the adjoining proposed impervious areas will be routed into the proposed Full-Spectrum Detention Basins B1 and B3.

Developed peak flows for Design Point B2 have been calculated as $Q_5 = 1.2$ cfs and $Q_{100} = 2.6$ cfs.

Basin B4

Basin B4 (0.41 acres) consists of the landscaped area along the northeasterly edge of the site (northeast of Building A), which will sheet flow northeasterly into the existing curb and gutter along the southwest side of Garden of the Gods Road. No significant impervious area improvements are planned for this basin as a part of this project. As depicted on the Developed Drainage Plan, the City Parks Department has a project planned for construction of a 10-foot wide sidewalk along this corridor.

Developed peak flows for Design Point B4 have been calculated as $Q_5 = 0.6$ cfs and $Q_{100} = 1.9$ cfs.

Combined Flows

Developed peak flows at Design Point #1 (combined Basins OA1, A1, B1-B4) have been calculated as $Q_5 = 24.9$ cfs and $Q_{100} = 57.2$ cfs. The total combined detained flows at Design Point #1 (accounting for detained outflows from Detention Basins B1 and B3) are calculated as $Q_5 = 4.5$ cfs and $Q_{100} = 16.8$ cfs. The total detained 100-year flows are well below the existing downstream storm sewer capacity identified in the previously approved drainage reports.

Drainage Facility Design:

Hydrologic calculations are detailed in Appendix B, and hydraulic calculations for proposed drainage improvements are enclosed in Appendix C.

The emergency overflow path for drainage from this site consists of sheet flow northeasterly to the existing curb and gutter and public storm sewer system along Arrowswest Drive and Garden of the Gods Road.

As detailed in the “Storm Inlet Sizing Summary” table in Appendix B, inlet flows have been calculated based on the proportional drainage basin area draining to each individual inlet, and the selected inlets have been sized to provide Inlet Capacity exceeding the calculated 100-year flow entering each inlet. As such, no bypass flow is anticipated from any of the inlets.

As listed in the “Storm Sewer Sizing Summary” table in Appendix B, the selected storm drain pipes have been sized to provide pipe capacity exceeding the calculated 100-year flow entering each pipe.

Detailed hydraulic grade line calculations for the proposed storm sewer improvements will be provided as a future addendum to this report.

V. DRAINAGE PLANNING – FOUR STEP PROCESS

City of Colorado Springs Drainage Criteria require drainage planning to include a Four Step Process for receiving water protection that focuses on reducing runoff volumes, treating the water quality capture volume (WQCV), stabilizing drainageways, and implementing long-term source controls. As stated in DCM Volume 2, the Four Step Process is applicable to all new and re-development projects with construction activities that disturb one acre or greater or that disturb less than 1 acre but are part of a larger common plan of development.

The Four Step Process will be implemented as follows in this project:

Step 1: Employ Runoff Reduction Practices

- **Minimize Impacts:** The proposed apartment project will be constructed on previously platted lots in an infill part of the City, which inherently minimizes impact in comparison to alternative “non-infill” sites.
- **Minimize Directly Connected Impervious Areas:** Roof drain downspouts will be routed across vegetated areas where possible prior to entering storm sewer systems.
- **The Impervious Reduction Factor (IRF) worksheets** are enclosed in Appendix D1-D2.

Step 2: Implement BMPs that Provide a Water Quality Capture Volume with Slow Release

- FSD: Full-Spectrum Extended Detention Basins and Water Quality Facilities will be provided along the downstream boundaries of the site. Developed drainage will be routed through the private detention basin facilities, which will capture and slowly release the WQCV over an extended-release period.

Step 3: Stabilize Drainageways

- There are no major drainageways directly adjacent to this site. Impacts on downstream drainageways will be minimized by routing developed flows through the on-site Full-Spectrum Detention and Water Quality Facilities.
- Drainage basin fees paid during previous platting of this property provided the required contribution towards regional drainage improvements.
- The existing downstream public storm sewer system discharges into the concrete-lined Douglas Creek drainage channel, and the existing concrete lining provides sufficient channel stabilization. The existing storm sewer discharge point into the Douglas Creek channel is approximately 720 feet downstream of this site.

Step 4: Implement Site Specific and Other Source Control BMPs

- The proposed multi-family residential site development will implement a Stormwater Management Plan including proper housekeeping practices and spill containment procedures.

VI. GENERAL DRAINAGE RECOMMENDATIONS

The developed drainage plan for the site is to provide and maintain positive drainage away from structures and conform to the established drainage patterns for the overall site. JPS Engineering recommends that positive drainage be established and maintained away from all structures within the site in conformance with applicable building codes and geotechnical engineering recommendations.

In general, we recommend a minimum of 6 inches clearance from the top of concrete foundation walls to adjacent finished site grades. Positive drainage slopes should be maintained away from all structures, with a minimum recommended slope of 5 percent for the first 10 feet away from buildings in landscaped areas, a minimum recommended slope of 2 percent for the first 10 feet away from buildings in paved areas, and a minimum slope of 1 percent for paved areas beyond buildings.

VII. STORMWATER DETENTION & WATER QUALITY

As required by City Engineering policies for any development involving disturbed areas greater than one acre, stormwater detention and water quality improvements will be implemented with development of this site. The proposed drainage and grading plan will direct surface drainage to the proposed Private Full-Spectrum Detention (FSD) Basin facilities along the east side of the property, which will provide the required stormwater detention and water quality capture volume in accordance with the "City Drainage

Criteria Manual, Volumes 1 and 2.” The proposed on-site detention facilities will be privately owned and maintained by the property owner.

In accordance with current drainage policies, the proposed detention and water quality facilities have been designed for a 40-hour water quality capture volume release time, and a maximum 72-hour full-spectrum detention volume release time. The Extended Detention Basins providing full-spectrum detention have been designed utilizing the Mile High Flood District’s “MHFD-Detention_v4.04” software. The Full- Spectrum Detention Basins have been sized to provide the Water Quality Capture Volume (WQCV), Excess Urban Runoff Volume (EURV), and 100-year Detention Volume. Design parameters for the proposed Detention Basins are summarized as follows:

Basin	Tributary Drainage Basins	Tributary Area (ac)	Impervious Percentage	Min. WQCV (af)	Min. EURV (af)	Min. 100-Yr Vol. (af)	Design Volume (af)
B1	OB1,B1	5.87	47.5	0.098	0.165	0.51	0.52
B3	OA1,OA2,A1,B3	5.78	61.6	0.116	0.226	0.61	0.65

Detention Basins B1 and B3 will have grass-lined bottoms with concrete trickle channels and gravel access ramps extended to the pond bottoms for maintenance access. The proposed detention basins will have outlet control structures and discharge pipes connecting to the existing storm sewer pipe stubs along the west side of Arrowswest Drive.

The enclosed “MHFD-Detention_v4.04” design calculations provide the final basis of design for each detention basin including outlet structure dimensions, orifice plate design, and spillway design (see calculations in Appendix D1 and D2).

Additional detention basin design parameters have been calculated using “UD-BMP_v3.07,” including forebay volume sizing, forebay notch width, and micropool sizing. Hydraulic calculations for trickle channels are also enclosed in Appendix D1 and D2.

In the event of clogging, an emergency spillway and concrete chase will be constructed along the downstream side of each detention basin to allow for overflows to drain into the existing public street (Arrowswest Drive). The outlet structures from the on-site Detention Basins will discharge through 12-18-inch private HDPE pond outlet pipes connecting to the existing 18” RCP storm sewer lines that have been stubbed into the property along Arrowswest Drive.

Based on proximity to the existing public streets along the downstream boundaries of the site, the proposed Private Detention Basins will utilize retaining walls to provide the required detention volumes within the available site areas. The retaining walls are anticipated to be segmental block walls with appropriate structural design, permitting, and handrails. In accordance with DCM Volume 1, Chapter 13, Section 5.13, “a professional engineer licensed in the State of Colorado shall perform a structural analysis and design the retaining wall for

the various loading conditions the wall may encounter, including the differences in hydrostatic pressure between the front and back of wall. A drain system should be considered behind the wall to ensure that hydrostatic pressures are equalized as the water level changes in the pond.” Detailed design of the proposed retaining walls will be included in the Permanent Control Measure (PCM) plan for the project, and any required variances will be processed in conjunction with the PCM plans. Appropriate structural design along with railings and/or fencing will be utilized to justify variances for the horizontal distance between retaining walls and adjacent public sidewalks, roadways, and related features.

VIII. EROSION / SEDIMENT CONTROL

The Contractor will be required to implement proper Construction Control Measures (CCM's) for erosion control through the course of construction. Sediment control measures will include installation of silt fence along downgradient property boundaries to minimize off-site transport of construction sediment and other control measures as depicted on the Grading and Erosion Control Plans (to be submitted separately at a later date). Slopes will be stabilized during excavation as necessary and vegetation will be established for stabilization of disturbed areas as soon as possible. A Grading and Erosion Control Plan (GEC Plan) will be submitted to the Stormwater Enterprise for review and approval prior to construction.

IX. FLOODPLAIN IMPACTS

The site is located beyond the limits of any 100-year floodplain as shown in the FEMA floodplain map for this area, FIRM Panel No. 08041C0513G, dated December 7, 2018.

X. PUBLIC IMPROVEMENTS / DRAINAGE BASIN FEES

This project consists of a private multi-family residential site development with private drainage facilities within the property. No public drainage facilities are proposed as part of this project.

The proposed on-site stormwater detention facilities and private storm drainage improvements will be privately owned and maintained.

The site lies completely within the Douglas Creek Drainage Basin. Since this site was previously platted, no drainage basin fees or bridge fees are applicable at this time.

XI. CONSTRUCTION COST OPINION

The developer will pay all capital costs for the proposed private drainage improvements. Non-reimbursable private drainage facilities include the private storm sewer systems within the apartment site, as well as the private detention basin facilities. As detailed in Appendix E, the estimated cost of non-reimbursable private drainage facilities within the site is approximately \$140,740.

Additionally, the estimated cost of non-reimbursable private detention basin facilities within the site is approximately \$208,720.

XII. SUMMARY

The developed drainage patterns for the proposed Arrowswest Apartments will remain consistent with historic conditions and the overall drainage plan for this area. The proposed on-site stormwater detention facilities will provide stormwater detention and water quality treatment to mitigate developed drainage impacts from the site prior to discharge into the existing Garden of the Gods Road public storm sewer system.

The drainage planning in this report is in conformance with pertinent prior drainage studies, including the “Final Drainage Report for Shops at Arrowswest Filing No. 1,” as well as current City of Colorado Springs drainage criteria. Proper construction and maintenance of the proposed storm drainage and detention facilities, in conjunction with proper erosion control practices during and after construction, will ensure that developed drainage from this site has no significant adverse impact on the downstream drainage system.

APPENDIX A

EXCERPTS FROM PREVIOUS DRAINAGE REPORT



**FINAL DRAINAGE REPORT
FOR
SHOPS AT ARROWSWEST
FILING NO. 1**

APRIL 2002

PREPARED FOR:

**WESTERRA DEVELOPMENT COMPANY
520 E. COLORADO AVE
COLORADO SPRINGS, CO 80903
(719) 575-0083**

PREPARED BY:

**CLASSIC CONSULTING ENGINEERS & SURVEYORS, LLC
6385 CORPORATE DRIVE, SUITE 304
COLORADO SPRINGS, CO 80919
(719) 785-0790**

2050.00



Basin R, 1.11 Ac., ($Q_5 = 4$ cfs, $Q_{100} = 8$ cfs) consist of runoff generated by asphalt parking, driveway and landscaping. The flows are conveyed as sheet flow and concentrated flow carried by concrete curb and gutter into Arrows West Drive.

These flows will combine with flows from proposed Basins G, U, and existing Basins 300, 301, 313, 314, & 320, to be conveyed east down Garden of the Gods Road, Design Point 12 ($Q_5 = 11$ cfs, $Q_{100} = 24$ cfs). From the Garden of the Gods Road, Drainage Study, Widening Project, by Nolte Engineers, the 100 year conveyance is expected to be 34.9 cfs. Therefore, the proposed flows leaving the site are less than and have been accounted for downstream on Garden of the Gods.

Basin S, 0.47 Ac., ($Q_5 = 2$ cfs, $Q_{100} = 4$ cfs) consist of runoff generated by asphalt parking and landscaping. The flows are conveyed as sheet flow and concentrated flow carried by concrete curb and gutter to a 4' D-10-R sump inlet at Design Point 5 ($Q_5 = 2$ cfs, $Q_{100} = 4$ cfs). The flows collected at Design Point 5 will be carried by a 12" pipe (Pipe Run 11, $Q_5 = 2$ cfs, $Q_{100} = 4$ cfs) and conveyed downstream.

Basin T, 0.57 Ac., ($Q_5 = 3$ cfs, $Q_{100} = 5$ cfs) consist of runoff generated by asphalt parking and landscaping. The flows are conveyed as sheet flow and concentrated flow carried by concrete curb and gutter to a 4' D-10-R sump inlet at Design Point 6 ($Q_5 = 3$ cfs, $Q_{100} = 5$ cfs). The flows collected at Design Point 6 will be carried by a 12" pipe (Pipe Run 13, $Q_5 = 3$ cfs, $Q_{100} = 5$ cfs) to combine with flows from Pipe Run 12 to create Pipe Run 14, $Q_5 = 7$ cfs, $Q_{100} = 14$ cfs. These flows in combination with Pipe Run 21 will discharge into an existing 18" RCP storm sewer stub at the entrance, Pipe Run 22, $Q_5 = 15$ cfs, $Q_{100} = 30$ cfs. The existing 18" pipe is laid at 3.82% in Arrows West Drive, and combines with the system in Garden of the Gods Road to be conveyed to Douglas Creek.

Basin U, 0.92 Ac., ($Q_5 = 2$ cfs, $Q_{100} = 4$ cfs) consist of runoff generated by landscaping along Garden of the Gods Road. The flows are conveyed as sheet flow into the roadway to combine with the existing flows on the south side. The total flows in Garden of the Gods downstream of Arrows West Drive (Design Point 12,

ARROWSWEST

FINAL DRAINAGE REPORT

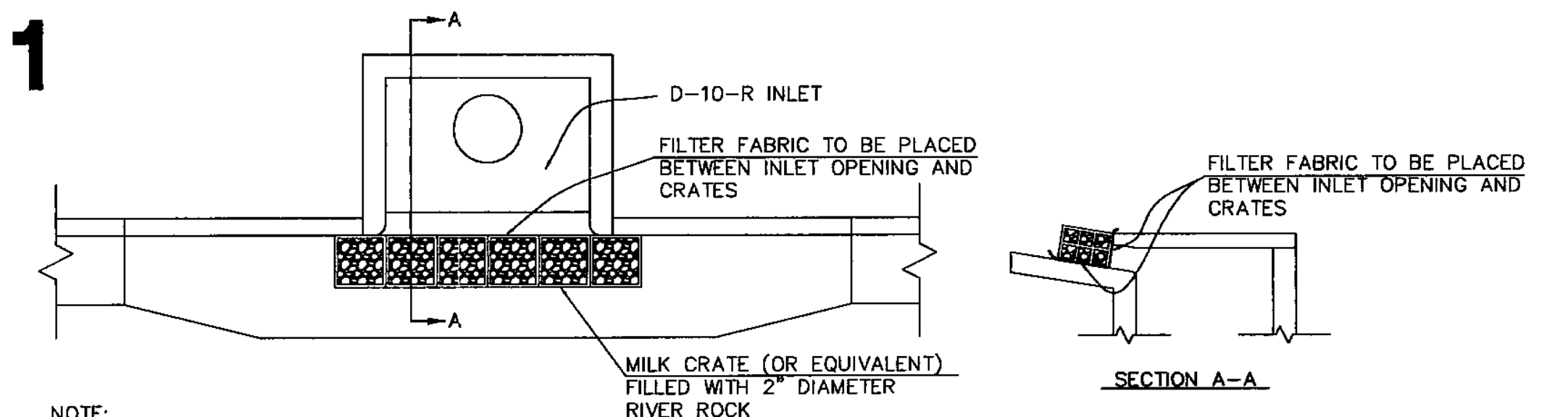
(Design Point Summary)

Design Point(s)	Contributing Basins	Equivalent CA(5)	Equivalent CA(100)	Maximum Tc	Intensity		Flow		
					I(5)	I(100)	Q(5)	Q(100)	Inlet Size
1	B	1.38	1.51	5.0	5.2	9.0	7	14	4' SUMP
2	D-1	0.26	0.28	8.3	4.3	7.6	1	2	4' SUMP
3	C	0.55	0.59	5.8	4.8	8.7	3	5	4' SUMP
4	OS-1, I	0.56	0.62	6.6	4.7	8.3	3	5	4' SUMP
5	S	0.38	0.40	5.0	5.2	9.0	2	4	4' SUMP
6	T	0.51	0.54	5.0	5.2	9.0	3	5	4' SUMP
7	M-1	0.26	0.28	5.0	5.2	9.0	1	2	4' SUMP
8	J, OS-2	1.28	1.55	9.9	4.1	7.1	5	11	4' SUMP
9	O	0.12	0.14	5.0	5.2	9.0	1	1	12" AREA DRAIN
10	300	1.71	2.24	12.5	3.7	6.4	6	14	10' AT GRADE
11	R, G	1.26	1.34	6.4	4.7	8.4	6	11	OFFSITE
12	R, G, U, 301, 313, 320, Flowby 314, Flowby DP 10	3.04	3.84	13.0	3.7	6.3	11	24	OFFSITE

SHOPS AT ARROWSWEST FILING NO. 1

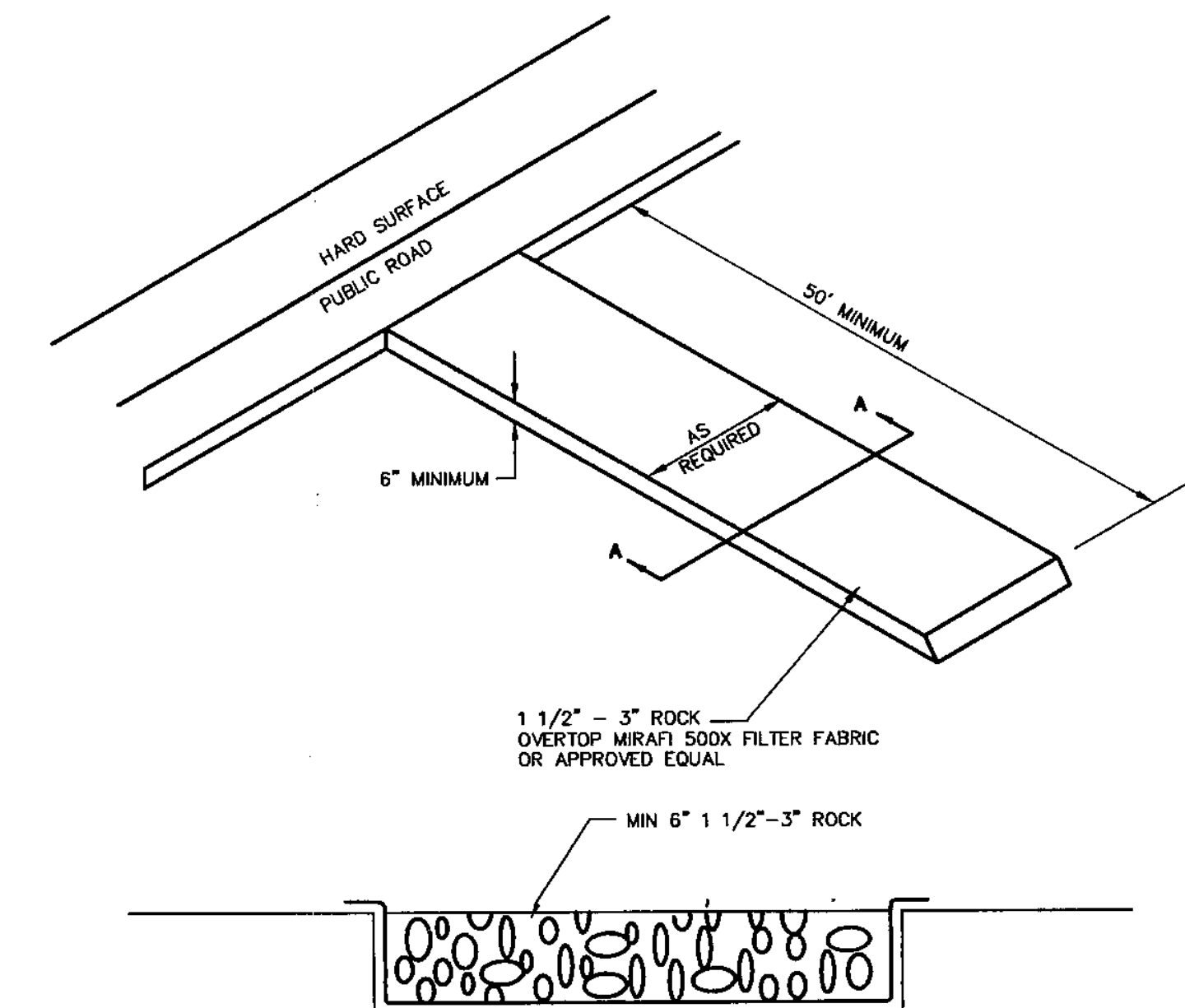
CITY OF COLORADO SPRINGS, EL PASO COUNTY

