The City of SAN DIEGO

Draft Hydrology and Hydraulics Validation Study

Point Loma Wastewater Treatment Plant Storm Water Diversion Project

September 2020

HDR

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ACRONYMS

BMP	Best Management Practice
cfs	cubic feet per second
DCV	design capture volume
ICM	Integrated Catchment Modeling
IGP	California General Permit for Storm Water Discharges Associated with Industrial Activities
PLWTP	Point Loma Wastewater Treatment Plant
project	Point Loma Wastewater Treatment Plant Storm Water Diversion Project
U.S.	United States

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ES.0 Executive Summary

ES.1 Project Description

In November 2018, the City of San Diego entered into a Consent Decree with San Diego Coastkeeper and Coastal Environmental Rights Foundation, which outlines obligations to reduce pollutant concentrations in storm water discharged from Point Loma Wastewater Treatment Plant (PLWTP) to below specific numeric levels. Based on preliminary analysis, the City of San Diego decided to capture and route storm water discharges to the PLWTP headworks for treatment and has requested design assistance from HDR to capture and divert discharges from the PLSD1, PLSD2, PLSD3, PLSD3A, and PLSD4 drainage areas. This design assistance is in accordance with requirements of the on-site compliance option of the 2018 amendments to the Statewide General Permit for Storm water Discharges Associated with Industrial Activities (IGP).

ES.2 Existing Hydrology

Hydrologic and hydraulic analysis was conducted for the PLWTP Storm Water Diversion Project (project) to provide peak discharge and design capture volume (DCV) estimates that will inform the design of storm water containment facilities required to meet storm water quality criteria. Peak discharges were estimated according to Rational Method guidance from the *San Diego County Hydrology Manual* (County of San Diego Department of Public Works 2003), and calculations were completed using InfoWorks Integrated Catchment Modeling (ICM) software to incorporate hydraulic routing through drainage system components. DCVs were estimated according to guidance from City of San Diego Best Management Practice (BMP) Design Manual (County of San Diego Department of Public Works 2016).

ES.1.1 Design Storms

Two design storms were evaluated: the 24-hour, 85th percentile storm (Storm 1) and a 24-hour storm with a rainfall depth 5 percent greater than the 24-hour (Storm 2). Total rainfall depths were 0.55 inch and 0.58 inch for Storm 1 and Storm 2, respectively. Hyetographs were developed from the design rainfall depths using the County of San Diego Nested Distribution (San Diego Nested) and National Oceanic and Atmospheric Administration Atlas-14 (Atlas-14) rainfall distributions. The San Diego Nested rainfall distribution is recommended for drainage design by the County of San Diego Hydrology Manual. The Atlas-14 distribution was included because it produces a larger peak rainfall and provides a more conservative runoff estimate. Rainfall intensities were derived from the hyetographs and used in Rational Method calculations.

ES.1.2 Drainage Areas

The total project area is approximately 57.5 acres and is comprised of the PLWTP operations area (PLWTP footprint), as well as adjacent areas that drain into the PLWTP footprint, including thickly vegetated hillslopes, Fort Rosecrans National Cemetery (cemetery), and United States

(U.S.) Naval properties just south of the cemetery. Drainage areas were delineated for eight drainage collection points within the project area: PLSD1A, PLSD1B, PLSD2, PLSD3A, PLSD3, PLSD4, Off-site Pacific, and Off-site North. Each drainage collection point corresponded to an existing sump or collection basin location within the project area or a location where runoff exits the project area. Runoff coefficients for drainage subareas within each drainage area were determined using guidance from the County of San Diego Hydrology Manual.

ES.1.3 Peak Discharges and Design Capture Volumes

Peak discharges and DCVs were estimated for both design storms using hyetographs developed from both rainfall distributions. Results derived from the San Diego Nested distribution will be used for design, with the Atlas-14 results available for consideration as a conservative upper limit. A summary of design peak discharges and DCVs for each drainage area can be found in Table ES-1.

Table ES-1. Hydrology Summary by Drainage Area

Drainage Area	Area (acres)	Average Runoff Coefficient	Peak Discharge (cfs)		DCV (cubic feet)	
			Storm 1	Storm 2	Storm 1	Storm 2
PLSD1A	1.16	0.87	0.140	0.147	2,013	2,112
PLSD1B	23.88	0.44	1.457	1.529	20,960	21,989
PLSD2	0.92	0.87	0.111	0.116	1,593	1,671
PLSD3A	1.64	0.87	0.198	0.208	2,847 **3,273**	2,987 **3,433**
PLSD3	4.72	0.87	0.570	0.598	8,197	8,600
PLSD4	22.19	0.63	2.097	2.200	30,170	31,651
Off-site North	1.35	0.53	0.162	0.170	2,337	2,451
Off-site Pacific	1.66	0.87	0.200	0.210	2,882	3,024

Note: **Bolded** values indicate runoff volume with no losses (C=1) for PLSD3A.

cfs=cubic feet per second; DCV=design capture volume

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1.0 Project Background

In November 2018, the City of San Diego entered into a Consent Decree with San Diego Coastkeeper and Coastal Environmental Rights Foundation for several City of San Diego-owned facilities regulated under IGP, including PLWTP. The Consent Decree outlines obligations to reduce pollutant concentration to below specific numeric levels in storm water runoff discharged from industrial areas of the facilities. The PLWTP Storm Water Diversion Project (project) addresses storm water discharges from the PLWTP footprint.

The City of San Diego investigated methods to reduce the discharge pollutants from the existing five storm water monitoring locations: PLSD1, PLSD2, PLSD3, PLSD3A, and PLSD4. Based on preliminary analysis, the city decided to capture and route storm water discharges to the PLWTP headworks for treatment. The City of San Diego has requested design assistance from HDR to capture and divert discharges from the PLSD1, PLSD2, PLSD3, PLSD3A, and PLSD4 drainage areas in accordance with requirements of the on-site compliance option of the 2018 IGP amendments.

Figure 1-1 shows the project area and the storm water monitoring locations.

Figure 1-1. Project Vicinity and Storm Water Monitoring Locations

2.0 Purpose and Scope

The Hydrology and Hydraulics Validation Study has been prepared to document hydrologic and hydraulic analyses conducted for existing site conditions that will support design of the storm water detention and handling facilities.