DRAINAGE MAP



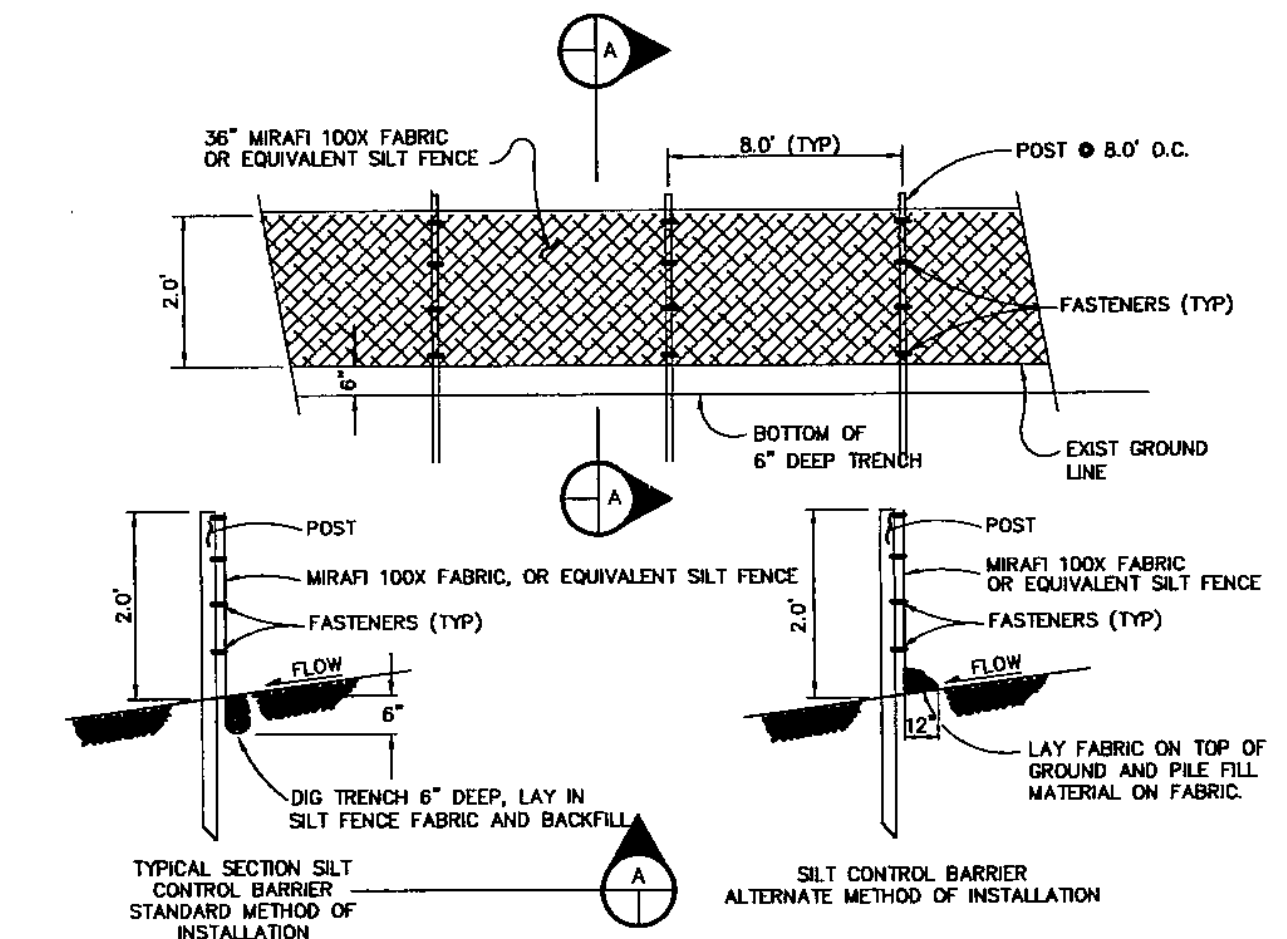
- NOTE:
1. EXTEND CRATES APPROXIMATELY ONE CRATE PAST ACTUAL INLET OPENING.
 2. INSPECT INLET PROTECTION AFTER EACH MAJOR STORM EVENT AND AT LEAST ONCE PER WEEK DURING DRY PERIODS.
 3. REMOVE SEDIMENT ONCE IT HAS REACHED ONE HALF THE HEIGHT OF THE CRATES.

P PERMANENT/INLET PROTECTION
N.T.S.



VTC VEHICLE TRACKING CONTROL
N.T.S.

DESCRIPTION	LEGEND	SYMBOL
BASIN BOUNDARY		—
DESIGN POINT		⊙
BASIN IDENTIFIER		BB
AREA IN ACRES		100
EXISTING DIRECTION OF FLOW		→
PIPE RUN		—
CROSSSPAN		—
PROPOSED CONTOUR-10		—
PROPOSED CONTOUR-2		—
EXISTING CONTOUR-10		—
EXISTING CONTOUR-2		—
HIGH POINT		X H.P.
LOW POINT		X L.P.
DIRECTION OF FLOW		→
SILT FENCE		—
STRAW BALE INLET PROTECTION		—
VEHICLE TRACKING CONTROL		VTC



SILT FENCE CONSTRUCTION DETAIL
N.T.S.

BASIN RUNOFF SUMMARY

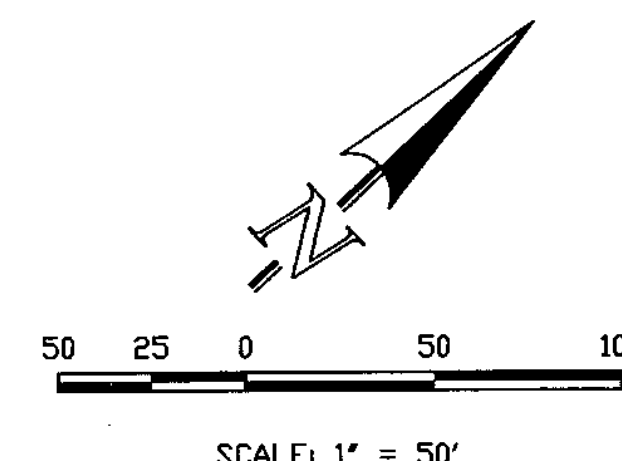
BASIN	Q5	Q100
A	0.4	1
B	6	12
C	3	5
D	1	2
D-1	1	3
E	1	1
F	0.5	1
G	2	3
H	1	1
I	3	5
J	4	8
K	0.4	1
L	0.4	1
M	1	1
M-1	1	2
N	1	1
O	0.6	1
P	0.6	1
Q	1	1
R	4	8
S	2	4
T	3	5
U	2	4
OS-1	0.01	0.03
OS-2	2	4
300	6	14
301	1	1
313	1	2
314	1	2
320	1	1

PIPE ROUTING SUMMARY

PIPE RUN	Q5	Q100	SIZE
1	1	1	12"
2	1	1	12"
3	0.4	1	12"
4	9	16	18"
5	9	17	18"
6	9	17	18"
7	2	4	12"
8	11	22	12"
9	1	1	12"
10	3	6	18"
11	2	4	12"
12	5	10	18"
13	3	5	12"
14	7	14	18"
15	2	4	12"
16	7	15	12"
17	7	15	18"
18	1	1	12"
19	9	18	12"
20	1	1	12"
21	9	19	18"
22	15	30	18"
23	6	14	18"

DESIGN POINT SUMMARY

DESIGN POINT	Q5	Q100
1	7	14
2	1	2
3	3	5
4	3	5
5	2	4
6	3	5
7	1	2
8	5	11
9	1	1
10	6	14
11	6	11
12	11	24



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(719) 785-0799 (fax)

SHOPS AT ARROWSWEST FILING NO. 1

DRAINAGE MAP

DESIGNED BY	VAS	SCALE	DATE
DRAWN BY	MES	(H) 1" = 50'	8/5/02
CHECKED BY	(V) 1" = N/A	SHEET 1 OF 1	JOB NO. 2050.00

APPENDIX B

HYDROLOGIC CALCULATIONS

Hydrologic Soil Group—El Paso County Area, Colorado
(Arrowswest Apartments)



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

Water Features

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

Background

Aerial Photography

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

MAP INFORMATION

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

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

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: El Paso County Area, Colorado
Survey Area Data: Version 18, Jun 5, 2020

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

Date(s) aerial images were photographed: Aug 19, 2018—Sep 23, 2018

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
54	Midway clay loam, 3 to 25 percent slopes	D	11.2	100.0%
Totals for Area of Interest			11.2	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

Table 6-6. Runoff Coefficients for Rational Method
(Source: UDFCD 2001)

Land Use or Surface Characteristics	Percent Impervious	Runoff Coefficients											
		2-year		5-year		10-year		25-year		50-year		100-year	
		HSG A&B	HSG C&D	HSG A&B	HSG C&D	HSG A&B	HSG C&D	HSG A&B	HSG C&D	HSG A&B	HSG C&D	HSG A&B	HSG C&D
Business													
Commercial Areas	95	0.79	0.80	0.81	0.82	0.83	0.84	0.85	0.87	0.87	0.88	0.88	0.89
Neighborhood Areas	70	0.45	0.49	0.49	0.53	0.53	0.57	0.58	0.62	0.60	0.65	0.62	0.68
Residential													
1/8 Acre or less	65	0.41	0.45	0.45	0.49	0.49	0.54	0.54	0.59	0.57	0.62	0.59	0.65
1/4 Acre	40	0.23	0.28	0.30	0.35	0.36	0.42	0.42	0.50	0.46	0.54	0.50	0.58
1/3 Acre	30	0.18	0.22	0.25	0.30	0.32	0.38	0.39	0.47	0.43	0.52	0.47	0.57
1/2 Acre	25	0.15	0.20	0.22	0.28	0.30	0.36	0.37	0.46	0.41	0.51	0.46	0.56
1 Acre	20	0.12	0.17	0.20	0.26	0.27	0.34	0.35	0.44	0.40	0.50	0.44	0.55
Industrial													
Light Areas	80	0.57	0.60	0.59	0.63	0.63	0.66	0.66	0.70	0.68	0.72	0.70	0.74
Heavy Areas	90	0.71	0.73	0.73	0.75	0.75	0.77	0.78	0.80	0.80	0.82	0.81	0.83
Parks and Cemeteries	7	0.05	0.09	0.12	0.19	0.20	0.29	0.30	0.40	0.34	0.46	0.39	0.52
Playgrounds	13	0.07	0.13	0.16	0.23	0.24	0.31	0.32	0.42	0.37	0.48	0.41	0.54
Railroad Yard Areas	40	0.23	0.28	0.30	0.35	0.36	0.42	0.42	0.50	0.46	0.54	0.50	0.58
Undeveloped Areas													
Historic Flow Analysis-- Greenbelts, Agriculture	2	0.03	0.05	0.09	0.16	0.17	0.26	0.26	0.38	0.31	0.45	0.36	0.51
Pasture/Meadow	0	0.02	0.04	0.08	0.15	0.15	0.25	0.25	0.37	0.30	0.44	0.35	0.50
Forest	0	0.02	0.04	0.08	0.15	0.15	0.25	0.25	0.37	0.30	0.44	0.35	0.50
Exposed Rock	100	0.89	0.89	0.90	0.90	0.92	0.92	0.94	0.94	0.95	0.95	0.96	0.96
Offsite Flow Analysis (when landuse is undefined)	45	0.26	0.31	0.32	0.37	0.38	0.44	0.44	0.51	0.48	0.55	0.51	0.59
Streets													
Paved	100	0.89	0.89	0.90	0.90	0.92	0.92	0.94	0.94	0.95	0.95	0.96	0.96
Gravel	80	0.57	0.60	0.59	0.63	0.63	0.66	0.66	0.70	0.68	0.72	0.70	0.74
Drive and Walks	100	0.89	0.89	0.90	0.90	0.92	0.92	0.94	0.94	0.95	0.95	0.96	0.96
Roofs	90	0.71	0.73	0.73	0.75	0.75	0.77	0.78	0.80	0.80	0.82	0.81	0.83
Lawns	0	0.02	0.04	0.08	0.15	0.15	0.25	0.25	0.37	0.30	0.44	0.35	0.50

3.2 Time of Concentration

One of the basic assumptions underlying the Rational Method is that runoff is a function of the average rainfall rate during the time required for water to flow from the hydraulically most remote part of the drainage area under consideration to the design point. However, in practice, the time of concentration can be an empirical value that results in reasonable and acceptable peak flow calculations.

For urban areas, the time of concentration (t_c) consists of an initial time or overland flow time (t_i) plus the travel time (t_r) in the storm sewer, paved gutter, roadside drainage ditch, or drainage channel. For non-urban areas, the time of concentration consists of an overland flow time (t_i) plus the time of travel in a concentrated form, such as a swale or drainageway. The travel portion (t_r) of the time of concentration can be estimated from the hydraulic properties of the storm sewer, gutter, swale, ditch, or drainageway. Initial time, on the other hand, will vary with surface slope, depression storage, surface cover, antecedent rainfall, and infiltration capacity of the soil, as well as distance of surface flow. The time of concentration is represented by Equation 6-7 for both urban and non-urban areas.

$$t_c = t_i + t_t \quad (\text{Eq. 6-7})$$

Where:

t_c = time of concentration (min)

t_i = overland (initial) flow time (min)

t_t = travel time in the ditch, channel, gutter, storm sewer, etc. (min)

3.2.1 Overland (Initial) Flow Time

The overland flow time, t_i , may be calculated using Equation 6-8.

$$t_i = \frac{0.395(1.1 - C_5)\sqrt{L}}{S^{0.33}} \quad (\text{Eq. 6-8})$$

Where:

t_i = overland (initial) flow time (min)

C_5 = runoff coefficient for 5-year frequency (see Table 6-6)

L = length of overland flow (300 ft maximum for non-urban land uses, 100 ft maximum for urban land uses)

S = average basin slope (ft/ft)

Note that in some urban watersheds, the overland flow time may be very small because flows quickly concentrate and channelize.

3.2.2 Travel Time

For catchments with overland and channelized flow, the time of concentration needs to be considered in combination with the travel time, t_t , which is calculated using the hydraulic properties of the swale, ditch, or channel. For preliminary work, the overland travel time, t_t , can be estimated with the help of Figure 6-25 or Equation 6-9 (Guo 1999).

$$V = C_v S_w^{0.5} \quad (\text{Eq. 6-9})$$

Where:

V = velocity (ft/s)

C_v = conveyance coefficient (from Table 6-7)

S_w = watercourse slope (ft/ft)

Table 6-7. Conveyance Coefficient, C_v

Type of Land Surface	C_v
Heavy meadow	2.5
Tillage/field	5
Riprap (not buried)*	6.5
Short pasture and lawns	7
Nearly bare ground	10
Grassed waterway	15
Paved areas and shallow paved swales	20

* For buried riprap, select C_v value based on type of vegetative cover.

The travel time is calculated by dividing the flow distance (in feet) by the velocity calculated using Equation 6-9 and converting units to minutes.

The time of concentration (t_c) is then the sum of the overland flow time (t_i) and the travel time (t_t) per Equation 6-7.

3.2.3 First Design Point Time of Concentration in Urban Catchments

Using this procedure, the time of concentration at the first design point (typically the first inlet in the system) in an urbanized catchment should not exceed the time of concentration calculated using Equation 6-10. The first design point is defined as the point where runoff first enters the storm sewer system.

$$t_c = \frac{L}{180} + 10 \quad (\text{Eq. 6-10})$$

Where:

t_c = maximum time of concentration at the first design point in an urban watershed (min)

L = waterway length (ft)

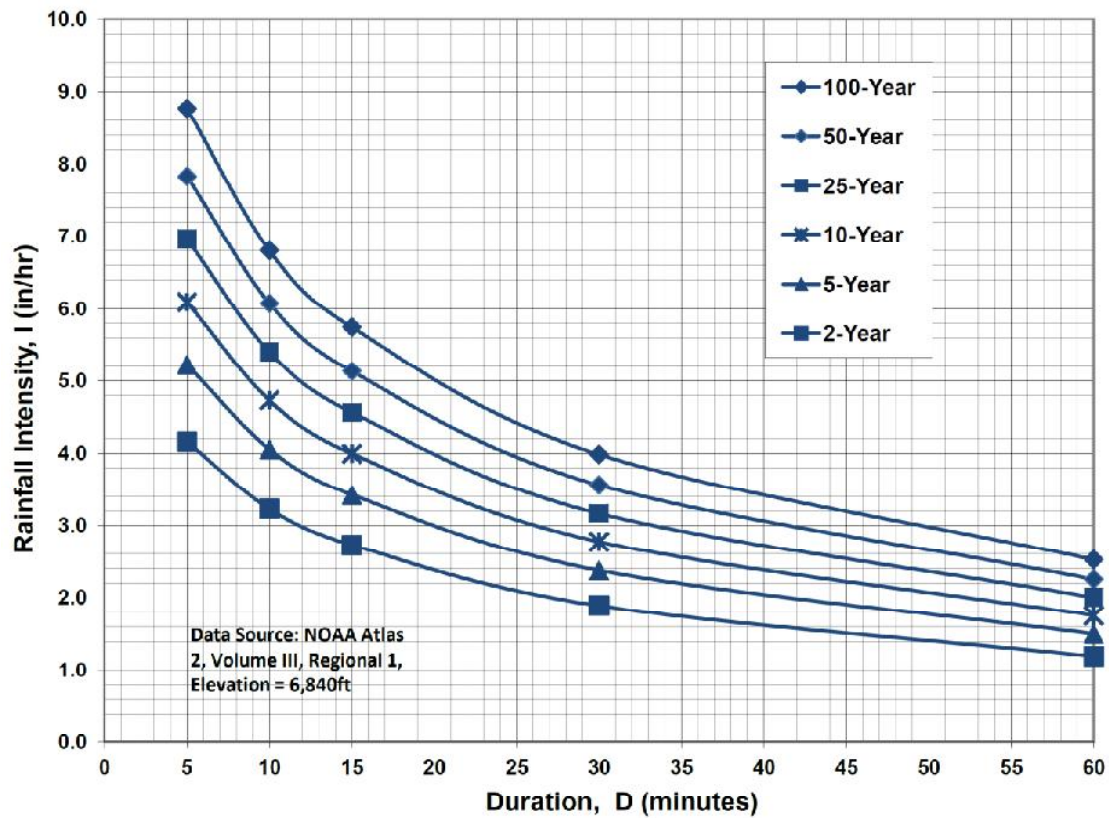
Equation 6-10 was developed using the rainfall-runoff data collected in the Denver region and, in essence, represents regional “calibration” of the Rational Method. Normally, Equation 6-10 will result in a lesser time of concentration at the first design point and will govern in an urbanized watershed. For subsequent design points, the time of concentration is calculated by accumulating the travel times in downstream drainageway reaches.

3.2.4 Minimum Time of Concentration

If the calculations result in a t_c of less than 10 minutes for undeveloped conditions, it is recommended that a minimum value of 10 minutes be used. The minimum t_c for urbanized areas is 5 minutes.

3.2.5 Post-Development Time of Concentration

As Equation 6-8 indicates, the time of concentration is a function of the 5-year runoff coefficient for a drainage basin. Typically, higher levels of imperviousness (higher 5-year runoff coefficients) correspond to shorter times of concentration, and lower levels of imperviousness correspond to longer times of

Figure 6-5. Colorado Springs Rainfall Intensity Duration Frequency**IDF Equations**

$$I_{100} = -2.52 \ln(D) + 12.735$$

$$I_{50} = -2.25 \ln(D) + 11.375$$

$$I_{25} = -2.00 \ln(D) + 10.111$$

$$I_{10} = -1.75 \ln(D) + 8.847$$

$$I_5 = -1.50 \ln(D) + 7.583$$

$$I_2 = -1.19 \ln(D) + 6.035$$

Note: Values calculated by
equations may not precisely
duplicate values read from figure.