Existing flows and drainage areas within the project area previously determined by Carollo Engineers, Inc. (2018) were verified and revised by HDR, as necessary. Hydrology for two design conditions were evaluated using guidance from the *City of San Diego Storm Water Standards* (City of San Diego 2018) and *San Diego County Hydrology Manual* (County of San Diego Department of Public Works 2003) guidelines and are discussed in depth in Section 3.1. Specifications for hydrologic analyses from the agreed upon scope of work were as follows:

PLSD3 and PLSD4: Flow detention at these locations will be limited to a wet well from which storm water will be pumped to the headworks facility. Design volumes and flow rates for the specified design conditions were required at these locations.

PLSD3A: The primary anticipated design approach at this location is construction of a flow detention basin. Design volume for the detention basin for the specified design conditions were to be determined by multiplying rainfall depth by contributing area (i.e., no losses).

PLSD2: Potential flow detention alternatives at this location include a wet well for PLSD2 pump station, detention basin for evacuation by pump truck, and will be determined when more is known about the site and hydrology conditions.

PLSD1 (PS1A and PS1B): Potential flow detention alternatives were not discussed at the time of scope of work development; however, analysis of the PS1A and PS1B pump station upgrades/replacement was requested.

Storm Drain Hydraulics: Mainline storm drain hydraulics were analyzed for the drainage systems of PLSD1, PLSD2, PLSD3, PLSD3A, and PLSD4 using WSPG-W.

Hydrologic and hydraulic analyses were conducted in accordance with the scope of work, with the exception that InfoWorks ICM software was used for hydraulic analysis in lieu of WSPG-W for consistency with the previous analysis conducted by Carollo Engineers, Inc. (2018). HDR utilized the best available data from City of San Diego records, as-built drawings, and previous reporting (Geosyntec Consultants, Inc. 2018; Carollo Engineers, Inc. 2018) to complete this analysis. Results of hydrologic and hydraulic analysis will be used to determine the appropriate sizing of each flow detention facility for compliance with the Consent Decree and the IGP.

3.0 Approach

The methodologies used to develop the design rainfall events (design storms) and characterize existing hydrology and hydraulics are described in this section.

3.1 Design Storms

3.1.1 Design Criteria

Development of the design storms was based on the criteria for on-site compliance in the 2018 IGP amendments. Per the 2018 IGP amendments, runoff capture BMPs must be designed to capture the volume of runoff produced during the 85th percentile 24-hour storm with a 24-hour drawdown time or with additional storage volume to offset a longer drawdown time.

To maximize flexibility for design and compliance with the 2018 IGP amendments, consideration of two design conditions was requested by the City of San Diego:

1. Capture and diversion of runoff produced during the 85th percentile, 24-hour storm with a 24-hour drawdown time (Storm 1)

2. Capture and diversion of runoff produced during the 85th percentile, 24-hour storm multiplied by a factor of 1.05 (i.e., 5 percent increase), with a 24-hour drawdown time as contingency (Storm 2)

3.1.2 85th Percentile Rainfall Depth

The 85th percentile, 24-hour storm is the event that has a precipitation total greater than or equal to 85 percent of all daily storm events larger than 0.01 inch over a given period of record in a specific area or location. The 85th percentile, 24-hour rainfall depth of 0.55 inch used in this analysis was obtained from the San Diego County 85th Percentile Isopluvials map (County of San Diego Department of Public Works 2003), which is included in Appendix A. The map was developed by San Diego County using long-term (30 years or greater) daily rainfall records from local gages, from which a gridded surface of 85th percentile, 24-hour rainfall depths was interpolated. A detailed description of the map's development can be found in the San Diego County BMP Design Manual (County of San Diego Department of Public Works 2016) and referenced in the *City of San Diego Storm Water Standards* (City of San Diego 2018).

3.1.3 Hyetographs

Storm 1 and Storm 2 were derived from the 85th percentile rainfall depth to provide the rainfall intensities that were required for Rational Method calculations. Two rainfall distributions were considered in the development of the hyetographs and will herein be referred to as the San Diego Nested and Atlas-14 distributions. A brief description of each distribution is provided below; more detailed descriptions of each distribution can be found in the San Diego Rainfall Distribution Study (County of San Diego, Watershed Protection Program Department of Public Works 2013) and documentation for the Atlas-14 distribution development (Merkel et al. 2015). The hyetographs resulting from each rainfall distribution can be found in Appendix A.

The San Diego Nested distribution is supported by San Diego County and is used in the current Hydrology Manual (County of San Diego Department of Public Works 2003). It is a skewed, nested distribution, with two-thirds of the total rainfall depth falling prior to and including the peak, which occurs around hour 16 of a 24-hour storm. The distribution time interval is 0.5 hour.

The Natural Resources Conservation Service developed rainfall distributions for regions of California using National Oceanic and Atmospheric Administration Atlas-14 data. The distribution developed for California, Region 5, which includes the PLWTP footprint, was used for this analysis. The Atlas-14 distribution is a symmetrical, nested distribution with approximately half of the total rainfall depth falling on either side of the peak, which occurs around hour 12 of a 24-hour storm. The distribution time interval is 0.1 hour.

The resulting hyetographs from both rainfall distributions were used in flow calculations to provide a range of potential flow peaks and distributions inform pump sizing.

3.2 Existing Hydrology

3.2.1 Drainage Areas and Drainage System

Drainage areas and subareas were based on those previously delineated (Carollo Engineers, Inc. 2018) and were modified according to information obtained from available as-builts, 1-foot contours, field observations, and PLWTP operators. As-built records were provided by PLWTP and were used to identify locations of drainage system inlets. The 1-foot contours were derived from LIDAR survey data collected in 2017 by the U.S. Geological Survey and were used to confirm the contributing area for each drainage system inlet. Locations at which drainage direction or existence of an inlet was unclear were investigated during a site visit in May 2020; additional insight was provided by PLWTP operators during and following the site visit.

Drainage system information was obtained from available as-builts. Invert elevations that were not present in the as-builts were obtained from survey data collected in August 2020 by O'Day Consultants using National Geodetic Vertical Datum 1929. Additionally, several control points were surveyed to determine a datum correction elevations obtained from as-builts, where applicable. Several invert elevations for which no as-built or survey data was available were estimated using information from the surrounding drainage system components. Other elements of drainage system information (i.e., conduit shape, dimensions, material) not available in as-builts were assigned values from the previous ICM model developed (Carollo Engineers, Inc. 2018), where applicable, or estimated using information from the surrounding drainage system components. Invert elevations, conduit dimensions, and conduit material were used to represent the drainage system in the updated ICM model.

3.2.2 Peak Discharge

Surface Runoff

The Rational Method was used to develop runoff hydrographs for each drainage area and calculate runoff volume. Due to the nature of the design rainfall event, certain aspects of the Rational Method guidance provided in the Hydrology Manual were modified for this analysis. The general equation for the Rational Method is:

$$Q = CIA \qquad \text{Eq. 1}$$

Where,

Q = Peak flowrate at the point of analysis; cubic feet per second (cfs)
C = Runoff coefficient; unitless average ratio of runoff per unit rainfall
I = Peak rainfall intensity; inch/hour
A = Tributary area; acres

Hydrology Manual guidance for the Rational Method calculates rainfall intensity using an equation based on the 6-hour rainfall depth for a specified storm frequency and a rainfall duration equal to the time of concentration. The 85th percentile rainfall depth required for this analysis is a 24-hour rainfall depth that does not correspond to a specified storm frequency; thus, rainfall intensities were calculated using the design storm hyetographs derived from 85th percentile rainfall depth (Section 3.1.3).

Runoff coefficients were estimated for each drainage subarea according to land use and hydrologic soil group using the runoff coefficients for urban areas table provided in the Hydrology Manual (Appendix B). A hydrologic soil group of D was assumed for all subareas, per the Hydrology Manual guidance for drainage design in urban areas.

Although not used to determine rainfall intensity, times of concentration were estimated for each drainage subarea and were used in development of the hydrographs. Time of concentration is the amount of time required for flow travel to the subarea outlet from the point hydraulically most distant from the outlet and was calculated using the following equation:

$$T_c = T_i + T_t \qquad \text{Eq. 2}$$

Where,

T_c = Time of concentration; minutes
T_i = Initial time of concentration, the travel time of flow prior to becoming concentrated (overland flow); minutes
T_t = Travel time, the time for concentrated flow; minutes

The initial time of concentration was estimated using the overland time of flow equation provided in the Hydrology Manual. Travel time was estimated using Manning's equation. Curb gutter dimensions provided in the Hydrology Manual were used to calculate travel time in curb gutters and concrete swales. Dimensions of concentrated flow across grassed areas and natural hillslopes were based on assumptions in Chapter 15 of the National Engineering Handbook (U.S. Department of Agriculture Natural Resources Conservation Service 2010). A flow depth of 0.2 feet was assumed for all travel time calculations. Time of concentration calculations are included in Appendix B.

Hydrographs

Hydrographs were developed using an ICM model, which incorporated hydraulic routing of surface runoff through the drainage system into its calculations. Peak discharges were extracted from the hydrographs. The ICM model generally followed Rational Method procedures for runoff generation, with the addition of catchment routing governed by the time of concentration. Runoff generated by each subarea was routed through the drainage system using dynamic routing and combined with flow from downstream subareas at junctions.

3.2.3 Design Capture Volume

DCV was calculated according to *City of San Diego Storm Water Standards* criteria for Priority Development Projects with only Pollutant Control Requirements, as the PLWTP is hydromodification exempt. Since the priority of the PLWTP is to capture the 85th percentile storm volume, all the DCV for the drainage areas will be captured for treatment. In order to determine the DCV, HDR used the equation under Section B.1 of the *City of San Diego Storm Water Standards,* which states:

$$DCV = 3{,}630 \times C \times d \times A \qquad \text{Eq. 3}$$

Where,

DCV = Design capture volume; cubic feet
C = Runoff factor; unitless average ratio of runoff per unit rainfall (equivalent of the runoff coefficient from Equation 1)
d = 85th percentile, 24-hour rainfall depth; inches
A = Tributary area; acres

DCV calculations assumed runoff factors equal to the runoff coefficients used to calculate peak discharge.

4.0 Results

4.1 Design Storms

Rainfall depths for Storm 1 and Storm 2 were 0.55 inch and 0.58 inch, respectively. The mapped isopluvials did not extend to the peninsula where PLWTP is located, so the value from the nearest inland isopluvial was selected as a conservative estimate of the 85th percentile, 24-hour rainfall depth. The Atlas-14 distribution produced the peak intensities approximately 2.5 times greater than the San Diego Nested distribution. Total rainfall depths and peak rainfall intensities produced by each hyetograph for both design storms are shown in Table 4-1.

Table 4-1. Design Storms by Hyetograph

Rainfall Distribution	Storm 1		Storm 2	
	Total Depth (inches)	Peak Intensity (inches/hour)	Total Depth (inches)	Peak Intensity (inches/hour)
San Diego Nested	0.55	0.138	0.58	0.144
Atlas-14	0.55	0.346	0.58	0.363

4.2 Existing Hydrology

4.2.1 Drainage Areas

The total project drainage area is approximately 57.5 acres and is comprised of the PLWTP operations area (footprint), as well as adjacent areas that drain into the PLWTP footprint, including the eastern hillslopes thickly vegetated with shrubs, the southern portion of Fort Rosecrans National Cemetery, and U.S. Naval properties south of the cemetery. The project site was divided into eight areas draining to existing monitoring locations or off-site locations (drainage areas). The General Industrial land use category (C=0.87) was assigned to drainage subareas within the PLWTP footprint. The eastern hillslopes were assigned the Permanent Open Space land use category (C=0.35). The Residential, 1.0 Dwelling Units per Acre (DU/A) or Less land use category (C=0.41) was considered appropriate for the contributing areas of the cemetery, which are covered primarily of short grass with limited impervious cover. General Commercial land use (C=0.82) was assigned to the U.S. Naval properties adjacent to the cemetery. Drainage areas (PLSD1A, PLSD1B, PLSD2, PLSD3A, PLSD3, PLSD4, Off-site North, Off-site Pacific) are summarized below.

PLSD1A has a 1.16-acre drainage area comprised of the northern parking lot area and consists of primarily impervious area with scattered vegetation at medians and along embankments (General Industrial: 100 percent).

PLSD1B has 23.9-acre drainage area, consisting primarily of the cemetery (Residential, 1.0 DU/A: 40 percent) and eastern hillslopes (Permanent Open Space: 48 percent) that drain into the PLWTP footprint. The remainder of the drainage area is comprised of U.S. Naval properties (General Commercial: 6 percent), the PLWTP North Operations Building, North Effluent Screening Facility, and Equipment Storage Area (General Industrial: 6 percent).

PLSD2 has a drainage area of 0.92 acre and collects drainage from the PLWTP Warehouse and Paint Booth, Maintenance Building, and Chemical Unloading and Tank Storage area (General Industrial: 100 percent).

PLSD3A has a 1.64-acre drainage area that encompasses the Enclosed Cargo Container Storage Area, San Diego Gas & Electric Substation, Gas Utilization Facility, Central Boiler Facility, and South Effluent Screening Facility (General Industrial: 100 percent).