ARROWSWEST APARTMENTS
RATIONAL METHOD

EXISTING CONDITION FLOWS

BASIN	DESIGN POINT	AREA (AC)	C		Overland Flow			Channel flow					TOTAL T _c ⁽⁴⁾ (MIN)	TOTAL T _c ⁽⁴⁾ (MIN)	INTENSITY ⁽⁵⁾		PEAK FLOW	
			5-YEAR	100-YEAR	LENGTH (FT)	SLOPE (FT/FT)	T _{co} ⁽¹⁾ (MIN)	CHANNEL LENGTH (FT)	CONVEYANCE COEFFICIENT C	SLOPE (FT/FT)	SCS ⁽²⁾ VELOCITY (FT/S)	T _t ⁽³⁾ (MIN)			5-YR (IN/HR)	100-YR (IN/HR)	Q ₅ ⁽⁶⁾ (CFS)	Q ₁₀₀ ⁽⁶⁾ (CFS)
OA1	OA1	0.40	0.150	0.500	300	0.24	10.4	80	15	0.15	5.81	0.2	10.6	10.6	4.04	6.78	0.24	1.36
OA2	OA2	1.04	0.750	0.868	100	0.40	1.9	530	20	0.057	4.77	1.8	3.7	5.0	5.17	8.68	4.03	7.83
OB1	OB1	1.60	0.150	0.500	300	0.28	9.9	70	15	0.229	7.18	0.2	10.1	10.1	4.12	6.91	0.99	5.53
A	A	9.47	0.150	0.500	300	0.15	12.2	490	15	0.051	3.39	2.4	14.6	14.6	3.56	5.97	5.05	28.28
OA1,OA2,OB1,A1	1	12.51	0.200	0.531									14.6	14.6	3.56	5.97	8.90	39.64

1) OVERLAND FLOW T_{co} = (0.395*(1.1-RUNOFF COEFFICIENT)*(OVERLAND FLOW LENGTH^{0.5})/(SLOPE^{0.333}))

2) SCS VELOCITY = C * ((SLOPE(FT/FT)^{0.5}))

C = 2.5 FOR HEAVY MEADOW

C = 5 FOR TILLAGE/FIELD

C = 7 FOR SHORT PASTURE AND LAWNS

C = 10 FOR NEARLY BARE GROUND

C = 15 FOR GRASSED WATERWAY

C = 20 FOR PAVED AREAS AND SHALLOW PAVED SWALES

3) MANNING'S CHANNEL TRAVEL TIME = L/V (WHEN CHANNEL VELOCITY IS KNOWN)

4) T_c = T_{co} + T_t

*** IF TOTAL TIME OF CONCENTRATION IS LESS THAN 5 MINUTES, THEN 5 MINUTES IS USED

5) INTENSITY BASED ON I-D-F EQUATIONS IN CITY OF COLORADO SPRINGS DRAINAGE CRITERIA MANUAL

$$I_5 = -1.5 * \ln(T_c) + 7.583$$

$$I_{100} = -2.52 * \ln(T_c) + 12.735$$

6) Q = CiA

ARROWSWEST APARTMENTS
COMPOSITE RUNOFF COEFFICIENTS

DEVELOPED CONDITIONS											
5-YEAR C VALUES											
BASIN	TOTAL AREA (AC)	(AC)	SUB-AREA 1 DEVELOPMENT/ COVER	C	AREA (AC)	SUB-AREA 2 DEVELOPMENT/ COVER	C	(AC)	SUB-AREA 3 DEVELOPMENT/ COVER	C	WEIGHTED C VALUE
OA1	0.40	0.40	MEADOW	0.15							0.150
OA2	1.04	0.83	BUILDING / PAVEMENT	0.9	0.21	LANDSCAPED	0.15				0.750
A1	2.51	1.53	BUILDING / PAVEMENT	0.9	0.98	LANDSCAPED	0.15				0.607
OA1,OA2,A1	3.95										0.598
B3	1.83	1.20	BUILDING / PAVEMENT	0.9	0.63	LANDSCAPED	0				0.590
OA1,OA2,A1,B3	5.78										0.596
OB1	1.60	1.60	MEADOW	0.15							0.150
B1	4.27	2.79	BUILDING / PAVEMENT	0.9	1.48	LANDSCAPED	0.15				0.640
OB1,B1	5.87										0.506
B2	0.47	0.30	PAVEMENT	0.9	0.17	LANDSCAPED	0.15				0.629
B4	0.41	0.11	PAVEMENT	0.9	0.30	LANDSCAPED	0.15				0.351
OA1-OA2,A1,B1-B4	12.53										0.547
100-YEAR C VALUES											
BASIN	TOTAL AREA (AC)	(AC)	SUB-AREA 1 DEVELOPMENT/ COVER	C	AREA (AC)	SUB-AREA 2 DEVELOPMENT/ COVER	C	(AC)	SUB-AREA 3 DEVELOPMENT/ COVER	C	WEIGHTED C VALUE
OA1	0.40	0.40	MEADOW	0.5							0.500
OA2	1.04	0.83	BUILDING / PAVEMENT	0.96	0.21	LANDSCAPED	0.5				0.868
A1	2.51	1.53	BUILDING / PAVEMENT	0.96	0.98	LANDSCAPED	0.5				0.780
OA1,OA2,A1	3.95										0.775
B3	1.83	1.20	BUILDING / PAVEMENT	0.96	0.63	LANDSCAPED	0.5				0.802
OA1,OA2,A1,B3	5.78										0.783
OB1	1.60	1.60	MEADOW	0.5							0.500
B1	4.27	2.79	BUILDING / PAVEMENT	0.96	1.48	LANDSCAPED	0.5				0.801
OB1,B1	5.87										0.719
B2	0.47	0.30	PAVEMENT	0.96	0.17	LANDSCAPED	0.5				0.794
B4	0.41	0.11	PAVEMENT	0.96	0.30	LANDSCAPED	0.5				0.623
OA1-OA2,A1,B1-B4	12.53										0.748

ARROWSWEST APARTMENTS COMPOSITE IMPERVIOUS AREAS											
IMPERVIOUS AREAS											
BASIN	TOTAL AREA (AC)	(AC)	SUB-AREA 1 DEVELOPMENT/ COVER	PERCENT IMPERVIOUS	AREA (AC)	SUB-AREA 2 DEVELOPMENT/ COVER	PERCENT IMPERVIOUS	(AC)	SUB-AREA 3 DEVELOPMENT/ COVER	PERCENT IMPERVIOUS	WEIGHTED % IMP
OA1	0.40	0.40	MEADOW	0							0.000
OA2	1.04	0.83	BUILDING / PAVEMENT	100	0.21	LANDSCAPED	0				80.000
A1	2.51	1.53	BUILDING / PAVEMENT	100	0.98	LANDSCAPED	0				60.956
OA1,OA2,A1	3.95										59.797
B3	1.83	1.20	BUILDING / PAVEMENT	100	0.63	LANDSCAPED	0				65.574
OA1,OA2,A1,B3	5.78										61.626
OB1	1.60	1.60	MEADOW	0							0.000
B1	4.27	2.79	BUILDING / PAVEMENT	100	1.48	LANDSCAPED	0				65.340
OB1,B1	5.87										47.530
B2	0.47	0.30	PAVEMENT	100	0.17	LANDSCAPED	0				63.830
B4	0.41	0.11	PAVEMENT	100	0.30	LANDSCAPED	0				26.829
OA1-OA2,A1,B1-B4	12.53										53.966

ARROWSWEST APARTMENTS
RATIONAL METHOD

DEVELOPED FLOWS

BASIN	DESIGN POINT	AREA (AC)	C		Overland Flow			Channel flow					TOTAL T _c ⁽⁴⁾ (MIN)	TOTAL T _c ⁽⁴⁾ (MIN)	INTENSITY ⁽⁵⁾		PEAK FLOW	
			5-YEAR	100-YEAR	LENGTH (FT)	SLOPE (FT/FT)	T _{co} ⁽¹⁾ (MIN)	CHANNEL LENGTH (FT)	CONVEYANCE COEFFICIENT C	SLOPE (FT/FT)	SCS ⁽²⁾ VELOCITY (FT/S)	T _t ⁽³⁾ (MIN)			5-YR (IN/HR)	100-YR (IN/HR)	Q5 ⁽⁶⁾ (CFS)	Q100 ⁽⁶⁾ (CFS)
OA1	OA1	0.40	0.150	0.500	300	0.24	10.4	80	15	0.15	5.81	0.2	10.6	10.6	4.04	6.78	0.24	1.36
OA2	OA2	1.04	0.750	0.868	100	0.40	1.9	530	20	0.057	4.77	1.8	3.7	5.0	5.17	8.68	4.03	7.83
Tt OA1-A1								765	20	0.088	5.93	2.1						
A1	A1	2.51	0.607	0.780	100	0.40	2.6	530	20	0.057	4.77	1.8	4.5	5.0	5.17	8.68	7.88	16.99
OA1,OA2,A1	A1.1	3.95	0.598	0.775									12.8	12.8	3.76	6.31	8.88	19.32
B3	B3	1.83	0.590	0.802	100	0.01	9.3	440	20	0.03	3.46	2.1	11.5	11.5	3.93	6.59	4.24	9.67
Tt A1-B3								325	20	0.062	4.98	1.1						
OA1,OA2,A1,B3	B3.1	5.78	0.596	0.783									13.9	13.9	3.64	6.11	12.53	27.64
OB1	OB1	1.60	0.150	0.500	300	0.28	9.9	70	15	0.229	7.18	0.2	10.1	10.1	4.12	6.91	0.99	5.53
Tt OB1-B1								500	20	0.112	6.69	1.2						
B1	B1	4.27	0.640	0.801	100	0.40	2.5	510	20	0.022	2.97	2.9	5.3	5.3	5.07	8.52	13.86	29.13
OB1,B1	B1.1	5.87	0.506	0.719									11.3	11.3	3.94	6.62	11.70	27.92
B2	B2	0.47	0.629	0.794	100	0.02	7.5	500	20	0.026	3.22	2.6	10.1	10.1	4.11	6.90	1.22	2.58
B4	B4	0.41	0.351	0.623	50	0.04	6.1	455	20	0.044	4.20	1.8	7.9	7.9	4.48	7.52	0.64	1.92
OA1,OA2,OB1,A1,B1-B4	1	12.53	0.547	0.748									13.9	13.9	3.64	6.11	24.93	57.24

DETAINED FLOWS

BASIN	DESIGN POINT	AREA (AC)	C		Overland Flow			Channel flow					TOTAL T _c ⁽⁴⁾ (MIN)	TOTAL T _c ⁽⁴⁾ (MIN)	INTENSITY ⁽⁵⁾		PEAK FLOW	
			5-YEAR	100-YEAR	LENGTH (FT)	SLOPE (FT/FT)	T _{co} ⁽¹⁾ (MIN)	CHANNEL LENGTH (FT)	CONVEYANCE COEFFICIENT C	SLOPE (FT/FT)	SCS ⁽²⁾ VELOCITY (FT/S)	T _t ⁽³⁾ (MIN)			5-YR (IN/HR)	100-YR (IN/HR)	Q5 ⁽⁶⁾ (CFS)	Q100 ⁽⁶⁾ (CFS)
POND B1 DISCHARGE	B1.1d	5.87															2.40	6.80
POND B3 DISCHARGE	B3.1d	5.78															0.20	5.50
B2	B2	0.47	0.629	0.794	100	0.02	7.5	500	20	0.026	3.22	2.6	10.1	10.1	4.11	6.90	1.22	2.58
B4	B4	0.41	0.351	0.623	50	0.04	6.1	455	20	0.044	4.20	1.8	7.9	7.9	4.48	7.52	0.64	1.92
OA1,A1,B1-B3 (DET)	1d	12.53															4.46	16.80

1) OVERLAND FLOW T_{co} = (0.395*(1.1-RUNOFF COEFFICIENT))*(OVERLAND FLOW LENGTH*(0.5)/(SLOPE*(0.333))

2) SCS VELOCITY = C * ((SLOPE(FT/FT)*0.5)

C = 2.5 FOR HEAVY MEADOW

C = 5 FOR TILLAGE/FIELD

C = 7 FOR SHORT PASTURE AND LAWNS

C = 10 FOR NEARLY BARE GROUND

C = 15 FOR GRASSED WATERWAY

C = 20 FOR PAVED AREAS AND SHALLOW PAVED SWALES

3) MANNING'S CHANNEL TRAVEL TIME = L/V (WHEN CHANNEL VELOCITY IS KNOWN)

4) T_c = T_{co} + T_t

*** IF TOTAL TIME OF CONCENTRATION IS LESS THAN 5 MINUTES, THEN 5 MINUTES IS USED

5) INTENSITY BASED ON I-D-F EQUATIONS IN CITY OF COLORADO SPRINGS DRAINAGE CRITERIA MANUAL

$$I_5 = -1.5 * \ln(T_c) + 7.583$$

$$I_{100} = -2.52 * \ln(T_c) + 12.735$$

6) Q = C*I

APPENDIX C

HYDRAULIC CALCULATIONS

ARROWSWEST APARTMENTS
CHANNEL CALCULATION SUMMARY - SITE DRAINAGE SWALES

PROPOSED CHANNEL / SWALE	MIN. SLOPE (%)	SIDE SLOPE (Z)	CHANNEL DEPTH (FT)	FRICTION FACTOR (n)	BASIN	Q100 FLOW (CFS)	Q100 DEPTH (FT)	Q100 VELOCITY (FT/S)	CHANNEL LINING
SWALE A1	0.6	3:1	2.0	0.030	A1 *	6.8	0.99	2.3	GRASS
SWALE OB1	0.5	3:1	2.0	0.030	OB1	5.5	0.95	2.1	GRASS

* SWALE A1 FLOW = (BASIN OA1 + 32% OF BASIN A1): Q100 = 1.4 + (.32 * 17.0) = 6.8 CFS

ASSUMPTIONS:

- 1) Channel flow calculations based on Manning's Equation
- 2) Channel depth includes 1' minimum freeboard
- 3) n = 0.03 for grass-lined non-irrigated channels (minimum)
- 4) n = 0.035 for riprap-lined channels
- 5) Vmax = 5.0 fps for 100-year flows w/ grass-lined channels
- 6) Vmax = 8.0 fps for 100-year flows w/ Erosion Control Blankets (Tensar Eronet SC150 or equal)
- 7) Vmax = 10.0 fps for 100-year flows w/ Erosion Control Blankets (Tensar Eronet C125 or equal)

Hydraulic Analysis Report

Project Data

Project Title: Arrowswest Apartments – Site Drainage Swales

Designer: JPS

Project Date: Wednesday, October 5, 2022

Project Units: U.S. Customary Units

Notes:

Channel Analysis: Channel Analysis - Swale A1

Notes:

Input Parameters

Channel Type: Triangular

Side Slope 1 (Z1): 3.0000 ft/ft

Side Slope 2 (Z2): 3.0000 ft/ft

Longitudinal Slope: 0.0060 ft/ft

Manning's n: 0.0300

Flow: 6.8000 cfs = **Q100**

Result Parameters

Depth: 0.9891 ft (**>1' Freeboard provided in 2-ft deep ditch**)

Area of Flow: 2.9352 ft²

Wetted Perimeter: 6.2559 ft

Hydraulic Radius: 0.4692 ft

Average Velocity: 2.3167 ft/s **< 5 fps Grass-Lining OK**

Top Width: 5.9348 ft

Froude Number: 0.5805

Critical Depth: 0.7958 ft

Critical Velocity: 3.5794 ft/s

Critical Slope: 0.0191 ft/ft

Critical Top Width: 4.77 ft

Calculated Max Shear Stress: 0.3703 lb/ft²

Calculated Avg Shear Stress: 0.1757 lb/ft²

Channel Analysis: Channel Analysis - Swale OB1

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 3.0000 ft/ft
Side Slope 2 (Z2): 3.0000 ft/ft
Longitudinal Slope: 0.0050 ft/ft
Manning's n: 0.0300
Flow: 5.5000 cfs = **Q100**

Result Parameters

Depth: 0.9453 ft (**>1' Freeboard provided in 2-ft deep ditch**)
Area of Flow: 2.6805 ft²
Wetted Perimeter: 5.9783 ft
Hydraulic Radius: 0.4484 ft
Average Velocity: 2.0518 ft/s **< 5 fps Grass-Lining OK**
Top Width: 5.6715 ft
Froude Number: 0.5260
Critical Depth: 0.7310 ft
Critical Velocity: 3.4307 ft/s
Critical Slope: 0.0197 ft/ft
Critical Top Width: 4.39 ft
Calculated Max Shear Stress: 0.2949 lb/ft²
Calculated Avg Shear Stress: 0.1399 lb/ft²

JPS ENGINEERING

ARROWSWEST APARTMENTS STORM INLET SIZING SUMMARY

INLET	BASIN FLOW			INLET FLOW			INLET CONDITION / TYPE	INLET SIZE	INLET CAPACITY (CFS)
	BASIN/ DP	Q5 FLOW (CFS)	Q100 FLOW (CFS)	INLET FLOW % OF BASIN	Q5 FLOW (CFS)	Q100 FLOW (CFS)			
A1A	A	7.9	17.0	50	4.0	8.5	SUMP D10R	5'	16.2
A1B	A	7.9	17.0	10	0.8	1.7	SUMP D10R	5'	16.2
A1C	A	7.9	17.0	40	3.2	6.8	SUMP D10R	5'	16.2
B3A	B3	4.2	9.7	75	3.2	7.3	SUMP D10R	5'	16.2
B3B	B3	4.2	9.7	20	0.8	1.9	SUMP D10R	5'	16.2
B3D	B3	4.2	9.7	5	0.2	0.5	(ROOF DRAINS)		
OB1.1	OB1	1.0	5.5	25	0.3	1.4	SUMP NYOPLAST	18" DIA.	1.4
OB1.2	OB1	1.0	5.5	25	0.3	1.4	SUMP NYOPLAST	18" DIA.	1.4
OB1.3	OB1	1.0	5.5	25	0.3	1.4	SUMP NYOPLAST	18" DIA.	1.4
OB1.4	OB1	1.0	5.5	25	0.3	1.4	SUMP NYOPLAST	18" DIA.	1.4
B1A	B1	13.9	29.1	5	0.7	1.5	SUMP NYOPLAST	18" DIA.	1.4
B1B	B1	13.9	29.1	5	0.7	1.5	SUMP NYOPLAST	18" DIA.	1.4
B1C	B1	13.9	29.1	5	0.7	1.5	SUMP NYOPLAST	18" DIA.	1.4
B1D	B1	13.9	29.1	10	1.4	2.9	SUMP TYPE 13	SGL	5.4
B1E*	B1	13.9	29.1	70	9.7	20.4			
B1E*	B1E+OB1				10.7	25.9	SUMP D10R	10'	31.9
B1F	B1	13.9	29.1	5	0.7	1.5	(ROOF DRAINS)		

INLET MANAGEMENT

Worksheet Protected

INLET NAME	Inlet 5-ft D10R
Site Type (Urban or Rural)	URBAN
Inlet Application (Street or Area)	STREET
Hydraulic Condition	
Inlet Type	

USER-DEFINED INPUT**User-Defined Design Flows**

Minor Q_{Known} (cfs)	5.0
Major Q_{Known} (cfs)	10.0

Bypass (Carry-Over) Flow from Upstream

Receive Bypass Flow from:	No Bypass Flow Received
Minor Bypass Flow Received, Q_b (cfs)	0.0
Major Bypass Flow Received, Q_b (cfs)	0.0

Watershed Characteristics

Subcatchment Area (acres)	
Percent Impervious	
NRCS Soil Type	

Watershed Profile

Overland Slope (ft/ft)	
Overland Length (ft)	
Channel Slope (ft/ft)	
Channel Length (ft)	

Minor Storm Rainfall Input

Design Storm Return Period, T_r (years)	
One-Hour Precipitation, P_1 (inches)	

Major Storm Rainfall Input

Design Storm Return Period, T_r (years)	
One-Hour Precipitation, P_1 (inches)	

CALCULATED OUTPUT

Minor Total Design Peak Flow, Q (cfs)	5.0
Major Total Design Peak Flow, Q (cfs)	10.0
Minor Flow Bypassed Downstream, Q_b (cfs)	
Major Flow Bypassed Downstream, Q_b (cfs)	

Minor Storm (Calculated) Analysis of Flow Time

C	N/A
C_s	N/A
Overland Flow Velocity, V_i	N/A
Channel Flow Velocity, V_t	N/A
Overland Flow Time, T_i	N/A
Channel Travel Time, T_t	N/A
Calculated Time of Concentration, T_c	N/A
Regional T_c	N/A
Recommended T_c	N/A
T_c selected by User	N/A
Design Rainfall Intensity, I	N/A
Calculated Local Peak Flow, Q_p	N/A

Major Storm (Calculated) Analysis of Flow Time

C	N/A
C_s	N/A
Overland Flow Velocity, V_i	N/A
Channel Flow Velocity, V_t	N/A
Overland Flow Time, T_i	N/A
Channel Travel Time, T_t	N/A
Calculated Time of Concentration, T_c	N/A
Regional T_c	N/A
Recommended T_c	N/A
T_c selected by User	N/A
Design Rainfall Intensity, I	N/A
Calculated Local Peak Flow, Q_p	N/A

ALLOWABLE CAPACITY FOR ONE-HALF OF STREET (Minor & Major Storm)

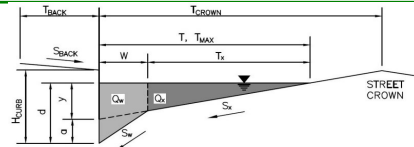
(Based on Regulated Criteria for Maximum Allowable Flow Depth and Spread)

Project:

Arrowswest Apartments - 5' D10R Inlets (A1A-A1C; B3A-B3B)

Inlet ID:

Inlet 5-ft D10R

**Gutter Geometry (Enter data in the blue cells)**

Maximum Allowable Width for Spread Behind Curb
 Side Slope Behind Curb (leave blank for no conveyance credit behind curb)
 Manning's Roughness Behind Curb (typically between 0.012 and 0.020)

$T_{BACK} = 4.0$ ft
 $S_{BACK} = 0.020$ ft/ft
 $n_{BACK} = 0.020$

Height of Curb at Gutter Flow Line
 Distance from Curb Face to Street Crown
 Gutter Width
 Street Transverse Slope
 Gutter Cross Slope (typically 2 inches over 24 inches or 0.083 ft/ft)
 Street Longitudinal Slope - Enter 0 for sump condition
 Manning's Roughness for Street Section (typically between 0.012 and 0.020)

$H_{CURB} = 6.00$ inches
 $T_{CROWN} = 30.0$ ft
 $W = 2.00$ ft
 $S_X = 0.020$ ft/ft
 $S_W = 0.083$ ft/ft
 $S_O = 0.000$ ft/ft
 $n_{STREET} = 0.016$

Max. Allowable Spread for Minor & Major Storm
 Max. Allowable Depth at Gutter Flowline for Minor & Major Storm
 Check boxes are not applicable in SUMP conditions

	Minor Storm	Major Storm	
$T_{MAX} =$	30.0	30.0	ft
$d_{MAX} =$	6.0	12.0	inches
	☐	☐	

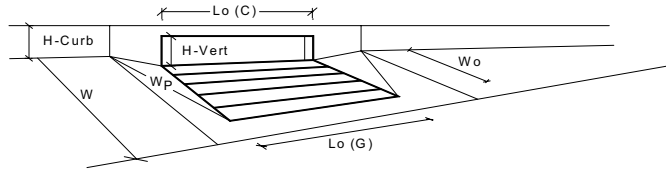
MINOR STORM Allowable Capacity is based on Depth Criterion
MAJOR STORM Allowable Capacity is based on Depth Criterion

$Q_{allow} =$

Minor Storm	Major Storm	
SUMP	SUMP	cfs

INLET IN A SUMP OR SAG LOCATION

Version 4.05 Released March 2017



Design Information (Input)

Type of Inlet: Colorado Springs D-10-R
 Local Depression (additional to continuous gutter depression 'a' from above)
 Number of Unit Inlets (Grate or Curb Opening)
 Water Depth at Flowline (outside of local depression)
Grate Information
 Length of a Unit Grate
 Width of a Unit Grate
 Area Opening Ratio for a Grate (typical values 0.15-0.90)
 Clogging Factor for a Single Grate (typical value 0.50 - 0.70)
 Grate Weir Coefficient (typical value 2.15 - 3.60)
 Grate Orifice Coefficient (typical value 0.60 - 0.80)