PLSD3 collects drainage from a 4.72-acre area within the PLWTP footprint. Contributing area includes the western portion of the Primary Sedimentation Tanks and Head Works facilities, as well as part of the Engineering Building (General Industrial,:100 percent).

PLSD4 has a drainage area of 22.2 acres, with roughly half of the area residing within the PLWTP footprint, including the Primary Sedimentations Tanks and Odor Control facilities, Digester Tanks and Gas Capture Facility, Recycling Bin Storage Area, Methane Gas Storage and Transfer facilities, Sludge Pump Station, and Engineering Building (General Industrial: 55 percent). Site 4 also collects drainage the eastern hillslopes (Permanent Open Space: 35 percent) and U.S. Naval Property (General Commercial: 10 percent).

The Off-site Pacific drainage area is 1.66 acre and encompasses the plant area west of the Warehouse and Paint Booth, and Maintenance Building, including the Hydraulic Generator and South Effluent Outfall Control Building (General Industrial: 100 percent).

The Off-site North drainage area is 1.35 acre and includes the Empty Bin and Empty Tanks Storage area and the northern part of the Pilot Equipment Testing/Equipment Storage Area (General Industrial: 100 percent).

A summary of drainage area properties can be found in Table 4-2. Properties for individual drainage subareas can be found in Appendix C (Exhibit 1).

Table 4-2. Drainage Area Summary

Drainage Area	Area (acres)	Area (%)	Land Use Composition	Average Runoff Coefficient	Drainage Collection Point
PLSD1A	1.16	2	General Industrial (100%)	0.87	Sump

Table 4-2. Drainage Area Summary

Drainage Area	Area (acres)	Area (%)	Land Use Composition	Average Runoff Coefficient	Drainage Collection Point
PLSD1B	23.9	42	General Industrial (6%) General Commercial (6%) Residential, 1.0 DU/A (40%) Open Space (48%)	0.44	Sump
PLSD2	0.92	2	General Industrial (100%)	0.87	Sump
PLSD3A	1.64	3	General Industrial (100%)	0.87	Collection basin
PLSD3	4.72	8	General Industrial (100%)	0.87	Sump
PLSD4	22.2	39	General Industrial (55%) General Commercial (10%) Open Space (35%)	0.68	Sump
Off-site North	1.35	2	General Industrial (100%)	0.87	Storm drain north of PLWTP footprint
Off-site Pacific	1.66	3	General Industrial (100%)	0.87	Pacific Ocean
PLWTP total	*57.5*	*100*	*General Industrial (44%)* *General Commercial (6%)* *Residential, 1.0 DU/A (17%)* *Open Space (33%)*	*0.62*	—

Notes:

PLWTP=Point Loma Wastewater Treatment Plant

4.2.2 Peak Discharge

This section focuses on results produced by the San Diego Nested hyetograph, as it is the hyetograph recommended in the Hydrology Manual. The Atlas-14 hyetograph, however, produced peak discharges roughly twice as large as those produced by the San Diego Nested hyetograph and may serve a conservative upper limit to peak discharge estimate for Storm 1 and Storm 2. Peak discharge estimates for both design storms and both hyetographs are summarized in Table 4-3.

Storm 1

Peak discharges for Storm 1 ranged from approximately 0.11 cfs to 2.10 cfs. Drainage areas for PLSD1B and PLSD4 generated the greatest peak discharges of approximately 1.46 cfs and 2.10 cfs, respectively. PLSD3 also produced a relatively high peak discharge of 0.57 cfs. Peak discharges for the remaining drainage areas were equal to or less than 0.20 cfs.

Storm 2

Peak discharges produced by Storm 2 were all approximately 5 percent higher than those produced by Storm 1, which is proportional to the increase in total rainfall depth. Peak discharges for Storm 2 ranged from approximately 0.12 to 2.20 cfs. Peak discharges at PLSD1B and PLSD4 were 1.53 cfs and 2.20 cfs, respectively. PLSD3 generated a peak discharge of approximately 0.60 cfs; the remaining drainage areas each generated peak discharges equal to or less than 0.21 cfs.

Table 4-3. Peak Discharge by Drainage Area

Drainage Area	Area (acres)	Rainfall Distribution	Peak Discharge (cfs)	
			Storm 1	Storm 2
PLSD1A	1.16	San Diego Nested	0.140	0.147
		Atlas-14	**0.333**	**0.349**
PLSD1B	23.88	San Diego Nested	1.457	1.529
		Atlas-14	**3.005**	**3.152**
PLSD2	0.92	San Diego Nested	0.111	0.116
		Atlas-14	**0.264**	**0.277**
PLSD3A	1.64	San Diego Nested	0.198	0.208
		Atlas-14	**0.472**	**0.495**
PLSD3	4.72	San Diego Nested	0.570	0.598
		Atlas-14	**1.147**	**1.203**
PLSD4	22.19	San Diego Nested	2.097	2.200
		Atlas-14	**4.353**	**4.562**
Off-site North	1.35	San Diego Nested	0.162	0.170
		Atlas-14	**0.386**	**0.405**
Off-site Pacific	1.66	San Diego Nested	0.200	0.210
		Atlas-14	**0.477**	**0.500**

Table 4-3. Peak Discharge by Drainage Area

Drainage Area	Area (acres)	Rainfall Distribution	Peak Discharge (cfs)	
			Storm 1	Storm 2

Note: **Bolded** values indicate the greatest total peak discharge produced by the two hyetographs.

cfs=cubic feet per second

4.2.3 Design Capture Volume

Storm 1

DCV for Storm 1 ranged from 1,593 to 30,170 cubic feet. PLSD1B and PLSD4, which had the largest contributing areas, produced roughly 70 percent of the total runoff volume generated at the PLWTP site, with DCV of 20,960 cubic feet and 30,170 cubic feet, respectively. Runoff volume at PLSD3 was the next largest with a value 8,187 cubic feet. The remaining drainage areas each produced DCV of less than 3,000 cubic feet.

Storm 2

DCV produced by Storm 2 were all approximately 5 percent higher than those produced by Storm 1, which is proportional to the increase in total rainfall depth. DCV for Storm 2 ranged from 1,503 to 31,651 cubic feet. As with Storm 1, PLSD1B and PLSD4 produced the majority of the runoff generated at the PLWTP site, with DCV of 21,989 cubic feet and 31,651 cubic feet, respectively. DCV at PLSD3 was 8,600 cubic feet, while DCV for the remaining drainage areas were approximately 3,000 cubic feet or less.

DCV estimates for both design storms are summarized in Table 4-4.

Table 4-4. Design Capture Volume by Drainage Area

Drainage Area	Area (acres)	DCV (cubic feet)	
		Storm 1	Storm 2
PLSD1A	1.16	2,013	2,112
PLSD1B	23.88	20,960	21,989
PLSD2	0.92	1,593	1,671
PLSD3A	1.64	2,847 **3,273**	2,987 **3,433**
PLSD3	4.72	8,197	8,600

Table 4-4. Design Capture Volume by Drainage Area

Drainage Area	Area (acres)	DCV (cubic feet)	
		Storm 1	Storm 2
PLSD4	22.19	30,170	31,651
Off-site North	1.35	2,337	2,451
Off-site Pacific	1.66	2,882	3,024

Note: **Bolded** values indicate runoff volume with no losses (C=1) for PLSD3A.

DCV=design capture volume

5.0 Conclusions and Recommendations

Hydrologic and hydraulic analysis was performed to provide estimates for peak flows and runoff volumes that will inform the design runoff capture facilities at PLWTP. Two rainfall distributions (San Diego Nested and Atlas-14) were used to provide a range of values. The San Diego Nested rainfall distribution is recommended by the Hydrology Manual and has been used to support storm water management plans across San Diego County; thus, results produced by this approach will be used by HDR in development of design for PLWTP. However, the Atlas-14 rainfall distribution produced substantially larger peak discharges than San Diego Nested rainfall distribution, and resulting flows may serve as a conservative upper limit for peak discharges that may be taken into consideration for pump sizing, particularly at PLSD4, where estimated peak discharges were high and storage is limited to a wet well.

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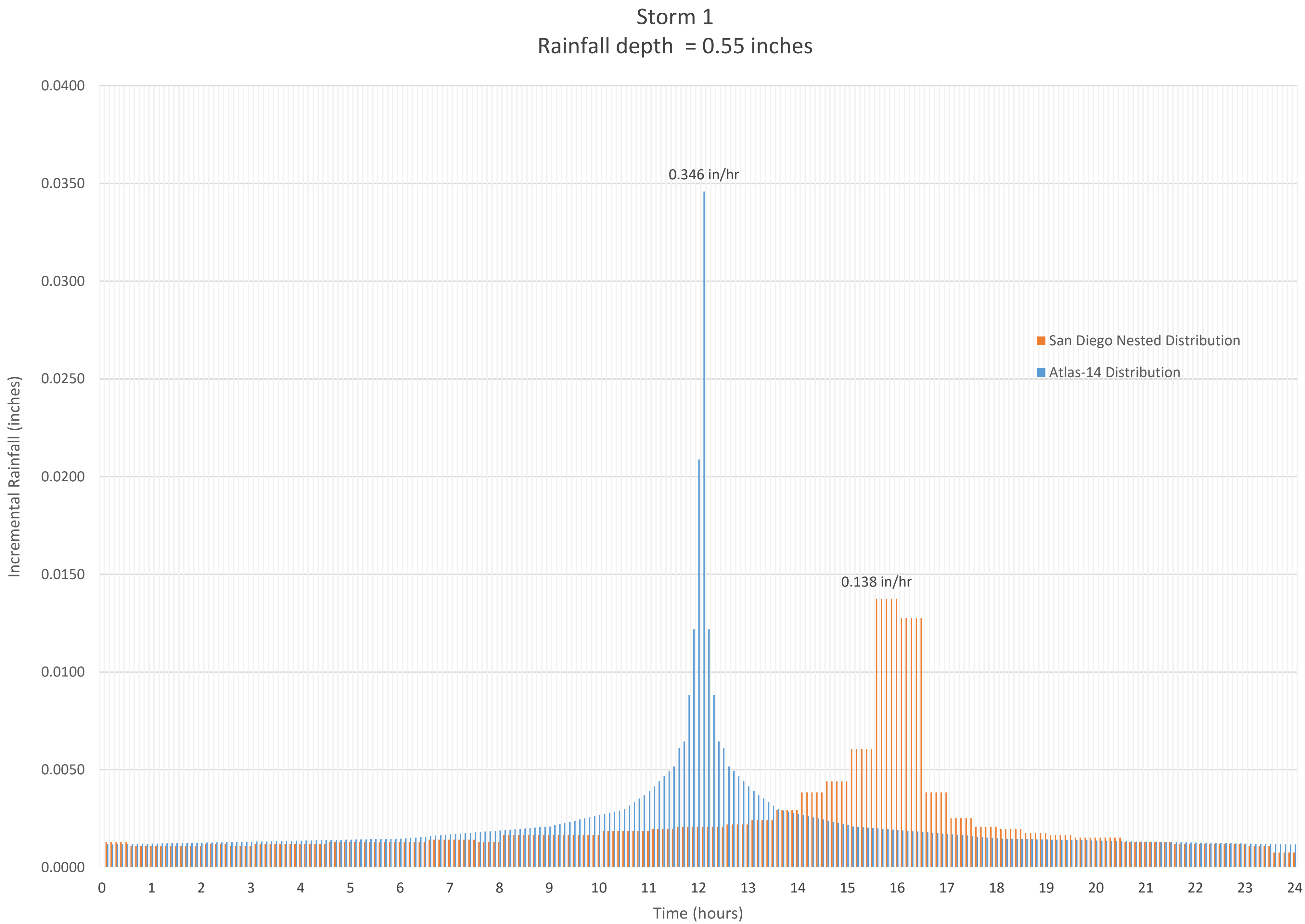
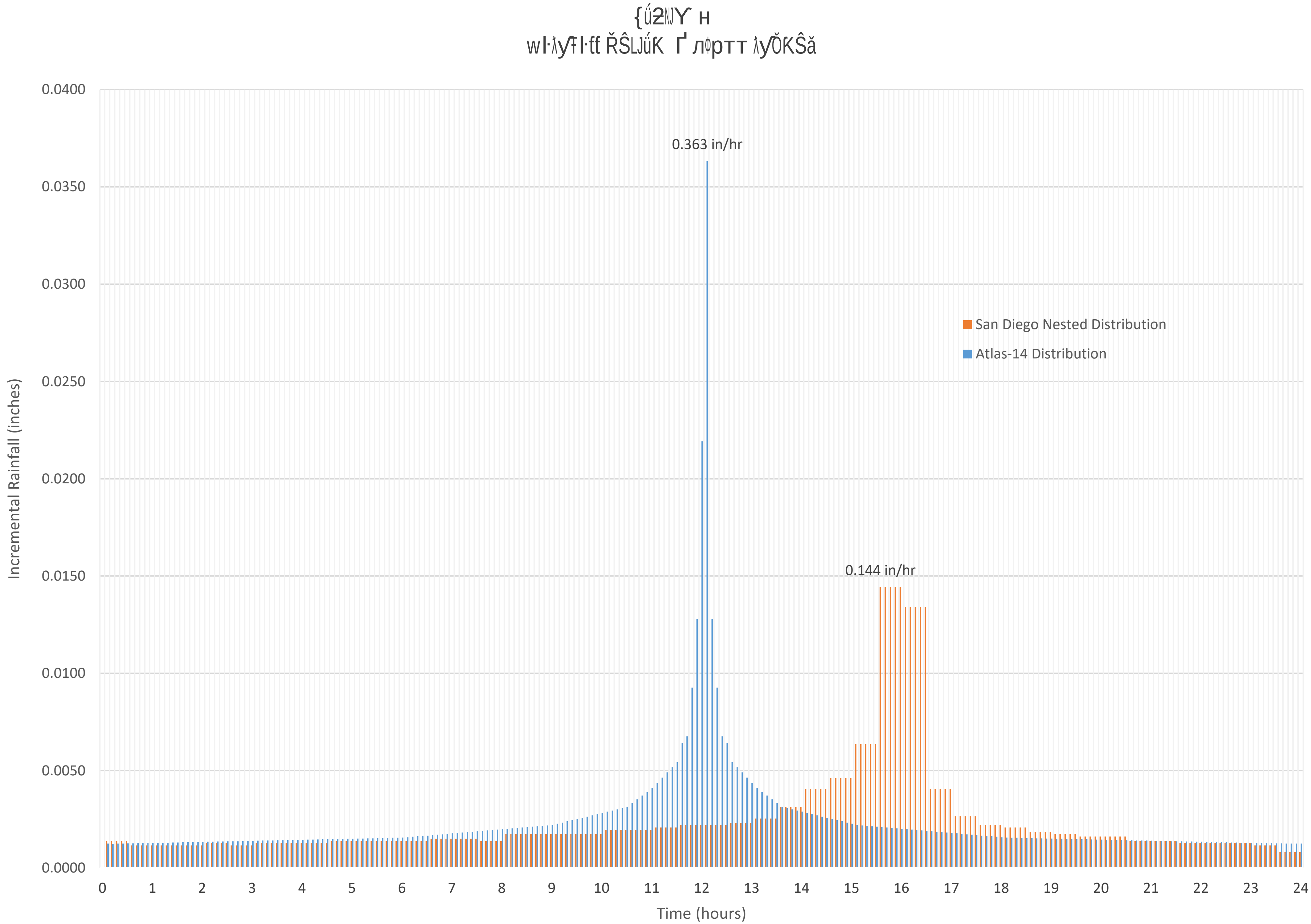
Appendix A: Hyetographs