Curb Opening Information

Length of a Unit Curb Opening
 Height of Vertical Curb Opening in Inches
 Height of Curb Orifice Throat in Inches
 Angle of Throat (see USDCM Figure ST-5)
 Side Width for Depression Pan (typically the gutter width of 2 feet)
 Clogging Factor for a Single Curb Opening (typical value 0.10)
 Curb Opening Weir Coefficient (typical value 2.3-3.7)
 Curb Opening Orifice Coefficient (typical value 0.60 - 0.70)

Low Head Performance Reduction (Calculated)

Depth for Grate Midwidth
 Depth for Curb Opening Weir Equation
 Combination Inlet Performance Reduction Factor for Long Inlets
 Curb Opening Performance Reduction Factor for Long Inlets
 Grated Inlet Performance Reduction Factor for Long Inlets

Total Inlet Interception Capacity (assumes clogged condition)

Inlet Capacity IS GOOD for Minor and Major Storms(>Q PEAK)

	MINOR	MAJOR	
Type =	Colorado Springs D-10-R		
a _{local} =	4.00	4.00	inches
No =	1	1	
Ponding Depth =	6.0	12.0	inches
	MINOR	MAJOR	☒ Override Depths
L _o (G) =	N/A	N/A	feet
W _o =	N/A	N/A	feet
A _{ratio} =	N/A	N/A	
C _r (G) =	N/A	N/A	
C _w (G) =	N/A	N/A	
C _o (G) =	N/A	N/A	
	MINOR	MAJOR	
L _o (C) =	5.00	5.00	feet
H _{vert} =	8.00	8.00	inches
H _{throat} =	8.00	8.00	inches
Theta =	81.00	81.00	degrees
W _p =	2.00	2.00	feet
C _r (C) =	0.10	0.10	
C _w (C) =	3.60	3.60	
C _o (C) =	0.67	0.67	
	MINOR	MAJOR	
d _{Grate} =	N/A	N/A	ft
d _{Curb} =	0.33	0.83	ft
RF _{Combination} =	0.77	1.00	
RF _{Curb} =	1.00	1.00	
RF _{Grate} =	N/A	N/A	
	MINOR	MAJOR	
Q _a =	5.4	16.2	cfs
Q _{PEAK REQUIRED} =	5.0	10.0	cfs

INLET MANAGEMENT

Worksheet Protected

INLET NAME	Inlet B1D
Site Type (Urban or Rural)	URBAN
Inlet Application (Street or Area)	STREET
Hydraulic Condition	In Sump
Inlet Type	CDOT/Denver 13 Valley Grate

USER-DEFINED INPUT**User-Defined Design Flows**

Minor Q_{Known} (cfs)	1.4
Major Q_{Known} (cfs)	2.9

Bypass (Carry-Over) Flow from Upstream

Receive Bypass Flow from:	No Bypass Flow Received
Minor Bypass Flow Received, Q_b (cfs)	0.0
Major Bypass Flow Received, Q_b (cfs)	0.0

Watershed Characteristics

Subcatchment Area (acres)	
Percent Impervious	
NRCS Soil Type	

Watershed Profile

Overland Slope (ft/ft)	
Overland Length (ft)	
Channel Slope (ft/ft)	
Channel Length (ft)	

Minor Storm Rainfall Input

Design Storm Return Period, T_r (years)	
One-Hour Precipitation, P_1 (inches)	

Major Storm Rainfall Input

Design Storm Return Period, T_r (years)	
One-Hour Precipitation, P_1 (inches)	

CALCULATED OUTPUT

Minor Total Design Peak Flow, Q (cfs)	1.4
Major Total Design Peak Flow, Q (cfs)	2.9
Minor Flow Bypassed Downstream, Q_b (cfs)	N/A
Major Flow Bypassed Downstream, Q_b (cfs)	N/A

Minor Storm (Calculated) Analysis of Flow Time

C	N/A
C_5	N/A
Overland Flow Velocity, V_i	N/A
Channel Flow Velocity, V_t	N/A
Overland Flow Time, T_i	N/A
Channel Travel Time, T_t	N/A
Calculated Time of Concentration, T_c	N/A
Regional T_c	N/A
Recommended T_c	N/A
T_c selected by User	N/A
Design Rainfall Intensity, I	N/A
Calculated Local Peak Flow, Q_p	N/A

Major Storm (Calculated) Analysis of Flow Time

C	N/A
C_5	N/A
Overland Flow Velocity, V_i	N/A
Channel Flow Velocity, V_t	N/A
Overland Flow Time, T_i	N/A
Channel Travel Time, T_t	N/A
Calculated Time of Concentration, T_c	N/A
Regional T_c	N/A
Recommended T_c	N/A
T_c selected by User	N/A
Design Rainfall Intensity, I	N/A
Calculated Local Peak Flow, Q_p	N/A

ALLOWABLE CAPACITY FOR ONE-HALF OF STREET (Minor & Major Storm)

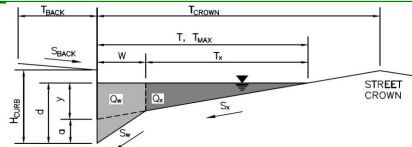
(Based on Regulated Criteria for Maximum Allowable Flow Depth and Spread)

Project:

Arrowswest Apartments - Inlet B1D

Inlet ID:

Inlet B1D

**Gutter Geometry (Enter data in the blue cells)**

Maximum Allowable Width for Spread Behind Curb
 Side Slope Behind Curb (leave blank for no conveyance credit behind curb)
 Manning's Roughness Behind Curb (typically between 0.012 and 0.020)

$T_{BACK} = 18.0$ ft
 $S_{BACK} = 0.030$ ft/ft
 $n_{BACK} = 0.016$

Height of Curb at Gutter Flow Line
 Distance from Curb Face to Street Crown
 Gutter Width
 Street Transverse Slope
 Gutter Cross Slope (typically 2 inches over 24 inches or 0.083 ft/ft)
 Street Longitudinal Slope - Enter 0 for sump condition
 Manning's Roughness for Street Section (typically between 0.012 and 0.020)

$H_{CURB} = 0.00$ inches
 $T_{CROWN} = 30.0$ ft
 $W = 2.00$ ft
 $S_x = 0.040$ ft/ft
 $S_w = 0.083$ ft/ft
 $S_o = 0.000$ ft/ft
 $n_{STREET} = 0.016$

Max. Allowable Spread for Minor & Major Storm
 Max. Allowable Depth at Gutter Flowline for Minor & Major Storm
 Check boxes are not applicable in SUMP conditions

	Minor Storm	Major Storm	
$T_{MAX} =$	30.0	30.0	ft
$d_{MAX} =$	6.0	12.0	inches
	☐	☐	

MINOR STORM Allowable Capacity is based on Depth Criterion
MAJOR STORM Allowable Capacity is based on Depth Criterion

$Q_{allow} =$

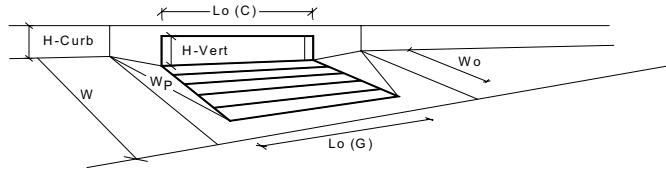
Minor Storm	Major Storm	
SUMP	SUMP	cfs

Warning 02

Valley Gutter (Crosspan)

INLET IN A SUMP OR SAG LOCATION

Version 4.05 Released March 2017



Design Information (Input)

Type of Inlet CDOT/Denver 13 Valley Grate
 Local Depression (additional to continuous gutter depression 'a' from above)
 Number of Unit Inlets (Grate or Curb Opening)
 Water Depth at Flowline (outside of local depression)
Grate Information
 Length of a Unit Grate
 Width of a Unit Grate
 Area Opening Ratio for a Grate (typical values 0.15-0.90)
 Clogging Factor for a Single Grate (typical value 0.50 - 0.70)
 Grate Weir Coefficient (typical value 2.15 - 3.60)
 Grate Orifice Coefficient (typical value 0.60 - 0.80)

Curb Opening Information

Length of a Unit Curb Opening
 Height of Vertical Curb Opening in Inches
 Height of Curb Orifice Throat in Inches
 Angle of Throat (see USDCM Figure ST-5)
 Side Width for Depression Pan (typically the gutter width of 2 feet)
 Clogging Factor for a Single Curb Opening (typical value 0.10)
 Curb Opening Weir Coefficient (typical value 2.3-3.7)
 Curb Opening Orifice Coefficient (typical value 0.60 - 0.70)

Low Head Performance Reduction (Calculated)

Depth for Grate Midwidth
 Depth for Curb Opening Weir Equation
 Combination Inlet Performance Reduction Factor for Long Inlets
 Curb Opening Performance Reduction Factor for Long Inlets
 Grated Inlet Performance Reduction Factor for Long Inlets

Total Inlet Interception Capacity (assumes clogged condition)

Inlet Capacity IS GOOD for Minor and Major Storms(>Q PEAK)

	MINOR	MAJOR	
Type =	CDOT/Denver 13 Valley Grate		
a_{local} =	2.00	2.00	inches
No =	1	1	
Ponding Depth =	6.0	12.0	inches
	MINOR	MAJOR	☐ Override Depths
$L_o (G)$ =	3.00	3.00	feet
W_o =	1.73	1.73	feet
A_{ratio} =	0.43	0.43	
$C_r (G)$ =	0.50	0.50	
$C_w (G)$ =	3.30	3.30	
$C_o (G)$ =	0.60	0.60	
	MINOR	MAJOR	
$L_o (C)$ =	N/A	N/A	feet
H_{vert} =	N/A	N/A	inches
H_{throat} =	N/A	N/A	inches
Theta =	N/A	N/A	degrees
W_p =	N/A	N/A	feet
$C_r (C)$ =	N/A	N/A	
$C_w (C)$ =	N/A	N/A	
$C_o (C)$ =	N/A	N/A	
	MINOR	MAJOR	
d_{Grate} =	0.523	1.023	ft
d_{Curb} =	N/A	N/A	ft
RF _{Combination} =	N/A	N/A	
RF _{Curb} =	N/A	N/A	
RF _{Grate} =	0.94	1.00	
	MINOR	MAJOR	
Q_a =	2.6	5.4	cfs
$Q_{PEAK REQUIRED}$ =	1.4	2.9	cfs

INLET MANAGEMENT

Worksheet Protected

INLET NAME	Inlet B1E
Site Type (Urban or Rural)	URBAN
Inlet Application (Street or Area)	STREET
Hydraulic Condition	In Sump
Inlet Type	Colorado Springs D-10-R

USER-DEFINED INPUT**User-Defined Design Flows**

Minor Q_{Known} (cfs)	10.7
Major Q_{Known} (cfs)	25.9

Bypass (Carry-Over) Flow from Upstream

Receive Bypass Flow from:	No Bypass Flow Received
Minor Bypass Flow Received, Q_b (cfs)	0.0
Major Bypass Flow Received, Q_b (cfs)	0.0

Watershed Characteristics

Subcatchment Area (acres)	
Percent Impervious	
NRCS Soil Type	

Watershed Profile

Overland Slope (ft/ft)	
Overland Length (ft)	
Channel Slope (ft/ft)	
Channel Length (ft)	

Minor Storm Rainfall Input

Design Storm Return Period, T_r (years)	
One-Hour Precipitation, P_1 (inches)	

Major Storm Rainfall Input

Design Storm Return Period, T_r (years)	
One-Hour Precipitation, P_1 (inches)	

CALCULATED OUTPUT

Minor Total Design Peak Flow, Q (cfs)	10.7
Major Total Design Peak Flow, Q (cfs)	25.9
Minor Flow Bypassed Downstream, Q_b (cfs)	N/A
Major Flow Bypassed Downstream, Q_b (cfs)	N/A

Minor Storm (Calculated) Analysis of Flow Time

C	N/A
C_5	N/A
Overland Flow Velocity, V_i	N/A
Channel Flow Velocity, V_t	N/A
Overland Flow Time, T_i	N/A
Channel Travel Time, T_t	N/A
Calculated Time of Concentration, T_c	N/A
Regional T_c	N/A
Recommended T_c	N/A
T_c selected by User	N/A
Design Rainfall Intensity, I	N/A
Calculated Local Peak Flow, Q_p	N/A

Major Storm (Calculated) Analysis of Flow Time

C	N/A
C_5	N/A
Overland Flow Velocity, V_i	N/A
Channel Flow Velocity, V_t	N/A
Overland Flow Time, T_i	N/A
Channel Travel Time, T_t	N/A
Calculated Time of Concentration, T_c	N/A
Regional T_c	N/A
Recommended T_c	N/A
T_c selected by User	N/A
Design Rainfall Intensity, I	N/A
Calculated Local Peak Flow, Q_p	N/A

ALLOWABLE CAPACITY FOR ONE-HALF OF STREET (Minor & Major Storm)

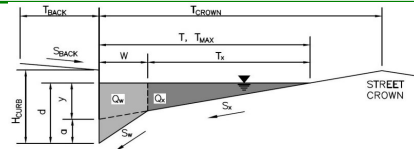
(Based on Regulated Criteria for Maximum Allowable Flow Depth and Spread)

Project:

Arrowswest Apartments - Inlet B1E

Inlet ID:

Inlet B1E

**Gutter Geometry (Enter data in the blue cells)**

Maximum Allowable Width for Spread Behind Curb
 Side Slope Behind Curb (leave blank for no conveyance credit behind curb)
 Manning's Roughness Behind Curb (typically between 0.012 and 0.020)

$T_{BACK} = 4.0$ ft
 $S_{BACK} = 0.020$ ft/ft
 $n_{BACK} = 0.020$

Height of Curb at Gutter Flow Line
 Distance from Curb Face to Street Crown
 Gutter Width
 Street Transverse Slope
 Gutter Cross Slope (typically 2 inches over 24 inches or 0.083 ft/ft)
 Street Longitudinal Slope - Enter 0 for sump condition
 Manning's Roughness for Street Section (typically between 0.012 and 0.020)

$H_{CURB} = 9.00$ inches
 $T_{CROWN} = 30.0$ ft
 $W = 2.00$ ft
 $S_x = 0.020$ ft/ft
 $S_w = 0.083$ ft/ft
 $S_o = 0.000$ ft/ft
 $n_{STREET} = 0.016$

Max. Allowable Spread for Minor & Major Storm
 Max. Allowable Depth at Gutter Flowline for Minor & Major Storm
 Check boxes are not applicable in SUMP conditions

	Minor Storm	Major Storm	
$T_{MAX} =$	30.0	30.0	ft
$d_{MAX} =$	9.0	12.0	inches

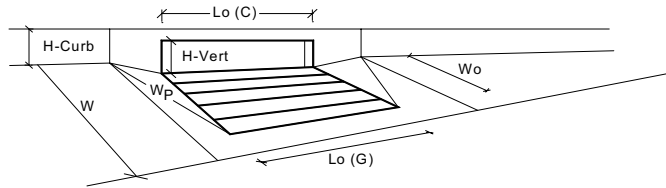
MINOR STORM Allowable Capacity is based on Depth Criterion
MAJOR STORM Allowable Capacity is based on Depth Criterion

$Q_{allow} =$

Minor Storm	Major Storm	
SUMP	SUMP	cfs

INLET IN A SUMP OR SAG LOCATION

Version 4.05 Released March 2017



Design Information (Input)

Type of Inlet Colorado Springs D-10-R

Local Depression (additional to continuous gutter depression 'a' from above)

Number of Unit Inlets (Grate or Curb Opening)

Water Depth at Flowline (outside of local depression)

Grate Information

Length of a Unit Grate

Width of a Unit Grate

Area Opening Ratio for a Grate (typical values 0.15-0.90)

Clogging Factor for a Single Grate (typical value 0.50 - 0.70)

Grate Weir Coefficient (typical value 2.15 - 3.60)

Grate Orifice Coefficient (typical value 0.60 - 0.80)

Curb Opening Information

Length of a Unit Curb Opening

Height of Vertical Curb Opening in Inches

Height of Curb Orifice Throat in Inches

Angle of Throat (see USDCM Figure ST-5)

Side Width for Depression Pan (typically the gutter width of 2 feet)

Clogging Factor for a Single Curb Opening (typical value 0.10)

Curb Opening Weir Coefficient (typical value 2.3-3.7)

Curb Opening Orifice Coefficient (typical value 0.60 - 0.70)

Low Head Performance Reduction (Calculated)

Depth for Grate Midwidth

Depth for Curb Opening Weir Equation

Combination Inlet Performance Reduction Factor for Long Inlets

Curb Opening Performance Reduction Factor for Long Inlets

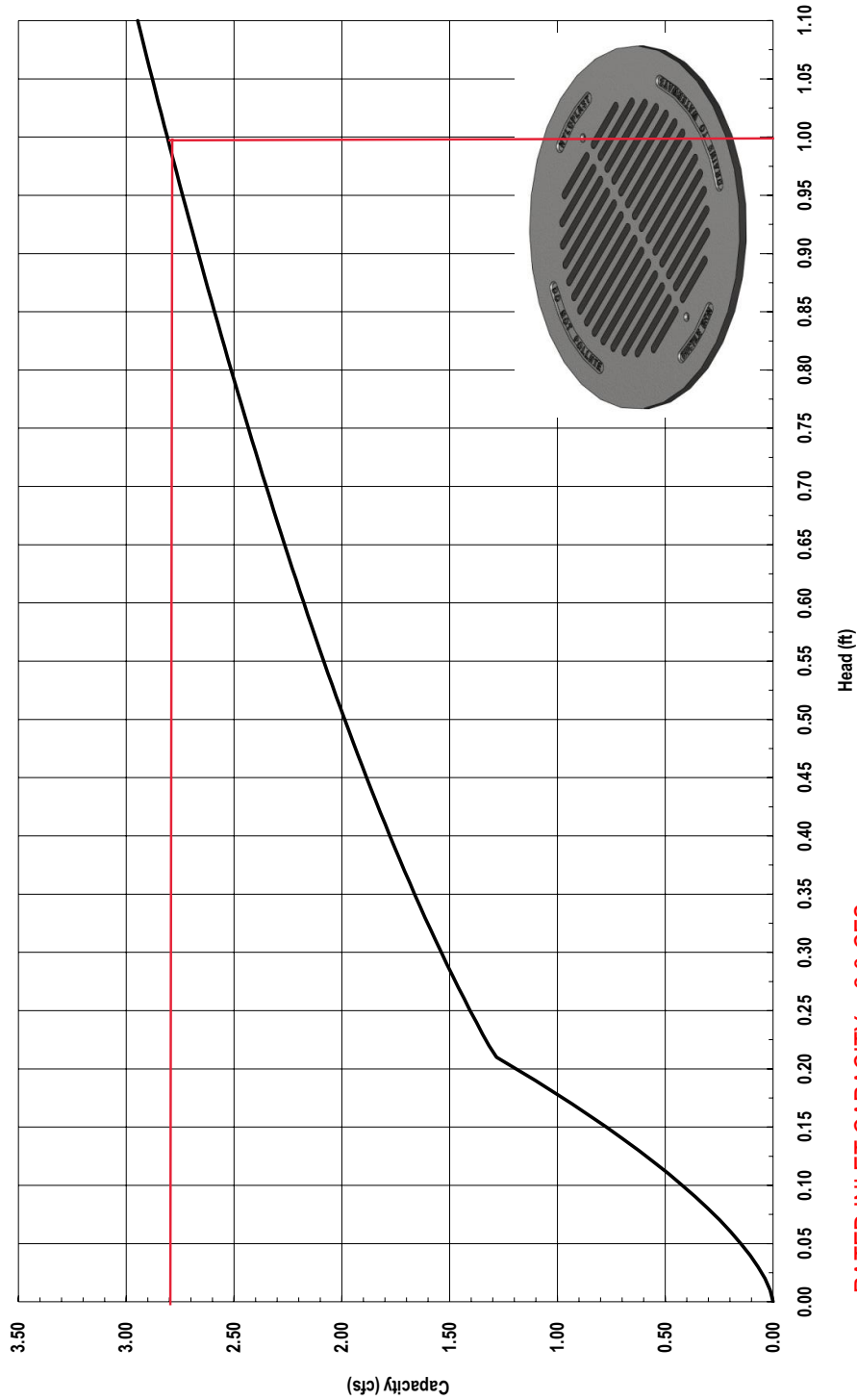
Grated Inlet Performance Reduction Factor for Long Inlets

Total Inlet Interception Capacity (assumes clogged condition)

Inlet Capacity IS GOOD for Minor and Major Storms(>Q PEAK)

	MINOR	MAJOR	
Type =	Colorado Springs D-10-R		
a _{local} =	4.00	4.00	inches
No =	1	1	
Ponding Depth =	7.0	12.0	inches
	MINOR	MAJOR	☒ Override Depths
L _o (G) =	N/A	N/A	feet
W _o =	N/A	N/A	feet
A _{ratio} =	N/A	N/A	
C _r (G) =	N/A	N/A	
C _w (G) =	N/A	N/A	
C _o (G) =	N/A	N/A	
	MINOR	MAJOR	
L _o (C) =	10.00	10.00	feet
H _{vert} =	8.00	8.00	inches
H _{throat} =	8.00	8.00	inches
Theta =	81.00	81.00	degrees
W _p =	2.00	2.00	feet
C _r (C) =	0.10	0.10	
C _w (C) =	3.60	3.60	
C _o (C) =	0.67	0.67	
	MINOR	MAJOR	
d _{Grate} =	N/A	N/A	ft
d _{Curb} =	0.42	0.83	ft
RF _{Combination} =	0.66	1.00	
RF _{Curb} =	0.99	1.00	
RF _{Grate} =	N/A	N/A	
	MINOR	MAJOR	
Q _a =	12.2	31.9	cfs
Q _{PEAK REQUIRED} =	10.7	25.9	cfs