San Diego County
85th Percentile Isopluvials
85th Percentile Rainfall in Inches
Freeway
Highway
Major Road
Street
Municipal Boundary
Water Body
Note:
The 85th percentile is a 24-hour rainfall total.
It represents a value such that 85% of the
observed 24-hour rainfall totals will be less
than that value.
LUEG GIS
Land Use & Environment Group
Geographic Information Service
SanGIS
0 1 2 3 4 Miles
SAN DIEGO BAY
MISSION BAY



Storm 1
Rainfall depth = 0.55 inches
0.0400
0.0350
0.0300
0.0250
0.0200
0.0150
0.0100
0.0050
0.0000
Incremental Rainfall (inches)
0.346 in/hr
0.138 in/hr
San Diego Nested Distribution
Atlas-14 Distribution
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
Time (hours)



0.363 in/hr
0.144 in/hr
San Diego Nested Distribution
Atlas-14 Distribution
Incremental Rainfall (inches)
0.0400
0.0350
0.0300
0.0250
0.0200
0.0150
0.0100
0.0050
0.0000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Time (hours)

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Appendix B:
Rational Method Parameters

Table 3-1
RUNOFF COEFFICIENTS FOR URBAN AREAS

Land Use		Runoff Coefficient "C"				
			Soil Type			
NRCS Elements	County Elements	% IMPER.	A	B	C	D
Undisturbed Natural Terrain (Natural)	Permanent Open Space	0*	0.20	0.25	0.30	0.35
Low Density Residential (LDR)	Residential, 1.0 DU/A or less	10	0.27	0.32	0.36	0.41
Low Density Residential (LDR)	Residential, 2.0 DU/A or less	20	0.34	0.38	0.42	0.46
Low Density Residential (LDR)	Residential, 2.9 DU/A or less	25	0.38	0.41	0.45	0.49
Medium Density Residential (MDR)	Residential, 4.3 DU/A or less	30	0.41	0.45	0.48	0.52
Medium Density Residential (MDR)	Residential, 7.3 DU/A or less	40	0.48	0.51	0.54	0.57
Medium Density Residential (MDR)	Residential, 10.9 DU/A or less	45	0.52	0.54	0.57	0.60
Medium Density Residential (MDR)	Residential, 14.5 DU/A or less	50	0.55	0.58	0.60	0.63
High Density Residential (HDR)	Residential, 24.0 DU/A or less	65	0.66	0.67	0.69	0.71
High Density Residential (HDR)	Residential, 43.0 DU/A or less	80	0.76	0.77	0.78	0.79
Commercial/Industrial (N. Com)	Neighborhood Commercial	80	0.76	0.77	0.78	0.79
Commercial/Industrial (G. Com)	General Commercial	85	0.80	0.80	0.81	0.82
Commercial/Industrial (O.P. Com)	Office Professional/Commercial	90	0.83	0.84	0.84	0.85
Commercial/Industrial (Limited I.)	Limited Industrial	90	0.83	0.84	0.84	0.85
Commercial/Industrial (General I.)	General Industrial	95	0.87	0.87	0.87	0.87

*The values associated with 0% impervious may be used for direct calculation of the runoff coefficient as described in Section 3.1.2 (representing the pervious runoff coefficient, Cp, for the soil type), or for areas that will remain undisturbed in perpetuity. Justification must be given that the area will remain natural forever (e.g., the area is located in Cleveland National Forest).