Nyloplast 18" Drop In Grate Inlet Capacity Chart



RATED INLET CAPACITY = 2.8 CFS
W/ 50% CLOGGING FACTOR
DESIGN INLET CAPACITY = 1.4 CFS



Nyloplast®

3130 Verona Avenue • Buford, GA 30518
(866) 888-8479 / (770) 932-2443 • Fax: (770) 932-2490
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ARROWSWEST APARTMENTS STORM SEWER SIZING SUMMARY (PRELIMINARY)						
PIPE	PIPE FLOW			PIPE CAPACITY		
	INLETS / DP	Q5 FLOW (CFS)	Q100 FLOW (CFS)	PIPE SIZE (IN)	MIN. PIPE SLOPE	FULL PIPE CAPACITY (CFS)
A1A	A1A	4.0	8.5	18	1.0%	10.5
A1B	A1A,A1B	4.7	10.2	18	1.0%	10.5
A1C	A1C	3.2	6.8	18	1.0%	10.5
B3A	B3A	3.2	7.3	18	1.0%	10.5
B3B	A1A-A1C,B3A	11.1	24.3	24	1.2%	24.8
B3C	A1A-A1C,B3A-B3B	11.9	26.2	24	1.4%	26.8
B3D	B3D	0.2	0.5	8	1.0%	1.2
OB1.1	OB1.1	0.3	1.4	12	1.0%	3.6
OB1.2	OB1.1-OB1.2	0.5	2.8	12	1.0%	3.6
OB1.3	OB1.1-OB1.3	0.8	4.1	12	2.4%	5.5
OB1.4	OB1.1-OB1.4	1.0	5.5	12	2.4%	5.5
B1A	B1A	0.7	1.5	12	1.0%	3.6
B1B	B1B	0.7	1.5	12	1.0%	3.6
B1C	B1A-B1C	2.1	4.4	12	1.6%	4.5
B1D	B1A-B1D	3.5	7.3	15	1.4%	7.6
B1E	OB1,B1A-B1E	14.2	33.1	24	2.2%	33.6
B1F	B1F	0.7	1.5	8	1.5%	1.5
B1.1d	EXST. 18" SD (S)	2.4	6.8	18	3.4%	19.4
B3.1d	EXST. 18" SD (N)	0.2	5.5	18	5.0%	23.6
ASSUMPTIONS: 1. STORM SEWER PIPE TO BE RCP OR HDPE						

Hydraulic Analysis Report

Project Data

Project Title: Project - Arrowswest Apartments
Designer: JPS
Project Date: Thursday, October 21, 2021
Project Units: U.S. Customary Units
Notes:

Channel Analysis: SD-A1A-A1C

Notes:

Input Parameters

Channel Type: Circular
Pipe Diameter: 1.5000 ft
Longitudinal Slope: 0.0100 ft/ft
Manning's n: 0.0130
Depth: 1.5000 ft

Result Parameters

Flow: 10.5043 cfs
Area of Flow: 1.7671 ft²
Wetted Perimeter: 4.7124 ft
Hydraulic Radius: 0.3750 ft
Average Velocity: 5.9442 ft/s
Top Width: 0.0000 ft
Froude Number: 0.0000
Critical Depth: 1.2451 ft
Critical Velocity: 6.6989 ft/s
Critical Slope: 0.0098 ft/ft
Critical Top Width: 1.13 ft
Calculated Max Shear Stress: 0.9360 lb/ft²
Calculated Avg Shear Stress: 0.2340 lb/ft²

Channel Analysis: SD-B3A

Notes:

Input Parameters

Channel Type: Circular
Pipe Diameter: 1.5000 ft
Longitudinal Slope: 0.0100 ft/ft
Manning's n: 0.0130
Depth: 1.5000 ft

Result Parameters

Flow: 10.5043 cfs
Area of Flow: 1.7671 ft²
Wetted Perimeter: 4.7124 ft
Hydraulic Radius: 0.3750 ft
Average Velocity: 5.9442 ft/s
Top Width: 0.0000 ft
Froude Number: 0.0000
Critical Depth: 1.2451 ft
Critical Velocity: 6.6989 ft/s
Critical Slope: 0.0098 ft/ft
Critical Top Width: 1.13 ft
Calculated Max Shear Stress: 0.9360 lb/ft²
Calculated Avg Shear Stress: 0.2340 lb/ft²

Channel Analysis: SD-B3B

Notes:

Input Parameters

Channel Type: Circular
Pipe Diameter: 2.0000 ft
Longitudinal Slope: 0.0120 ft/ft
Manning's n: 0.0130
Depth: 2.0000 ft

Result Parameters

Flow: 24.7816 cfs
Area of Flow: 3.1416 ft²
Wetted Perimeter: 6.2832 ft
Hydraulic Radius: 0.5000 ft
Average Velocity: 7.8882 ft/s
Top Width: 0.0000 ft
Froude Number: 0.0000
Critical Depth: 1.7559 ft
Critical Velocity: 8.4792 ft/s
Critical Slope: 0.0108 ft/ft
Critical Top Width: 1.31 ft
Calculated Max Shear Stress: 1.4976 lb/ft²
Calculated Avg Shear Stress: 0.3744 lb/ft²

Channel Analysis: SD-B3C

Notes:

Input Parameters

Channel Type: Circular
Pipe Diameter: 2.0000 ft
Longitudinal Slope: 0.0140 ft/ft
Manning's n: 0.0130
Depth: 2.0000 ft

Result Parameters

Flow: 26.7672 cfs
Area of Flow: 3.1416 ft²
Wetted Perimeter: 6.2832 ft
Hydraulic Radius: 0.5000 ft
Average Velocity: 8.5203 ft/s
Top Width: 0.0000 ft
Froude Number: 0.0000
Critical Depth: 1.8027 ft
Critical Velocity: 8.9782 ft/s
Critical Slope: 0.0123 ft/ft
Critical Top Width: 1.19 ft
Calculated Max Shear Stress: 1.7472 lb/ft²
Calculated Avg Shear Stress: 0.4368 lb/ft²

Channel Analysis: SD-B3D

Notes:

Input Parameters

Channel Type: Circular
Pipe Diameter: 0.6700 ft
Longitudinal Slope: 0.0100 ft/ft
Manning's n: 0.0130
Depth: 0.6700 ft

Result Parameters

Flow: 1.2246 cfs
Area of Flow: 0.3526 ft²
Wetted Perimeter: 2.1049 ft
Hydraulic Radius: 0.1675 ft
Average Velocity: 3.4734 ft/s
Top Width: 0.0000 ft
Froude Number: 0.0000
Critical Depth: 0.5234 ft
Critical Velocity: 4.1439 ft/s
Critical Slope: 0.0110 ft/ft
Critical Top Width: 0.55 ft
Calculated Max Shear Stress: 0.4181 lb/ft²
Calculated Avg Shear Stress: 0.1045 lb/ft²

Channel Analysis: SD-OB1.1-OB1.2

Notes:

Input Parameters

Channel Type: Circular
Pipe Diameter: 1.0000 ft
Longitudinal Slope: 0.0100 ft/ft
Manning's n: 0.0130
Depth: 1.0000 ft

Result Parameters

Flow: 3.5628 cfs
Area of Flow: 0.7854 ft²
Wetted Perimeter: 3.1416 ft
Hydraulic Radius: 0.2500 ft
Average Velocity: 4.5363 ft/s
Top Width: 0.0000 ft
Froude Number: 0.0000
Critical Depth: 0.8057 ft
Critical Velocity: 5.2542 ft/s
Critical Slope: 0.0103 ft/ft
Critical Top Width: 0.79 ft
Calculated Max Shear Stress: 0.6240 lb/ft²
Calculated Avg Shear Stress: 0.1560 lb/ft²

Channel Analysis: SD-OB1.3-OB1.4

Notes:

Input Parameters

Channel Type: Circular
Pipe Diameter: 1.0000 ft
Longitudinal Slope: 0.0240 ft/ft
Manning's n: 0.0130
Depth: 1.0000 ft

Result Parameters

Flow: 5.5195 cfs
Area of Flow: 0.7854 ft²
Wetted Perimeter: 3.1416 ft
Hydraulic Radius: 0.2500 ft
Average Velocity: 7.0276 ft/s
Top Width: 0.0000 ft
Froude Number: 0.0000
Critical Depth: 0.9399 ft
Critical Velocity: 7.2043 ft/s
Critical Slope: 0.0207 ft/ft
Critical Top Width: 0.48 ft
Calculated Max Shear Stress: 1.4976 lb/ft²
Calculated Avg Shear Stress: 0.3744 lb/ft²

Channel Analysis: SD-B1A-B1C

Notes:

Input Parameters

Channel Type: Circular
Pipe Diameter: 1.0000 ft
Longitudinal Slope: 0.0160 ft/ft
Manning's n: 0.0130
Depth: 1.0000 ft

Result Parameters

Flow: 4.5066 cfs
Area of Flow: 0.7854 ft²
Wetted Perimeter: 3.1416 ft
Hydraulic Radius: 0.2500 ft
Average Velocity: 5.7380 ft/s
Top Width: 0.0000 ft
Froude Number: 0.0000
Critical Depth: 0.8867 ft
Critical Velocity: 6.1204 ft/s
Critical Slope: 0.0143 ft/ft
Critical Top Width: 0.63 ft
Calculated Max Shear Stress: 0.9984 lb/ft²
Calculated Avg Shear Stress: 0.2496 lb/ft²

Channel Analysis: SD-B1D

Notes:

Input Parameters

Channel Type: Circular
Pipe Diameter: 1.2500 ft
Longitudinal Slope: 0.0140 ft/ft
Manning's n: 0.0130
Depth: 1.2500 ft

Result Parameters

Flow: 7.6433 cfs
Area of Flow: 1.2272 ft²
Wetted Perimeter: 3.9270 ft
Hydraulic Radius: 0.3125 ft
Average Velocity: 6.2283 ft/s
Top Width: 0.0000 ft
Froude Number: 0.0000
Critical Depth: 1.0968 ft
Critical Velocity: 6.6979 ft/s
Critical Slope: 0.0126 ft/ft
Critical Top Width: 0.82 ft
Calculated Max Shear Stress: 1.0920 lb/ft²
Calculated Avg Shear Stress: 0.2730 lb/ft²

Channel Analysis: SD-B1E

Notes:

Input Parameters

Channel Type: Circular
Pipe Diameter: 2.0000 ft
Longitudinal Slope: 0.0220 ft/ft
Manning's n: 0.0130
Depth: 2.0000 ft

Result Parameters

Flow: 33.5544 cfs
Area of Flow: 3.1416 ft²
Wetted Perimeter: 6.2832 ft
Hydraulic Radius: 0.5000 ft
Average Velocity: 10.6807 ft/s
Top Width: 0.0000 ft
Froude Number: 0.0000
Critical Depth: 1.9067 ft
Critical Velocity: 10.8638 ft/s
Critical Slope: 0.0191 ft/ft
Critical Top Width: 0.84 ft
Calculated Max Shear Stress: 2.7456 lb/ft²
Calculated Avg Shear Stress: 0.6864 lb/ft²

Channel Analysis: SD-B1F

Notes:

Input Parameters

Channel Type: Circular
Pipe Diameter: 0.6700 ft
Longitudinal Slope: 0.0150 ft/ft
Manning's n: 0.0130
Depth: 0.6700 ft

Result Parameters

Flow: 1.4998 cfs
Area of Flow: 0.3526 ft²
Wetted Perimeter: 2.1049 ft
Hydraulic Radius: 0.1675 ft
Average Velocity: 4.2540 ft/s
Top Width: 0.0000 ft
Froude Number: 0.0000
Critical Depth: 0.5725 ft
Critical Velocity: 4.6747 ft/s
Critical Slope: 0.0140 ft/ft
Critical Top Width: 0.47 ft
Calculated Max Shear Stress: 0.6271 lb/ft²
Calculated Avg Shear Stress: 0.1568 lb/ft²

Channel Analysis: SD-Exst. 18"-S

Notes:

Input Parameters

Channel Type: Circular
Pipe Diameter: 1.5000 ft
Longitudinal Slope: 0.0340 ft/ft
Manning's n: 0.0130
Depth: 1.5000 ft

Result Parameters

Flow: 19.3690 cfs
Area of Flow: 1.7671 ft²
Wetted Perimeter: 4.7124 ft
Hydraulic Radius: 0.3750 ft
Average Velocity: 10.9606 ft/s
Top Width: 0.0000 ft
Froude Number: 0.0000
Critical Depth: 1.4630 ft
Critical Velocity: 11.0326 ft/s
Critical Slope: 0.0302 ft/ft
Critical Top Width: 0.47 ft
Calculated Max Shear Stress: 3.1824 lb/ft²
Calculated Avg Shear Stress: 0.7956 lb/ft²

Channel Analysis: SD-Exst. 18"-N

Notes:

Input Parameters

Channel Type: Circular
Pipe Diameter: 1.5000 ft
Longitudinal Slope: 0.0500 ft/ft
Manning's n: 0.0130
Depth: 1.5000 ft

Result Parameters

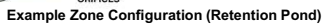
Flow: 23.4884 cfs
Area of Flow: 1.7671 ft²
Wetted Perimeter: 4.7124 ft
Hydraulic Radius: 0.3750 ft
Average Velocity: 13.2917 ft/s
Top Width: 0.0000 ft
Froude Number: 0.0000
Critical Depth: 1.4828 ft
Critical Velocity: 13.3194 ft/s
Critical Slope: 0.0458 ft/ft
Critical Top Width: 0.32 ft
Calculated Max Shear Stress: 4.6800 lb/ft²
Calculated Avg Shear Stress: 1.1700 lb/ft²

APPENDIX D1

STORMWATER DETENTION CALCULATIONS DETENTION BASIN B1

MHFD-Detention, Version 4.04 (February 2021)

Basin ID: B1



	acre-feet
	acre-feet
1.19	inches
1.50	inches
1.75	inches
2.00	inches
2.25	inches
2.52	inches
3.14	inches

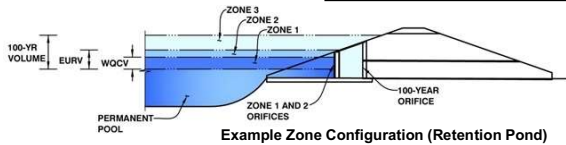
Zone 1 Volume (WQCV) =	0.098	acre-feet
Zone 2 Volume (EURV - Zone 1) =	0.165	acre-feet
Zone 3 Volume (100-year - Zones 1 & 2) =	0.250	acre-feet
Total Detention Basin Volume =	0.513	acre-feet

9/16/2022, 10:31 AM

DETENTION BASIN OUTLET STRUCTURE DESIGN

MHFD-Detention, Version 4.04 (February 2021)

Project: **Arrowswest Apartments**
Basin ID: **B1**



Example Zone Configuration (Retention Pond)

	Estimated Stage (ft)	Estimated Volume (ac-ft)	Outlet Type
Zone 1 (WQCV)	2.03	0.098	Orifice Plate
Zone 2 (EURV)	4.50	0.165	Orifice Plate
Zone 3 (100-year)	7.98	0.250	Weir&Pipe (Restrict)
Total (all zones)		0.513	

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

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

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 BMP)

Calculated Parameters for Plate

Invert of Lowest Orifice =	0.00	ft (relative to basin bottom at Stage = 0 ft)
Depth at top of Zone using Orifice Plate =	4.50	ft (relative to basin bottom at Stage = 0 ft)
Orifice Plate: Orifice Vertical Spacing =	27.90	inches
Orifice Plate: Orifice Area per Row =	N/A	inches

WQ Orifice Area per Row =	N/A	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	1.50	3.00					
Orifice Area (sq. inches)	0.80	0.40	0.50					

	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)

Calculated Parameters for Vertical Orifice

	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

	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)

Calculated Parameters for Overflow Weir

	Zone 3 Weir	Not Selected	
Overflow Weir Front Edge Height, H _o =	5.00	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 =	2.50	N/A	feet
Overflow Grate Type =	Type C Grate	N/A	
Debris Clogging % =	50%	N/A	%

	Zone 3 Weir	Not Selected	
Height of Grate Upper Edge, H _u =	5.00	N/A	feet
Overflow Weir Slope Length =	2.50	N/A	feet
Grate Open Area / 100-yr Orifice Area =	13.92	N/A	
Overflow Grate Open Area w/o Debris =	6.96	N/A	ft ²
Overflow Grate Open Area w/ Debris =	3.48	N/A	ft ²

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

Calculated Parameters for Outlet Pipe w/ Flow Restriction Plate

	Zone 3 Restrictor	Not Selected	
Depth to Invert of Outlet Pipe =	0.50	N/A	ft (distance below basin bottom at Stage = 0 ft)
Outlet Pipe Diameter =	12.00	N/A	inches
Restrictor Plate Height Above Pipe Invert =	7.30		inches

	Zone 3 Restrictor	Not Selected	
Outlet Orifice Area =	0.50	N/A	ft ²
Outlet Orifice Centroid =	0.34	N/A	feet
Half-Central Angle of Restrictor Plate on Pipe =	1.79	N/A	radians

User Input: Emergency Spillway (Rectangular or Trapezoidal)

Calculated Parameters for Spillway

Spillway Invert Stage =	8.00	ft (relative to basin bottom at Stage = 0 ft)
Spillway Crest Length =	6.00	feet
Spillway End Slopes =	0.00	H:V
Freeboard above Max Water Surface =	1.00	feet

Spillway Design Flow Depth =	0.95	feet
Stage at Top of Freeboard =	9.95	feet
Basin Area at Top of Freeboard =	0.08	acres
Basin Volume at Top of Freeboard =	0.66	acre-ft

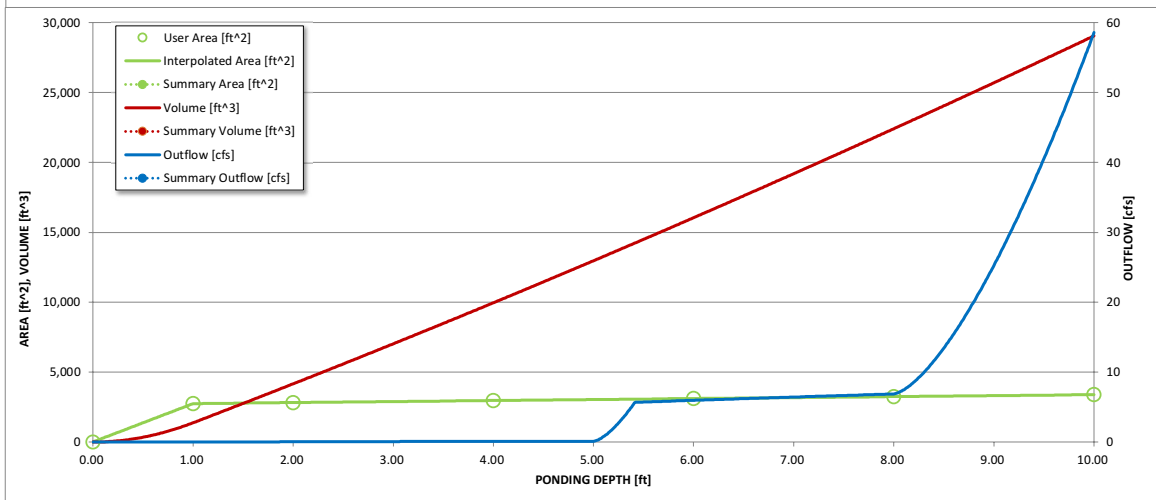
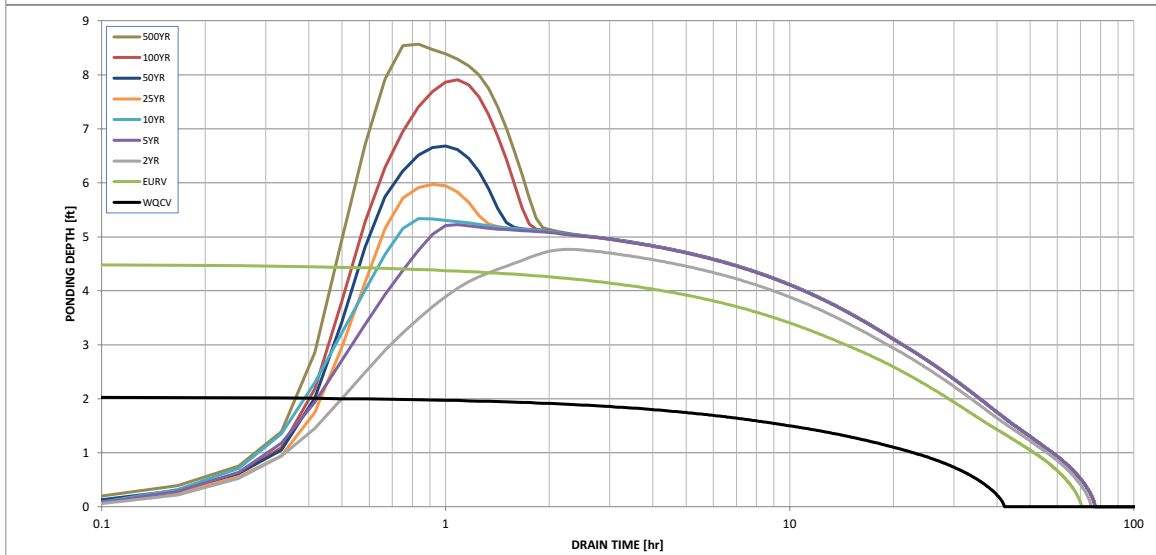
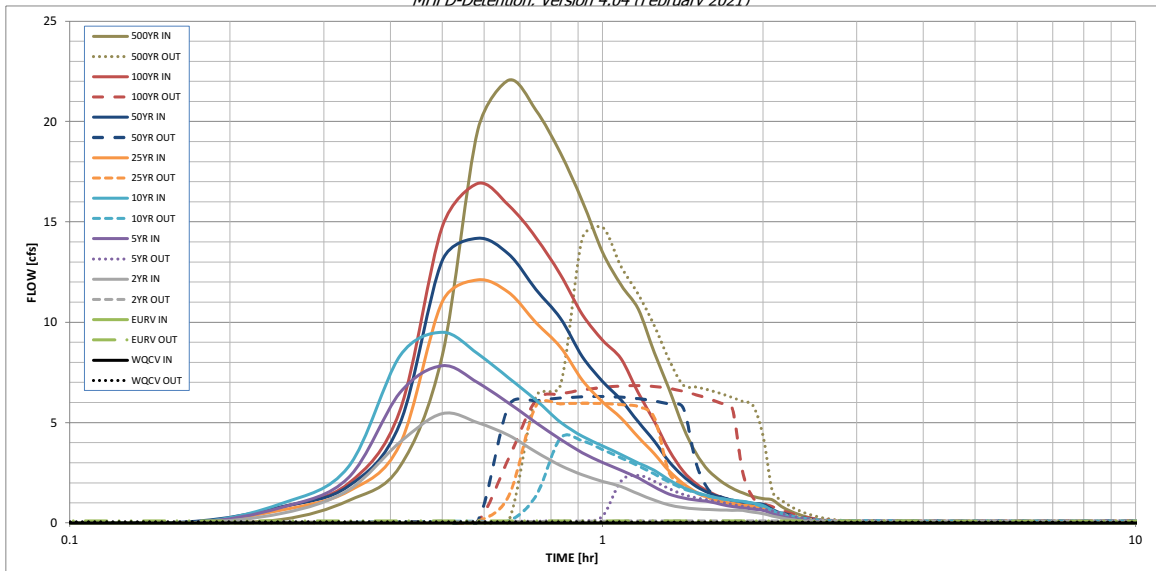
Routed Hydrograph Results

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

	WQCV	EURV	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year	500 Year
Design Storm Return Period =	N/A	N/A	1.19	1.50	1.75	2.00	2.25	2.52	3.14
One-Hour Rainfall Depth (in) =	N/A	N/A	0.263	0.297	0.432	0.547	0.683	0.804	1.258
CUHP Runoff Volume (acre-ft) =	0.098	0.263	0.297	0.432	0.547	0.683	0.804	0.953	1.258
Inflow Hydrograph Volume (acre-ft) =	N/A	N/A	0.297	0.432	0.547	0.683	0.804	0.953	1.258
CUHP Predevelopment Peak Q (cfs) =	N/A	N/A	1.4	2.9	4.0	6.2	7.6	9.4	12.9
OPTIONAL Override Predevelopment Peak Q (cfs) =	N/A	N/A							
Predevelopment Unit Peak Flow, q (cfs/acre) =	N/A	N/A	0.24	0.50	0.68	1.06	1.30	1.60	2.20
Peak Inflow Q (cfs) =	N/A	N/A	5.5	7.8	9.5	12.1	14.2	16.9	22.1
Peak Outflow Q (cfs) =	0.0	0.1	0.1	2.4	4.2	6.0	6.3	6.8	14.7
Ratio Peak Outflow to Predevelopment Q =	N/A	N/A	N/A	0.8	1.1	1.0	0.8	0.7	1.1
Structure Controlling Flow =	Plate	Plate	Plate	Overflow Weir 1	Overflow Weir 1	Outlet Plate 1	Outlet Plate 1	Outlet Plate 1	Spillway
Max Velocity through Grate 1 (fps) =	N/A	N/A	N/A	0.3	0.6	0.8	0.9	1.0	1.0
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	64	68	67	66	63	62	60	56
Time to Drain 99% of Inflow Volume (hours) =	41	68	72	73	72	71	70	70	68
Maximum Ponding Depth (ft) =	2.04	4.50	4.77	5.23	5.34	5.97	6.68	7.91	8.56
Area at Maximum Ponding Depth (acres) =	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08
Maximum Volume Stored (acre-ft) =	0.098	0.263	0.281	0.313	0.321	0.366	0.417	0.508	0.557

DETENTION BASIN OUTLET STRUCTURE DESIGN

MHFD-Detention, Version 4.04 (February 2021)



S-A-V-D Chart Axis Override

minimum bound	X-axis	Left Y-Axis	Right Y-Axis
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.

Time Interval	SOURCE	CUHP	CUHP	CUHP	CUHP	CUHP	CUHP	CUHP	CUHP	CUHP
	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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0:05:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0:10:00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.01	0.17
	0:15:00	0.00	0.00	0.48	0.78	0.96	0.65	0.80	0.79	1.11
	0:20:00	0.00	0.00	1.64	2.25	2.79	1.57	1.83	1.96	2.80
	0:25:00	0.00	0.00	4.01	6.47	8.32	3.90	4.93	5.58	8.33
	0:30:00	0.00	0.00	5.45	7.83	9.50	11.01	13.07	14.75	19.57
	0:35:00	0.00	0.00	4.99	6.98	8.43	12.11	14.19	16.91	22.07
	0:40:00	0.00	0.00	4.36	5.97	7.22	11.48	13.39	15.82	20.57
	0:45:00	0.00	0.00	3.53	4.99	6.13	9.97	11.63	14.22	18.44
	0:50:00	0.00	0.00	2.87	4.17	5.02	8.77	10.20	12.37	16.02
	0:55:00	0.00	0.00	2.39	3.49	4.32	7.11	8.29	10.39	13.49
	1:00:00	0.00	0.00	2.07	3.02	3.84	6.03	7.05	9.11	11.85
	1:05:00	0.00	0.00	1.81	2.61	3.41	5.22	6.13	8.18	10.65
	1:10:00	0.00	0.00	1.45	2.24	2.99	4.28	5.03	6.48	8.49
	1:15:00	0.00	0.00	1.14	1.80	2.62	3.45	4.08	5.06	6.67
	1:20:00	0.00	0.00	0.90	1.44	2.14	2.59	3.06	3.62	4.78
	1:25:00	0.00	0.00	0.76	1.24	1.76	1.97	2.33	2.58	3.43
	1:30:00	0.00	0.00	0.70	1.13	1.51	1.53	1.82	1.94	2.60
	1:35:00	0.00	0.00	0.66	1.06	1.34	1.26	1.49	1.56	2.09
	1:40:00	0.00	0.00	0.64	0.92	1.22	1.08	1.27	1.29	1.73
	1:45:00	0.00	0.00	0.63	0.82	1.13	0.95	1.13	1.11	1.49
	1:50:00	0.00	0.00	0.62	0.75	1.07	0.87	1.03	0.98	1.32
	1:55:00	0.00	0.00	0.53	0.69	0.99	0.82	0.97	0.89	1.20
	2:00:00	0.00	0.00	0.47	0.63	0.86	0.78	0.92	0.85	1.15
	2:05:00	0.00	0.00	0.34	0.46	0.62	0.57	0.67	0.62	0.83
	2:10:00	0.00	0.00	0.25	0.33	0.44	0.40	0.48	0.44	0.59
	2:15:00	0.00	0.00	0.17	0.23	0.31	0.29	0.34	0.32	0.42
	2:20:00	0.00	0.00	0.12	0.16	0.22	0.20	0.23	0.22	0.30
	2:25:00	0.00	0.00	0.08	0.10	0.15	0.14	0.16	0.15	0.20
	2:30:00	0.00	0.00	0.05	0.07	0.10	0.09	0.11	0.10	0.14
	2:35:00	0.00	0.00	0.03	0.04	0.06	0.06	0.07	0.07	0.09
	2:40:00	0.00	0.00	0.02	0.03	0.03	0.03	0.04	0.04	0.05
	2:45:00	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.02	0.02
	2:50:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
	2:55:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:00:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:05:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:10:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:15:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:20:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:25:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:30:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:35:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:40:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:45:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:50:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:55:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:00:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:05:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:10:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:15:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:20:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:25:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:30:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:35:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:40:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:45:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:50:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:55:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:00:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:05:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:10:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:15:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:20:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:25:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:30:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:35:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:40:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:45:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:50:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:55:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	6:00:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Design Procedure Form: Extended Detention Basin (EDB)

UD-BMP (Version 3.07, March 2018)

Sheet 1 of 3

Designer: JPS
Company: JPS
Date: September 16, 2022
Project: Arrowswest Apartments
Location: Detention Basin B1

1. Basin Storage Volume

A) Effective Imperviousness of Tributary Area, I_a

$I_a = 47.5$ %

B) Tributary Area's Imperviousness Ratio ($i = I_a / 100$)

$i = 0.475$

C) Contributing Watershed Area

Area = 5.870 ac

D) For Watersheds Outside of the Denver Region, Depth of Average Runoff Producing Storm

$d_0 =$ in

E) Design Concept
(Select EURV when also designing for flood control)

Choose One
☐ Water Quality Capture Volume (WQCV)
☒ Excess Urban Runoff Volume (EURV)

F) Design Volume (WQCV) Based on 40-hour Drain Time
($V_{DESIGN} = (1.0 * (0.91 * i^3 - 1.19 * i^2 + 0.78 * i) / 12 * Area)$)

$V_{DESIGN} = 0.098$ ac-ft

G) For Watersheds Outside of the Denver Region,
Water Quality Capture Volume (WQCV) Design Volume
($V_{WQCV\ OTHER} = (d_0 * (V_{DESIGN} / 0.43))$)

$V_{DESIGN\ OTHER} =$ ac-ft

H) User Input of Water Quality Capture Volume (WQCV) Design Volume
(Only if a different WQCV Design Volume is desired)

$V_{DESIGN\ USER} =$ ac-ft

I) NRCS Hydrologic Soil Groups of Tributary Watershed
i) Percentage of Watershed consisting of Type A Soils
ii) Percentage of Watershed consisting of Type B Soils
iii) Percentage of Watershed consisting of Type C/D Soils

HSG A = 0 %
HSG B = 0 %
HSG C/D = 100 %

J) Excess Urban Runoff Volume (EURV) Design Volume
For HSG A: $EURV_A = 1.68 * i^{1.28}$
For HSG B: $EURV_B = 1.36 * i^{1.08}$
For HSG C/D: $EURV_{C/D} = 1.20 * i^{1.08}$

$EURV_{DESIGN} = 0.263$ ac-ft

K) User Input of Excess Urban Runoff Volume (EURV) Design Volume
(Only if a different EURV Design Volume is desired)

$EURV_{DESIGN\ USER} =$ ac-ft

2. Basin Shape: Length to Width Ratio

(A basin length to width ratio of at least 2:1 will improve TSS reduction.)

$L : W = 4.0 : 1$

3. Basin Side Slopes

A) Basin Maximum Side Slopes
(Horizontal distance per unit vertical, 4:1 or flatter preferred)

$Z = 0.00$ ft / ft

4. Inlet

A) Describe means of providing energy dissipation at concentrated inflow locations:

Concrete Forebay

5. Forebay

A) Minimum Forebay Volume
($V_{FMIN} = 2\%$ of the WQCV)

$V_{FMIN} = 0.002$ ac-ft

B) Actual Forebay Volume

$V_F = 0.003$ ac-ft

C) Forebay Depth
($D_F = 18$ inch maximum)

$D_F = 18.0$ in

D) Forebay Discharge

i) Undetained 100-year Peak Discharge

$Q_{100} = 27.90$ cfs

ii) Forebay Discharge Design Flow
($Q_F = 0.02 * Q_{100}$)

$Q_F = 0.56$ cfs

E) Forebay Discharge Design

Choose One
☐ Berm With Pipe
☒ Wall with Rect. Notch
☐ Wall with V-Notch Weir

Flow too small for berm w/ pipe

F) Discharge Pipe Size (minimum 8-inches)

Calculated $D_p =$ in

G) Rectangular Notch Width

Calculated $W_N = 4.7$ in

Design Procedure Form: Extended Detention Basin (EDB)

Sheet 2 of 3

Designer: JPS
Company: JPS
Date: September 16, 2022
Project: Arrowswest Apartments
Location: Detention Basin B1

6. Trickle Channel

A) Type of Trickle Channel

F) Slope of Trickle Channel

Choose One
☒ Concrete
☐ Soft Bottom

S = 0.0050 ft / ft

7. Micropool and Outlet Structure

A) Depth of Micropool (2.5-feet minimum)

B) Surface Area of Micropool (10 ft² minimum)

C) Outlet Type

D_M = 2.5 ft

A_M = 10 sq ft

Choose One
☒ Orifice Plate
☐ Other (Describe):

D) Smallest Dimension of Orifice Opening Based on Hydrograph Routing
(Use UD-Detention)

E) Total Outlet Area

D_{orifice} = 0.40 inches

A_{or} = 1.70 square inches

8. Initial Surge Volume

A) Depth of Initial Surge Volume
(Minimum recommended depth is 4 inches)

B) Minimum Initial Surge Volume
(Minimum volume of 0.3% of the WQCV)

C) Initial Surge Provided Above Micropool

D_{IS} = 6 in

V_{IS} = cu ft

V_s = 5.0 cu ft

9. Trash Rack

A) Water Quality Screen Open Area: A_o = A_{tot} * 38.5*(e^{-0.095D})

B) Type of Screen (If specifying an alternative to the materials recommended in the USDCM, indicate "other" and enter the ratio of the total open area to the total screen area for the material specified.)

Other (Y/N): N

C) Ratio of Total Open Area to Total Area (only for type 'Other')

D) Total Water Quality Screen Area (based on screen type)

E) Depth of Design Volume (EURV or WQCV)
(Based on design concept chosen under 1E)

F) Height of Water Quality Screen (H_{TR})

G) Width of Water Quality Screen Opening (W_{opening})
(Minimum of 12 inches is recommended)

A_o = 63 square inches

S.S. Well Screen with 60% Open Area

User Ratio =

A_{total} = 105 sq. in.

H = 4.5 feet

H_{TR} = 82 inches

W_{opening} = 12.0 inches

VALUE LESS THAN RECOMMENDED MIN. WIDTH.
WIDTH HAS BEEN SET TO 12 INCHES.

Design Procedure Form: Extended Detention Basin (EDB)

Sheet 3 of 3

Designer: JPS
Company: JPS
Date: September 16, 2022
Project: Arrowswest Apartments
Location: Detention Basin B1

10. Overflow Embankment

A) Describe embankment protection for 100-year and greater overtopping:

Emergency spillway with concrete chase to street

B) Slope of Overflow Embankment
 (Horizontal distance per unit vertical, 4:1 or flatter preferred)

Ze = 4.00 ft / ft

11. Vegetation

Choose One

☐ Irrigated

☒ Not Irrigated

12. Access

A) Describe Sediment Removal Procedures

Periodic inspection and sediment removal as needed;
 Access ramp provided to pond bottom for maintenance

Notes:

Hydraulic Analysis Report

Project Data

Project Title: Project - Arrowswest Apartments

Designer: JPS

Project Date: Friday, September 16, 2022

Project Units: U.S. Customary Units

Notes:

Channel Analysis: Channel Analysis-Detention Basin B1 Trickle Channel

Notes:

Input Parameters

Channel Type: Triangular

Side Slope 1 (Z1): 4.0000 ft/ft

Side Slope 2 (Z2): 4.0000 ft/ft

Longitudinal Slope: 0.0050 ft/ft

Manning's n: 0.0130

Flow: 0.2800 cfs = (1% * Q100 Flow at DP-B1.1) = (1% * 27.9 cfs)

Result Parameters

Depth: 0.2019 ft **OK**

Area of Flow: 0.1630 ft²

Wetted Perimeter: 1.6649 ft

Hydraulic Radius: 0.0979 ft

Average Velocity: 1.7173 ft/s

Top Width: 1.6152 ft

Froude Number: 0.9525

Critical Depth: 0.1980 ft

Critical Velocity: 1.7855 ft/s

Critical Slope: 0.0055 ft/ft

Critical Top Width: 1.58 ft

Calculated Max Shear Stress: 0.0630 lb/ft²

Calculated Avg Shear Stress: 0.0306 lb/ft²

APPENDIX D2

STORMWATER DETENTION CALCULATIONS DETENTION BASIN B3

Worksheet Protected

1

Location: DP-B3.1 - Detention Basin B3

Volume (V), or Permeable Pavement (PP)

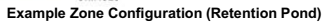
Effective Imperviousness for Optional User Defined Storm CUHP:

100-Year Event CREDIT**: Reduce Detention By:

Total Site Effective Imperviousness for Optional User Defined Storm CUHP:

*** Method assumes that 1-hour rainfall depth is equivalent to 1-hour intensity for calculation purposes

MHFD-Detention, Version 4.04 (February 2021)

Basin ID: B3

Zone 1 Volume (WQCV) =	0.116	acre-feet
Zone 2 Volume (EURV - Zone 1) =	0.226	acre-feet
Zone 3 Volume (100-year - Zones 1 & 2) =	0.264	acre-feet
Total Detention Basin Volume =	0.606	acre-feet

	acre-feet
	acre-feet
1.19	inches
1.50	inches
1.75	inches
2.00	inches
2.25	inches
2.52	inches
3.14	inches

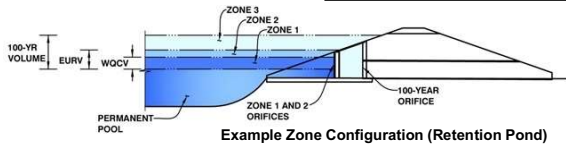
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DETENTION BASIN OUTLET STRUCTURE DESIGN

MHFD-Detention, Version 4.04 (February 2021)

Project: **Arrowswest Apartments**

Basin ID: **B3**



Example Zone Configuration (Retention Pond)

	Estimated Stage (ft)	Estimated Volume (ac-ft)	Outlet Type
Zone 1 (WQCV)	2.14	0.116	Orifice Plate
Zone 2 (EURV)	5.19	0.226	Orifice Plate
Zone 3 (100-year)	8.52	0.264	Weir&Pipe (Restrict)
Total (all zones)		0.606	

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

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 BMP)

Invert of Lowest Orifice =	0.00	ft (relative to basin bottom at Stage = 0 ft)
Depth at top of Zone using Orifice Plate =	5.19	ft (relative to basin bottom at Stage = 0 ft)
Orifice Plate: Orifice Vertical Spacing =	N/A	inches
Orifice Plate: Orifice Area per Row =	N/A	inches

Calculated Parameters for Plate

WQ Orifice Area per Row =	N/A	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	1.75	3.46					
Orifice Area (sq. inches)	0.95	0.95	0.40					

	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, H _o =	7.90	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 =	2.50	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 =	7.90	N/A	feet
Overflow Weir Slope Length =	2.50	N/A	feet
Grate Open Area / 100-yr Orifice Area =	18.95	N/A	
Overflow Grate Open Area w/o Debris =	6.96	N/A	ft ²
Overflow Grate Open Area w/ Debris =	3.48	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 =	0.50	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 =	4.70		inches

Calculated Parameters for Outlet Pipe w/ Flow Restriction Plate

	Zone 3 Restrictor	Not Selected	
Outlet Orifice Area =	0.37	N/A	ft ²
Outlet Orifice Centroid =	0.23	N/A	feet
Half-Central Angle of Restrictor Plate on Pipe =	1.07	N/A	radians

User Input: Emergency Spillway (Rectangular or Trapezoidal)

Spillway Invert Stage =	9.30	ft (relative to basin bottom at Stage = 0 ft)
Spillway Crest Length =	8.00	feet
Spillway End Slopes =	0.00	H:V
Freeboard above Max Water Surface =	1.00	feet

Calculated Parameters for Spillway

Spillway Design Flow Depth =	0.70	feet
Stage at Top of Freeboard =	11.00	feet
Basin Area at Top of Freeboard =	0.09	acres
Basin Volume at Top of Freeboard =	0.82	acre-ft