DU/A = dwelling units per acre

NRCS = National Resources Conservation Service

Eastern Hillslopes = Permanent Open Space
Cemetery = Residential, 1.0 DU/A or less
U.S. Naval Properties = General Commercial
PLWTP footprint = General Industrial
* Soil Type D assumed for all

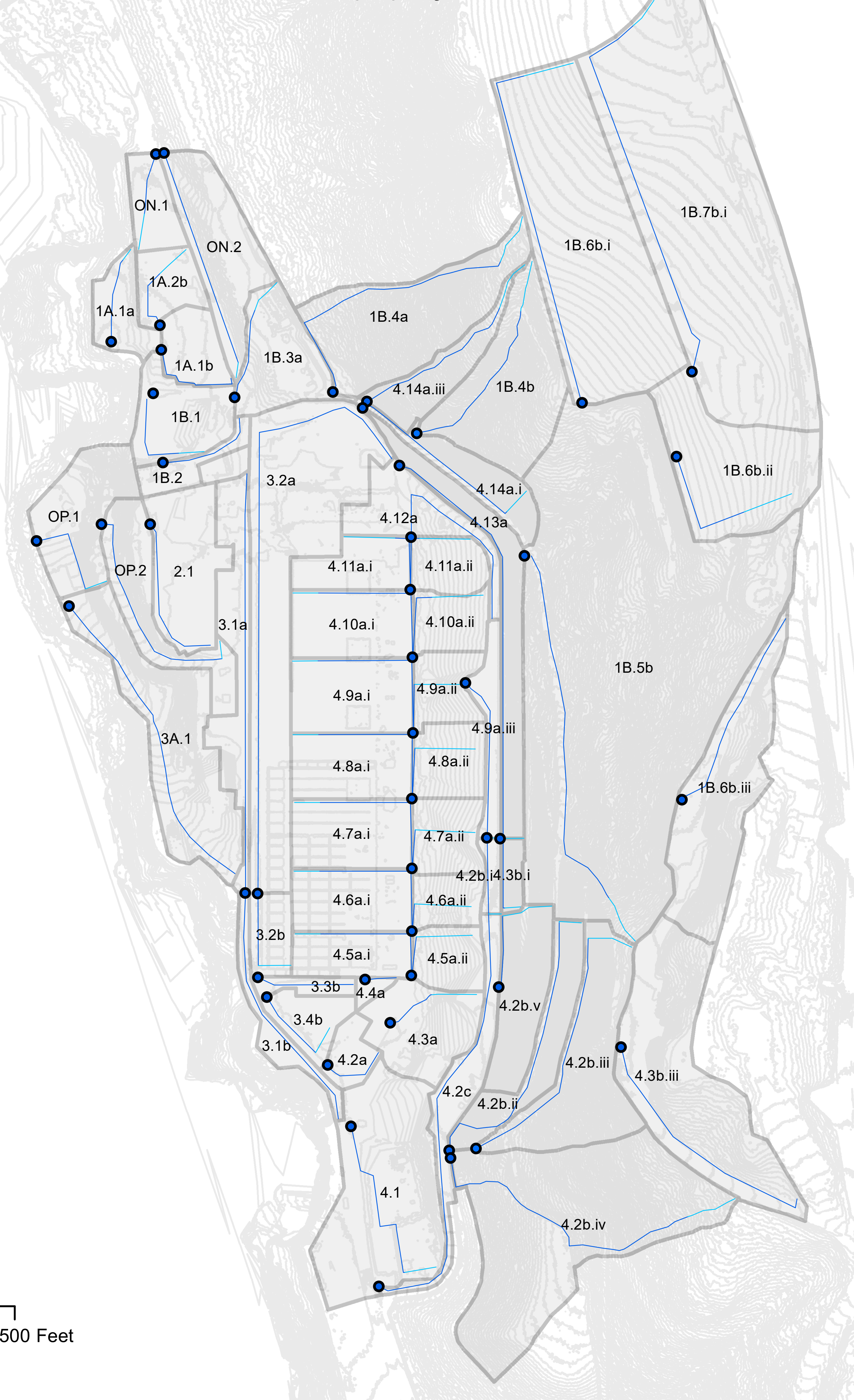
Time of Concentration Calculations

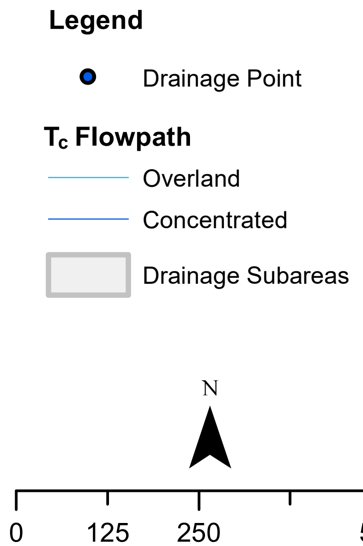
Subarea	Initial T_c T_i	Travel Time T_t	$T_i + T_t$	Time of Conc. (5 minutes minimum) T_c
1A.1a	0.7	0.8	1.6	5
1A.1b	0.0	1.0	1.0	5
1A.2b	3.9	0.7	4.6	5
1B.1	1.1	1.1	2.2	5
1B.2	0.0	0.7	0.7	5
1B.3a	1.8	0.3	2.1	5
1B.4a	4.8	1.2	6.0	6
1B.4b	4.5	0.5	5.0	5
1B.5b	4.1	1.8	5.9	6
1B.6b.i	5.2	2.9	8.1	8
1B.6b.ii	5.1	1.5	6.5	7
1B.6b.iii	0.0	1.6	1.6	5
1B.7b.i	7.3	4.1	11.4	11
2.1	0.0	2.6	2.6	5
3A.1	0.0	1.7	1.7	5
3.1a	0.0	6.7	6.7	7
3.1b	0.0	6.5	6.5	6
3.2a	0.0	10.3	10.3	10
3.2b	7.1	3.6	10.7	11
3.3b	0.0	1.2	1.2	5
3.4b	2.5	1.4	3.9	5
4.1	1.6	2.4	4.0	5
4.10a.i	6.3	3.9	10.2	10
4.10a.ii	1.5	0.6	2.1	5
4.11a.i	5.2	1.2	6.4	6
4.11a.ii	1.5	0.7	2.2	5
4.12a	0.0	1.2	1.2	5
4.13a	2.2	3.8	6.0	6
4.14a.i	2.6	0.7	3.3	5
4.14a.iii	4.9	0.4	5.3	5
4.2a	0.0	1.2	1.2	5
4.2b.i	1.3	3.8	5.1	5
4.2b.ii	2.4	1.1	3.4	5
4.2b.iii	3.4	0.9	4.3	5
4.2b.iv	4.5	1.3	5.7	6
4.2b.v	3.5	1.4	4.8	5
4.2c	1.3	3.7	5.0	5
4.3a	1.2	0.2	1.5	5
4.3b.i	1.9	3.5	5.5	5
4.3b.iii	0.0	2.2	2.2	5
4.4a	0.0	0.3	0.3	5
4.5a.i	6.3	3.1	9.5	9
4.5a.ii	1.5	0.5	2.0	5
4.6a.i	6.3	6.5	12.8	13
4.6a.ii	1.5	1.4	2.9	5
4.7a.i	6.3	6.7	13.0	13
4.7a.ii	1.5	1.9	3.5	5
4.8a.i	6.3	4.0	10.3	10
4.8a.ii	1.6	2.6	4.2	5
4.9a.i	6.3	4.2	10.6	11
4.9a.ii	1.4	2.5	3.8	5