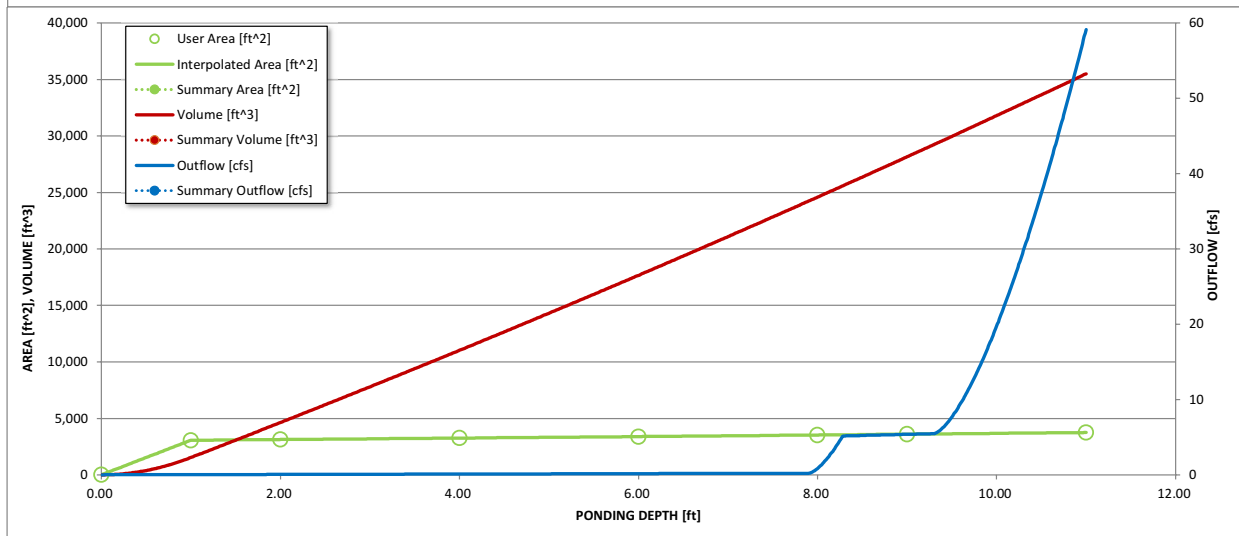
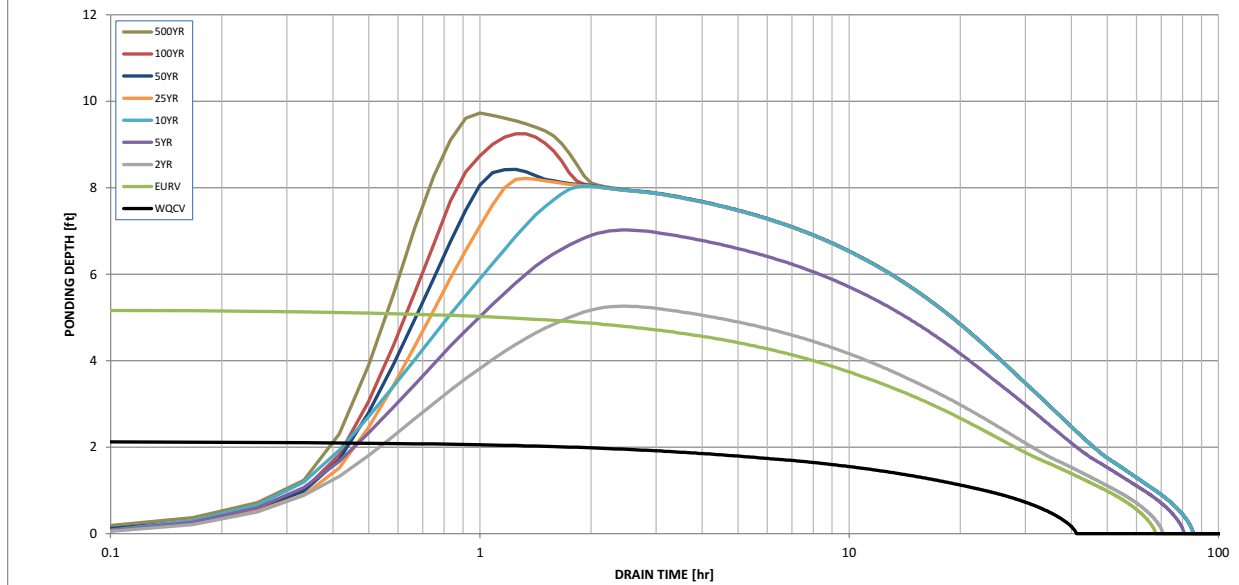
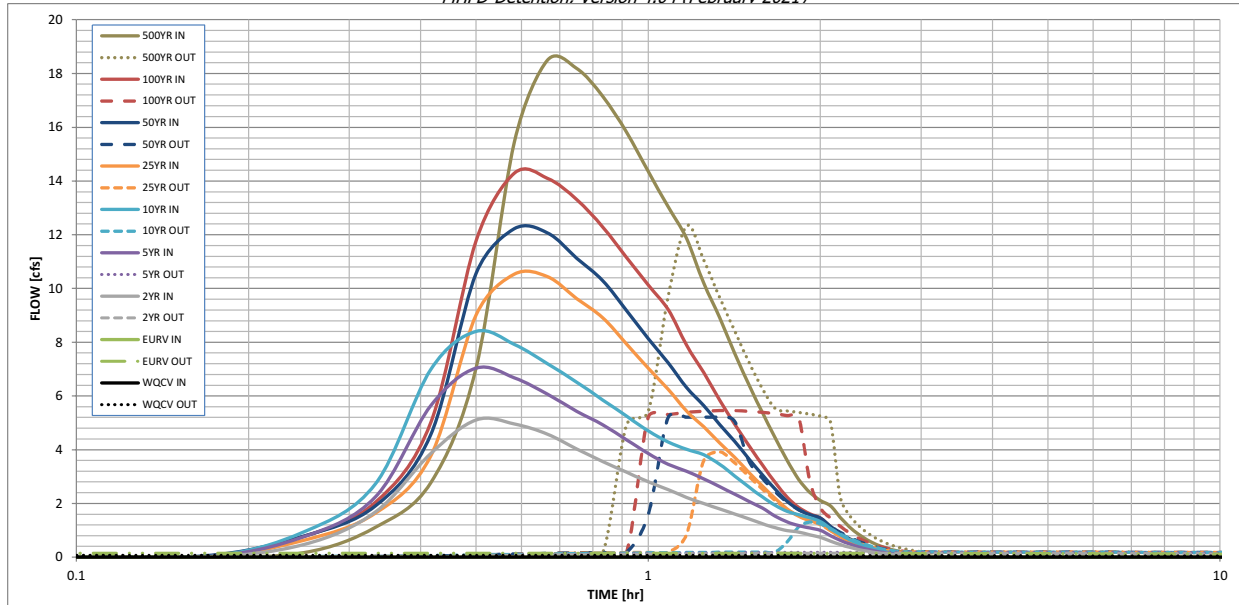
Routed Hydrograph Results

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

	WQCV	EURV	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year	500 Year
Design Storm Return Period =	N/A	N/A	1.19	1.50	1.75	2.00	2.25	2.52	3.14
One-Hour Rainfall Depth (in) =	0.116	0.343	0.373	0.516	0.637	0.772	0.897	1.045	1.358
CUHP Runoff Volume (acre-ft) =	N/A	N/A	0.373	0.516	0.637	0.772	0.897	1.045	1.358
Inflow Hydrograph Volume (acre-ft) =	N/A	N/A	0.9	1.8	2.5	4.1	5.0	6.3	8.7
CUHP Predevelopment Peak Q (cfs) =	N/A	N/A	0.15	0.32	0.44	0.70	0.87	1.09	1.50
OPTIONAL Override Predevelopment Peak Q (cfs) =	N/A	N/A	5.1	7.0	8.4	10.5	12.2	14.3	18.5
Predevelopment Unit Peak Flow, q (cfs/acre) =	N/A	N/A	0.1	0.2	0.3	0.5	0.7	0.9	1.2
Peak Inflow Q (cfs) =	N/A	N/A	0.1	0.2	0.3	0.5	0.7	0.9	1.2
Peak Outflow Q (cfs) =	N/A	N/A	0.1	0.2	0.3	0.5	0.7	0.9	1.2
Ratio Peak Outflow to Predevelopment Q =	N/A	N/A	N/A	0.1	0.5	1.0	1.0	0.9	1.4
Structure Controlling Flow =	Plate	Plate	Plate	Plate	Overflow Weir 1	Overflow Weir 1	Outlet Plate 1	Outlet Plate 1	Spillway
Max Velocity through Gate 1 (fps) =	N/A	N/A	N/A	N/A	0.2	0.5	0.7	0.8	0.8
Max Velocity through Gate 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) =	38	61	63	71	74	72	71	69	66
Time to Drain 99% of Inflow Volume (hours) =	40	65	68	77	81	80	79	78	77
Maximum Ponding Depth (ft) =	2.14	5.19	5.26	7.02	8.04	8.22	8.42	9.25	9.73
Area at Maximum Ponding Depth (acres) =	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Maximum Volume Stored (acre-ft) =	0.117	0.343	0.348	0.486	0.568	0.582	0.599	0.666	0.706

DETENTION BASIN OUTLET STRUCTURE DESIGN

MHFD-Detention, Version 4.04 (February 2021)



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.

Time Interval	SOURCE	CUHP	CUHP	CUHP	CUHP	CUHP	CUHP	CUHP	CUHP	CUHP
	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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0:05:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0:10:00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.01	0.17
	0:15:00	0.00	0.00	0.47	0.76	0.95	0.63	0.79	0.77	1.11
	0:20:00	0.00	0.00	1.68	2.24	2.73	1.64	1.91	2.04	2.78
	0:25:00	0.00	0.00	3.86	5.64	6.99	3.77	4.56	5.01	7.03
	0:30:00	0.00	0.00	5.11	7.03	8.40	9.01	10.55	11.77	15.43
	0:35:00	0.00	0.00	4.96	6.68	7.92	10.53	12.22	14.29	18.49
	0:40:00	0.00	0.00	4.58	6.07	7.20	10.44	12.07	14.10	18.19
	0:45:00	0.00	0.00	4.03	5.43	6.52	9.63	11.13	13.32	17.14
	0:50:00	0.00	0.00	3.56	4.93	5.85	8.91	10.29	12.28	15.81
	0:55:00	0.00	0.00	3.16	4.37	5.25	7.93	9.17	11.15	14.35
	1:00:00	0.00	0.00	2.80	3.86	4.70	7.03	8.14	10.13	13.04
	1:05:00	0.00	0.00	2.52	3.46	4.28	6.25	7.24	9.22	11.87
	1:10:00	0.00	0.00	2.23	3.20	4.02	5.44	6.32	7.90	10.21
	1:15:00	0.00	0.00	2.00	2.92	3.81	4.85	5.65	6.87	8.92
	1:20:00	0.00	0.00	1.80	2.62	3.46	4.25	4.94	5.85	7.59
	1:25:00	0.00	0.00	1.61	2.35	3.02	3.71	4.31	4.95	6.41
	1:30:00	0.00	0.00	1.43	2.08	2.61	3.16	3.66	4.16	5.38
	1:35:00	0.00	0.00	1.25	1.83	2.24	2.65	3.07	3.43	4.44
	1:40:00	0.00	0.00	1.10	1.53	1.93	2.19	2.53	2.78	3.60
	1:45:00	0.00	0.00	0.99	1.31	1.71	1.79	2.08	2.23	2.90
	1:50:00	0.00	0.00	0.94	1.18	1.58	1.52	1.77	1.85	2.42
	1:55:00	0.00	0.00	0.83	1.09	1.47	1.36	1.58	1.62	2.11
	2:00:00	0.00	0.00	0.74	1.00	1.33	1.25	1.46	1.46	1.91
	2:05:00	0.00	0.00	0.60	0.80	1.07	0.99	1.15	1.13	1.49
	2:10:00	0.00	0.00	0.47	0.63	0.84	0.77	0.89	0.86	1.13
	2:15:00	0.00	0.00	0.37	0.49	0.66	0.60	0.69	0.65	0.86
	2:20:00	0.00	0.00	0.29	0.38	0.51	0.46	0.53	0.49	0.64
	2:25:00	0.00	0.00	0.22	0.30	0.39	0.35	0.41	0.37	0.49
	2:30:00	0.00	0.00	0.17	0.22	0.29	0.27	0.31	0.28	0.37
	2:35:00	0.00	0.00	0.13	0.17	0.22	0.20	0.23	0.22	0.28
	2:40:00	0.00	0.00	0.10	0.13	0.17	0.15	0.17	0.16	0.22
	2:45:00	0.00	0.00	0.07	0.09	0.13	0.11	0.13	0.13	0.16
	2:50:00	0.00	0.00	0.05	0.07	0.09	0.08	0.10	0.09	0.12
	2:55:00	0.00	0.00	0.03	0.04	0.06	0.06	0.07	0.06	0.08
	3:00:00	0.00	0.00	0.02	0.03	0.04	0.04	0.04	0.04	0.05
	3:05:00	0.00	0.00	0.01	0.02	0.02	0.02	0.02	0.02	0.03
	3:10:00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01
	3:15:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:20:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:25:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:30:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:35:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:40:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:45:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:50:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:55:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:00:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:05:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:10:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:15:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:20:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:25:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:30:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:35:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:40:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:45:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:50:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:55:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:00:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:05:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:10:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:15:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:20:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:25:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:30:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:35:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:40:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:45:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:50:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:55:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	6:00:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Design Procedure Form: Extended Detention Basin (EDB)

UD-BMP (Version 3.07, March 2018)

Sheet 1 of 3

Designer: JPS
Company: JPS
Date: September 16, 2022
Project: Arrowswest Apartments
Location: Detention Basin B3

1. Basin Storage Volume

A) Effective Imperviousness of Tributary Area, I_a

$I_a = 61.6$ %

B) Tributary Area's Imperviousness Ratio ($i = I_a / 100$)

$i = 0.616$

C) Contributing Watershed Area

Area = 5.780 ac

D) For Watersheds Outside of the Denver Region, Depth of Average Runoff Producing Storm

$d_0 =$ in

E) Design Concept
(Select EURV when also designing for flood control)

Choose One
☐ Water Quality Capture Volume (WQCV)
☒ Excess Urban Runoff Volume (EURV)

F) Design Volume (WQCV) Based on 40-hour Drain Time
 $(V_{DESIGN} = (1.0 * (0.91 * i^3 - 1.19 * i^2 + 0.78 * i) / 12 * Area)$

$V_{DESIGN} = 0.116$ ac-ft

G) For Watersheds Outside of the Denver Region,
 Water Quality Capture Volume (WQCV) Design Volume
 $(V_{WQCV\ OTHER} = (d_0 * (V_{DESIGN} / 0.43))$

$V_{DESIGN\ OTHER} =$ ac-ft

H) User Input of Water Quality Capture Volume (WQCV) Design Volume
 (Only if a different WQCV Design Volume is desired)

$V_{DESIGN\ USER} =$ ac-ft

I) NRCS Hydrologic Soil Groups of Tributary Watershed
 i) Percentage of Watershed consisting of Type A Soils
 ii) Percentage of Watershed consisting of Type B Soils
 iii) Percentage of Watershed consisting of Type C/D Soils

$HSG_A = 0$ %
 $HSG_B = 0$ %
 $HSG_{C/D} = 100$ %

J) Excess Urban Runoff Volume (EURV) Design Volume
 For HSG A: $EURV_A = 1.68 * i^{1.28}$
 For HSG B: $EURV_B = 1.36 * i^{1.08}$
 For HSG C/D: $EURV_{C/D} = 1.20 * i^{1.08}$

$EURV_{DESIGN} = 0.343$ ac-ft

K) User Input of Excess Urban Runoff Volume (EURV) Design Volume
 (Only if a different EURV Design Volume is desired)

$EURV_{DESIGN\ USER} =$ ac-ft

2. Basin Shape: Length to Width Ratio

(A basin length to width ratio of at least 2:1 will improve TSS reduction.)

$L : W = 4.0 : 1$

3. Basin Side Slopes

A) Basin Maximum Side Slopes
 (Horizontal distance per unit vertical, 4:1 or flatter preferred)

$Z = 0.00$ ft / ft

4. Inlet

A) Describe means of providing energy dissipation at concentrated inflow locations:

Concrete Forebay

5. Forebay

A) Minimum Forebay Volume
 $(V_{FMIN} = 2\%$ of the WQCV)

$V_{FMIN} = 0.002$ ac-ft

B) Actual Forebay Volume

$V_F = 0.003$ ac-ft

C) Forebay Depth
 $(D_F = 18$ inch maximum)

$D_F = 18.0$ in

D) Forebay Discharge

i) Undetained 100-year Peak Discharge

$Q_{100} = 27.60$ cfs

ii) Forebay Discharge Design Flow
 $(Q_F = 0.02 * Q_{100})$

$Q_F = 0.55$ cfs

E) Forebay Discharge Design

Choose One
☐ Berm With Pipe
☒ Wall with Rect. Notch
☐ Wall with V-Notch Weir

Flow too small for berm w/ pipe

F) Discharge Pipe Size (minimum 8-inches)

Calculated $D_p =$ in

G) Rectangular Notch Width

Calculated $W_N = 4.7$ in

Design Procedure Form: Extended Detention Basin (EDB)

Sheet 2 of 3

Designer: JPS
 Company: JPS
 Date: September 16, 2022
 Project: Arrowswest Apartments
 Location: Detention Basin B3

6. Trickle Channel

A) Type of Trickle Channel

F) Slope of Trickle Channel

Choose One
☒ Concrete
☐ Soft Bottom

S = 0.0050 ft / ft

7. Micropool and Outlet Structure

A) Depth of Micropool (2.5-feet minimum)

B) Surface Area of Micropool (10 ft² minimum)

C) Outlet Type

D_M = 2.5 ft

A_M = 10 sq ft

Choose One
☒ Orifice Plate
☐ Other (Describe):

D) Smallest Dimension of Orifice Opening Based on Hydrograph Routing
 (Use UD-Detention)

E) Total Outlet Area

D_{orifice} = 0.40 inches

A_{or} = 2.30 square inches

8. Initial Surcharge Volume

A) Depth of Initial Surcharge Volume
 (Minimum recommended depth is 4 inches)

B) Minimum Initial Surcharge Volume
 (Minimum volume of 0.3% of the WQCV)

C) Initial Surcharge Provided Above Micropool

D_{IS} = 6 in

V_{IS} = cu ft

V_s = 5.0 cu ft

9. Trash Rack

A) Water Quality Screen Open Area: A_o = A_{st} * 38.5 * (e^{-0.095D})

B) Type of Screen (If specifying an alternative to the materials recommended in the USDCM, indicate "other" and enter the ratio of the total open area to the total screen area for the material specified.)

Other (Y/N): N

C) Ratio of Total Open Area to Total Area (only for type 'Other')

D) Total Water Quality Screen Area (based on screen type)

E) Depth of Design Volume (EURV or WQCV)
 (Based on design concept chosen under 1E)

F) Height of Water Quality Screen (H_{TR})

G) Width of Water Quality Screen Opening (W_{opening})
 (Minimum of 12 inches is recommended)

A_o = 85 square inches

S.S. Well Screen with 60% Open Area

User Ratio =

A_{total} = 142 sq. in.

H = 5.19 feet

H_{TR} = 90.28 inches

W_{opening} = 12.0 inches

VALUE LESS THAN RECOMMENDED MIN. WIDTH.
 WIDTH HAS BEEN SET TO 12 INCHES.

Design Procedure Form: Extended Detention Basin (EDB)

Sheet 3 of 3

Designer: JPS
 Company: JPS
 Date: September 16, 2022
 Project: Arrowswest Apartments
 Location: Detention Basin B3

10. Overflow Embankment

A) Describe embankment protection for 100-year and greater overtopping:

Emergency spillway with concrete chase to street

B) Slope of Overflow Embankment
(Horizontal distance per unit vertical, 4:1 or flatter preferred)

Ze = 4.00 ft / ft

11. Vegetation

Choose One
☐ Irrigated
☒ Not Irrigated

12. Access

A) Describe Sediment Removal Procedures

Periodic inspection and sediment removal as needed;
 Access ramp provided to pond bottom for maintenance

Notes:

Hydraulic Analysis Report

Project Data

Project Title: Project - Arrowswest Apartments

Designer: JPS

Project Date: Friday, September 16, 2022

Project Units: U.S. Customary Units

Notes:

Channel Analysis: Channel Analysis-Detention Basin B3 Trickle Channel

Notes:

Input Parameters

Channel Type: Triangular

Side Slope 1 (Z1): 4.0000 ft/ft

Side Slope 2 (Z2): 4.0000 ft/ft

Longitudinal Slope: 0.0050 ft/ft

Manning's n: 0.0130

Flow: 0.2800 cfs = (1% * Q100 Flow at DP-B3.1) = (1% * 27.6 cfs)

Result Parameters

Depth: 0.2019 ft **OK**

Area of Flow: 0.1630 ft²

Wetted Perimeter: 1.6649 ft

Hydraulic Radius: 0.0979 ft

Average Velocity: 1.7173 ft/s

Top Width: 1.6152 ft

Froude Number: 0.9525

Critical Depth: 0.1980 ft

Critical Velocity: 1.7855 ft/s

Critical Slope: 0.0055 ft/ft

Critical Top Width: 1.58 ft

Calculated Max Shear Stress: 0.0630 lb/ft²

Calculated Avg Shear Stress: 0.0306 lb/ft²

APPENDIX E

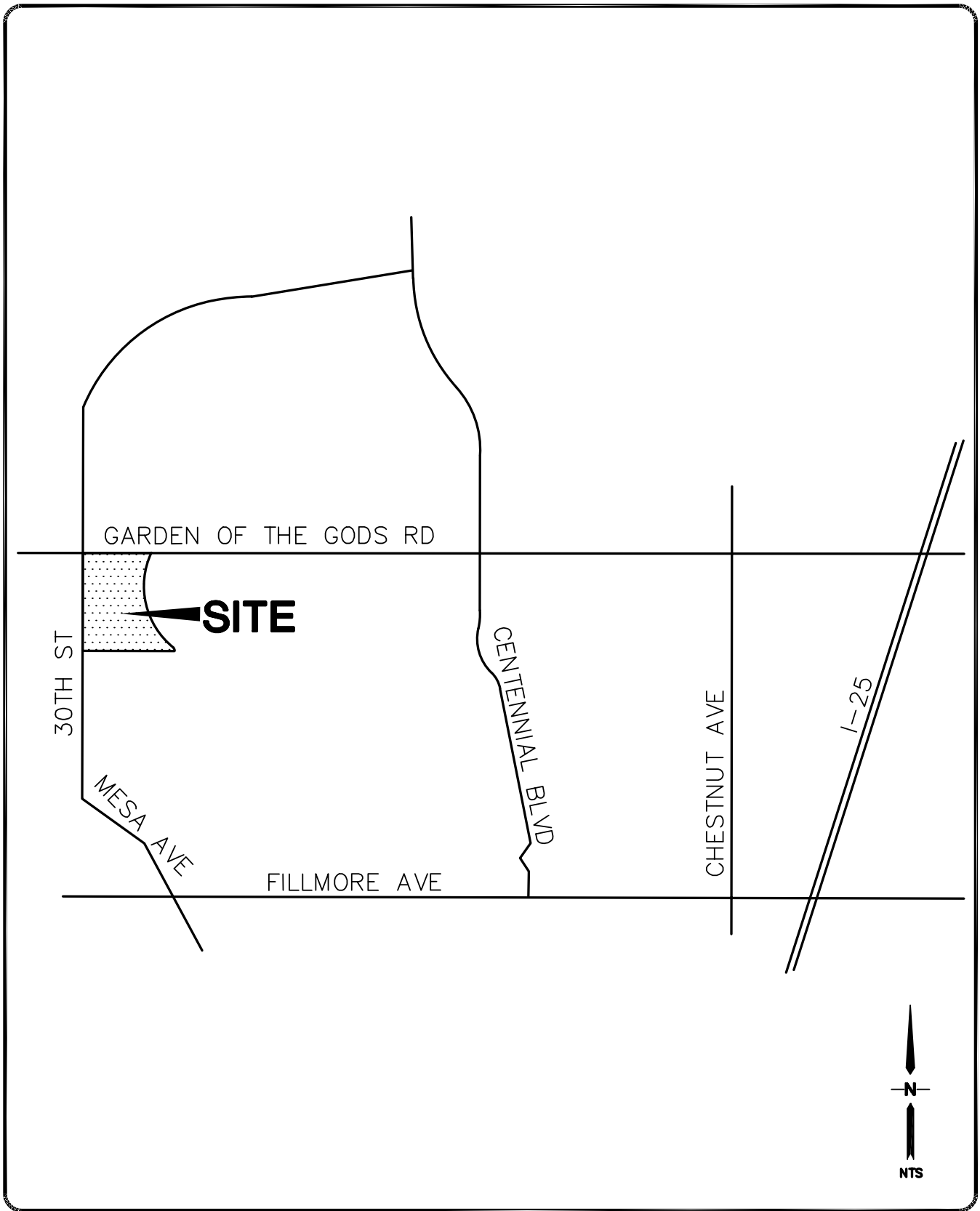
DRAINAGE COST ESTIMATE

ARROWSWEST APARTMENTS ENGINEER'S COST ESTIMATE DRAINAGE IMPROVEMENTS					
Item No.	Description	Quantity	Unit	Unit Cost (\$\$)	Total Cost (\$\$)
PRIVATE DRAINAGE FACILITIES (NON-REIMBURSABLE)					
603	12" HDPE Storm Drain	500	LF	\$55	\$27,500
603	15" HDPE Storm Drain	209	LF	\$65	\$13,585
603	18" HDPE Storm Drain	288	LF	\$70	\$20,160
603	24" HDPE Storm Drain	100	LF	\$85	\$8,500
604	18" Nyoplast Storm Inlet	7	EA	\$1,000	\$7,000
604	Type 13 Storm Inlet	1	EA	\$2,000	\$2,000
604	5' Type D10R Storm Inlet	5	EA	\$5,800	\$29,000
604	10' Type D10R Storm Inlet	1	EA	\$7,000	\$7,000
604	Storm Sewer Manhole	2	EA	\$6,600	\$13,200
	SUBTOTAL				\$127,945
	Engineering @ 10%				\$12,795
	TOTAL (REIMBURSABLE)				\$140,740
Note: This estimate does not include costs for street improvements and general civil costs (curb & gutter, crosspans, retaining walls, etc.)					
The cost estimate submitted herein is based on time-honored practices within the construction industry. As such the engineer does not control the cost of labor, materials, equipment or a contractor's method of determining prices and competitive bidding practices or market conditions. The estimate represents our best judgement as design professionals using current information available at the time of the preparation. The engineer cannot guarantee that proposals, bids and/or construction costs will not vary from this cost estimate.					

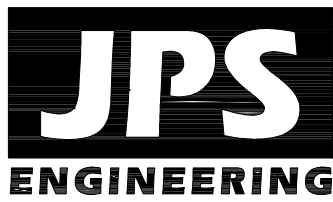
ARROWSWEST APARTMENTS ENGINEER'S COST ESTIMATE DRAINAGE IMPROVEMENTS - FULL-SPECTRUM DETENTION FACILITIES					
Item No.	Description	Quantity	Unit	Unit Cost (\$\$\$)	Total Cost (\$\$\$)
	PRIVATE DRAINAGE FACILITIES (NON-REIMBURSABLE)				
	FULL-SPECTRUM DETENTION BASIN B1				
203	Detention Basin Earthwork	1,080	CY	\$3	\$3,240
301	Concrete Forebay	1	LS	\$1,500	\$1,500
301	Concrete Trickle Channel	26	SY	\$40	\$1,040
301	Retaining Walls	3410	SF	\$25	\$85,250
604	Detention Basin Outlet Structure	1	LS	\$8,000	\$8,000
604	Spillway (Concrete Chase)	1	LS	\$1,500	\$1,500
604	Gravel Maintenance Access Road	190	SY	\$10	\$1,900
	SUBTOTAL				\$102,430
	FULL-SPECTRUM DETENTION BASIN B3				
203	Detention Basin Earthwork	1,080	CY	\$3	\$3,240
301	Concrete Forebay	1	LS	\$1,500	\$1,500
301	Concrete Trickle Channel	50	SY	\$40	\$2,000
301	Retaining Walls	3490	SF	\$25	\$87,250
604	Detention Basin Outlet Structure	1	LS	\$8,000	\$8,000
604	Spillway (Concrete Chase)	1	LS	\$2,000	\$2,000
604	Gravel Maintenance Access Road	230	SY	\$10	\$2,300
	SUBTOTAL				\$106,290
	TOTAL (NON-REIMBURSABLE)				\$208,720
	Note: This estimate does not include costs for street improvements and general civil costs (curb & gutter, crossspans, retaining walls, etc.)				
	The cost estimate submitted herein is based on time-honored practices within the construction industry. As such the engineer does not control the cost of labor, materials, equipment or a contractor's method of determining prices and competitive bidding practices or market conditions. The estimate represents our best judgement as design professionals using current information available at the time of the preparation. The engineer cannot guarantee that proposals, bids and/or construction costs will not vary from this cost estimate.				

APPENDIX F

FIGURES



VICINITY MAP



**ARROWSWEST
APARTMENTS**

FIGURE A1

JPS PROJ NO. 072002

National Flood Hazard Layer FIRMette

104°52'38"W 38°53'57"N



0 250 500 1,000 1,500 2,000 Feet 1:6,000

Basemap: USGS National Map: Orthoimagery: Data refreshed October, 2020

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS		Without Base Flood Elevation (BFE) Zone A, V, A99
		With BFE or Depth Zone AE, AO, AH, VE, AR
		Regulatory Floodway
OTHER AREAS OF FLOOD HAZARD		0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile Zone X
		Future Conditions 1% Annual Chance Flood Hazard Zone X
		Area with Reduced Flood Risk due to Levee. See Notes. Zone X
		Area with Flood Risk due to Levee Zone D
OTHER AREAS	NO SCREEN	Area of Minimal Flood Hazard Zone X
		Effective LOMRs
		Area of Undetermined Flood Hazard Zone D
GENERAL STRUCTURES		Channel, Culvert, or Storm Sewer
		Levee, Dike, or Floodwall
OTHER FEATURES		Cross Sections with 1% Annual Chance Water Surface Elevation
		Coastal Transect
		Base Flood Elevation Line (BFE)
		Limit of Study
		Jurisdiction Boundary
		Coastal Transect Baseline
MAP PANELS		Digital Data Available
		No Digital Data Available
		Unmapped



The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on **10/22/2021 at 2:39 PM** and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

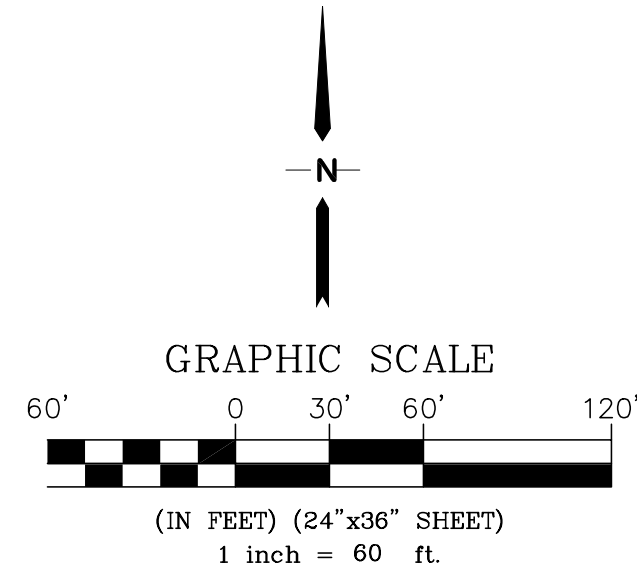
C:\Users\Owner\Dropbox\jpsprojects\072002\arrowswest\dwg\incoming\EXT1.dwg Sep 16, 2022 -- 2:50pm

BASIN SUMMARY TABLE

BASIN	Q5 (CFS)	Q100 (CFS)
OA1	0.2	1.4
OB1	1.0	5.5
OA2	4.0	7.8
A	5.1	28.3

SUMMARY HYDROLOGY TABLE

DESIGN POINT	Q5 (CFS)	Q100 (CFS)
1	8.9	39.6

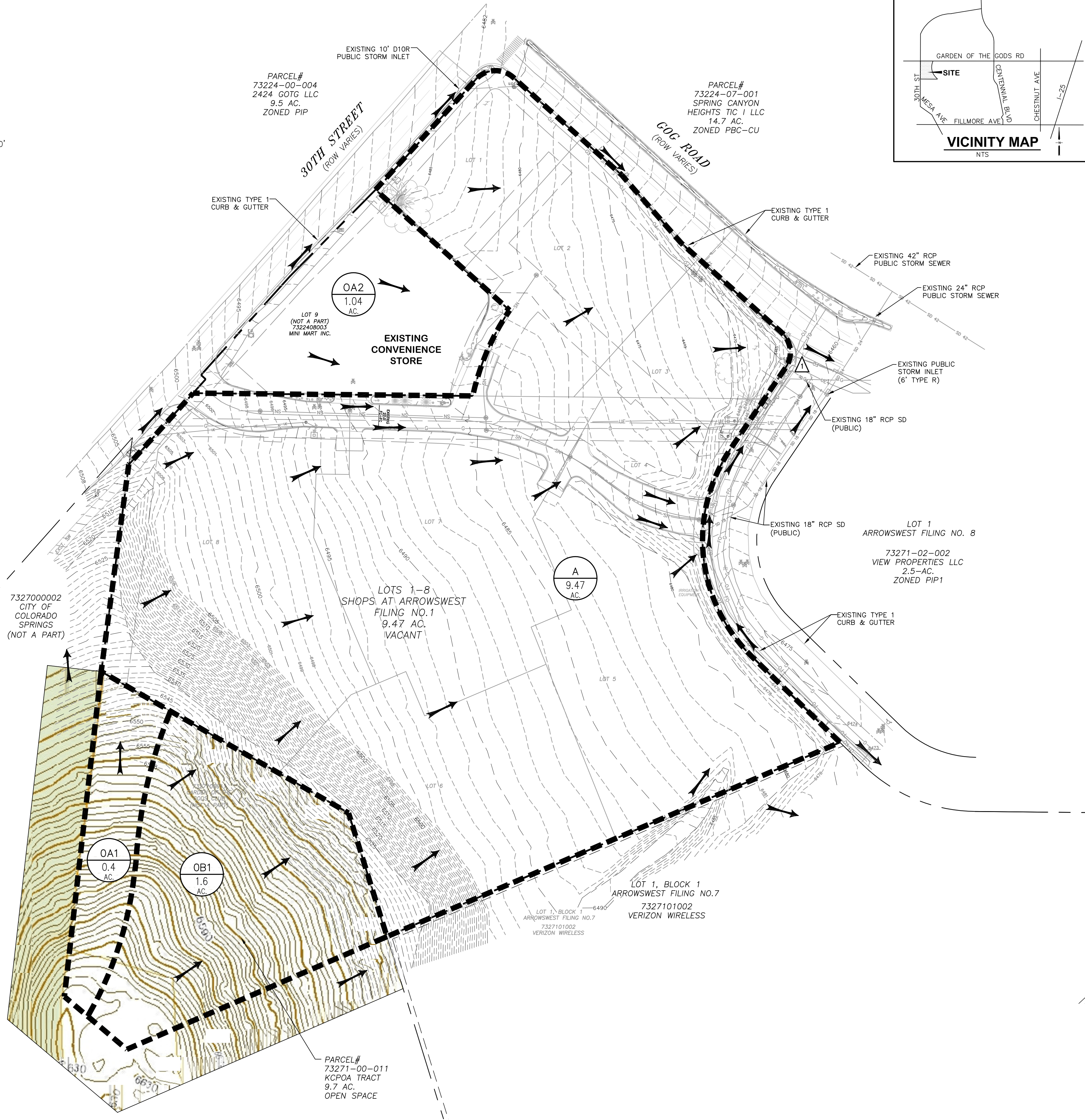


LEGEND

- PROPERTY LINE
- DRAINAGE BASIN BOUNDARY
- EXISTING CONTOUR
- DESIGN POINT
- BASIN DESIGNATION
- BASIN AREA (ACRES)
- EASEMENT LINE

BENCHMARK: NGS DESIGNATION CS 108,
PID DL2023; ELEV=6456.56
NAVD 88 DATUM

PARCEL#
73000-00-466
THE NAVIGATORS
403.3 AC.
ZONED R-A



IMPERVIOUS AREA CALCULATIONS:	
BASIN AREA A1	= 2.51 AC.
IMPERVIOUS AREAS:	
SURFACE TYPE	AREA
PARKING PAVEMENT	44,390 SF
BUILDING	10,572 SF
SIDEWALK	11,598 SF
TOTAL	66,560 SF
	= 1.53 AC
	= 61% IMPERVIOUS
BASIN AREA B1	= 4.27 AC.
IMPERVIOUS AREAS:	
SURFACE TYPE	AREA
PARKING PAVEMENT	55,757 SF
BUILDING	49,929 SF
SIDEWALK	15,721 SF
TOTAL	121,407 SF
	= 2.79 AC
	= 65% IMPERVIOUS
BASIN AREA B2	= 0.47 AC.
IMPERVIOUS AREAS:	
SURFACE TYPE	AREA
PAVEMENT	6,517 SF
SIDEWALK	6,379 SF
TOTAL	12,896 SF
	= 0.30 AC
	= 63.8% IMPERVIOUS
BASIN AREA B3	= 1.83 AC.
IMPERVIOUS AREAS:	
SURFACE TYPE	AREA
PARKING PAVEMENT	28,345 SF
BUILDING	17,796 SF
SIDEWALK	5,976 SF
TOTAL	52,117 SF
	= 1.20 AC
	= 66% IMPERVIOUS
BASIN AREA B4	= 0.41 AC.
IMPERVIOUS AREAS:	
SURFACE TYPE	AREA
PARKING PAVEMENT	0,000 SF
BUILDING	0,000 SF
SIDEWALK	4,979 SF
TOTAL	4,979 SF
	= 0.11 AC
	= 28% IMPERVIOUS

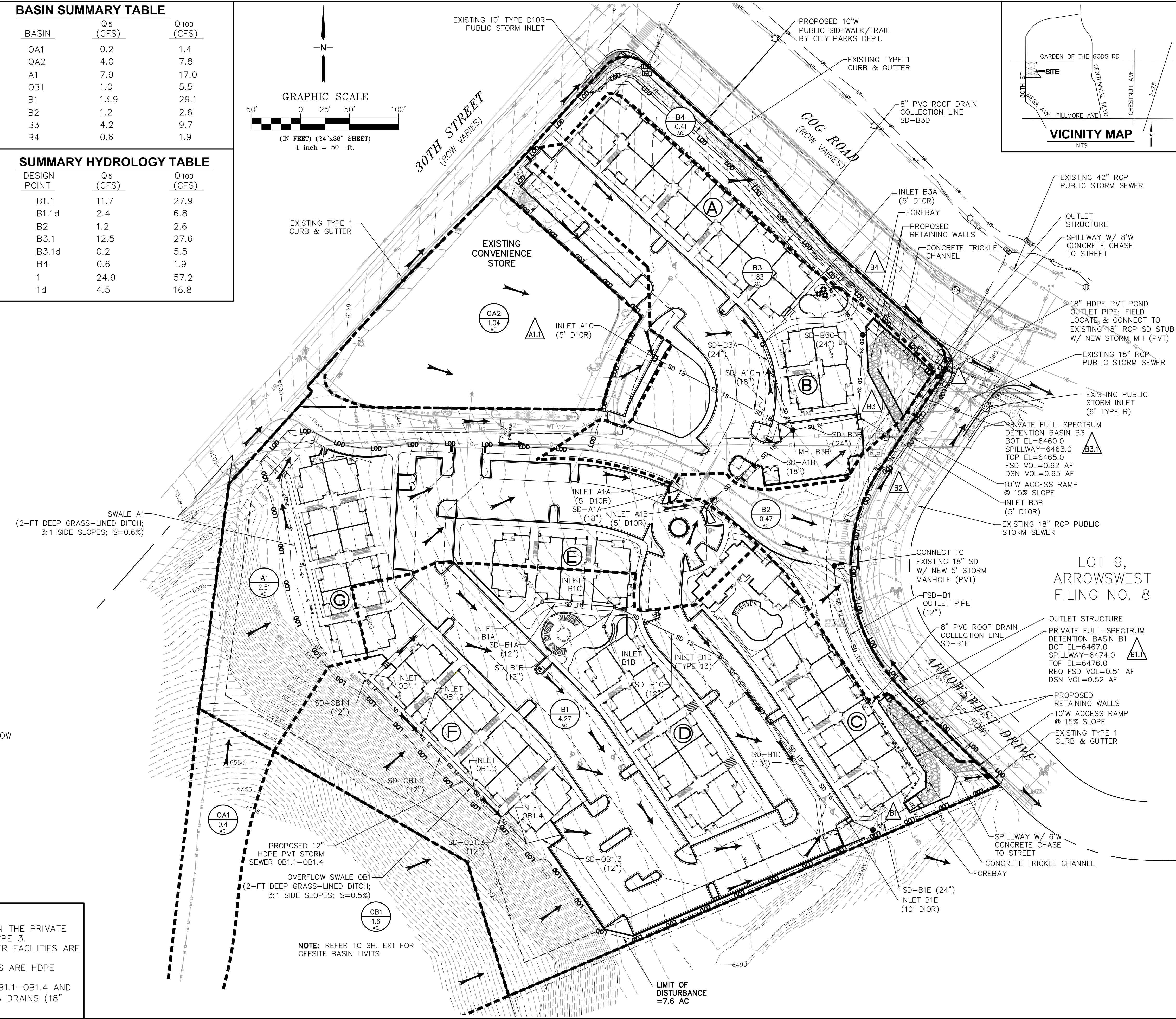
BASIN SUMMARY TABLE		
BASIN	Q5 (CFS)	Q100 (CFS)
OA1	0.2	1.4
OA2	4.0	7.8
A1	7.9	17.0
OB1	1.0	5.5
B1	13.9	29.1
B2	1.2	2.6
B3	4.2	9.7
B4	0.6	1.9

SUMMARY HYDROLOGY TABLE		
DESIGN POINT	Q5 (CFS)	Q100 (CFS)
B1.1	11.7	27.9
B1.1d	2.4	6.8
B2	1.2	2.6
B3.1	12.5	27.6
B3.1d	0.2	5.5
B4	0.6	1.9
1	24.9	57.2
1d	4.5	16.8

G:\Users\Owner\Dropbox\jpsprojects\072002\arrowswest\dwg\incoming\DI.dwg Oct 05, 2022 - 4:30pm

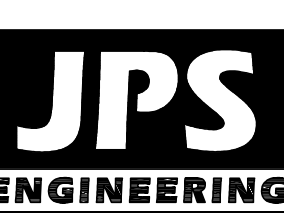
- LEGEND**
- PROPERTY LINE
 - DRAINAGE BASIN BOUNDARY
 - 6520 --- PROPOSED CONTOUR
 - 6520 --- EXISTING CONTOUR
 - PROPOSED FLOW DIRECTION ARROW
 - 1 --- DESIGN POINT
 - A --- BASIN DESIGNATION
 - A 524 --- BASIN AREA (ACRES)
 - F --- BUILDING #
 - EASEMENT LINE
 - X 99.00 --- PROPOSED SPOT ELEVATION (FLOWLINE)
 - X 99.00 --- EXIST. SPOT ELEVATION

- NOTES:**
- NEW CURB & GUTTER WITHIN THE PRIVATE APARTMENT SITE WILL BE TYPE 3.
 - ALL PROPOSED STORM WATER FACILITIES ARE PRIVATE.
 - ALL PROPOSED STORM PIPES ARE HDPE UNLESS NOTED OTHERWISE.
 - PROPOSED STORM INLETS OB1.1-OB1.4 AND B1A-B1C ARE GRATED AREA DRAINS (18" NYOPLAST OR EQUAL).

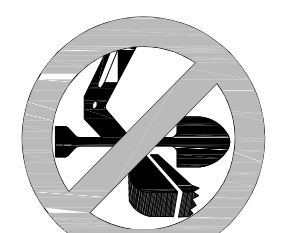


ARROWSWEST APARTMENTS
LOTS 1-8, SHOPS AT ARROWSWEST FIL NO. 1

DEVELOPED DRAINAGE PLAN



19 E. Willamette Ave.
Colorado Springs, CO 80903
PH: 719-477-9429
FAX: 719-471-0766
www.jpsengr.com



CALL UTILITY NOTIFICATION
CENTER OF COLORADO
1-800-922-1987
CALL 2-BUSINESS DAYS IN ADVANCE
BEFORE ANY GROUND-BREAKING
FOR THE MARKING OF UNDERGROUND
MEMBER UTILITIES.

HORIZ. SCALE: 1"=50'	DRAWN: PV
VERT. SCALE: N/A	DESIGNED: JPS
SURVEYED: RIDGELINE	CHECKED: JPS
CREATED: 11/09/20	LAST MODIFIED: 10/05/22
PROJECT NO: 072002	MODIFIED BY: PV
SHEET:	D1