4.9a.iii	4.5	2.7	7.2	7
ON.1	2.1	2.2	4.4	5
ON.2	0.6	3.3	3.9	5
OP.1	0.7	0.5	1.2	5
OP.2	1.3	1.1	2.4	5

Time of Concentration (T_c) by Subarea

Subarea	T_c (minutes)
1A.1a	5
1A.1b	5
1A.2b	5
1B.1	5
1B.2	5
1B.3a	5
1B.4a	6
1B.4b	5
1B.5b	6
1B.6b.i	8
1B.6b.ii	7
1B.6b.iii	5
1B.7b.i	11
2.1	5
3A.1	5
3.1a	7
3.1b	6
3.2a	10
3.2b	11
3.3b	5
3.4b	5
4.1	5
4.2a	5
4.2b.i	5
4.2b.ii	5
4.2b.iii	5
4.2b.iv	6
4.2b.v	5
4.2c	5
4.3a	5
4.3b.i	5
4.3b.iii	5
4.4a	5
4.5a.i	9
4.5a.ii	5
4.6a.i	13
4.6a.ii	5
4.7a.i	13
4.7a.ii	5
4.8a.i	10
4.8a.ii	5
4.9a.i	11
4.9a.ii	5
4.9a.iii	7
4.10a.i	10
4.10a.ii	5
4.11a.i	6
4.11a.ii	5
4.12a	5
4.13a	6
4.14a.i	5
4.14a.iii	5
ON.1	5
ON.2	5
OP.1	5
OP.2	5



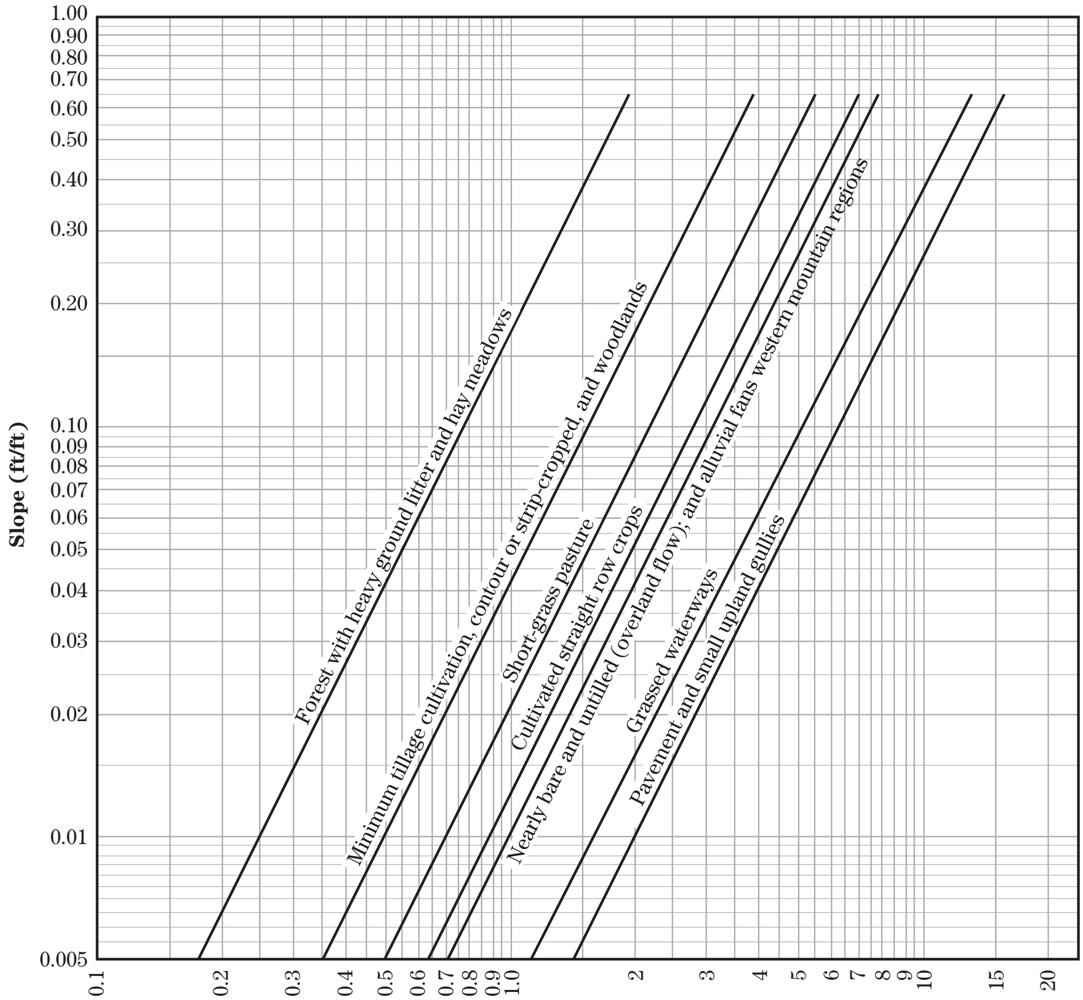


Travel Time Calculations

Subarea	Flowpath Material	Source of assumptions made for channel dimensions	$V = (1.49/n)R^{(2/3)}S^{(1/2)}$				$T_t = (V)(L)$	
			Manning's roughness (n)	Hydraulic Radius (R) [ft.]	Channel Slope (S) [ft./ft.]	Velocity (V) [fps]	Length (L) [ft.]	Travel Time (T_t) [min.]
1A.1a	gutter	Curb,Type G (24")	0.015	0.09	0.025	3.21	162	0.8
1A.1b	gutter	Curb,Type G (24")	0.015	0.09	0.026	3.27	196	1.0
1A.2b	gutter	Curb,Type G (24")	0.015	0.09	0.020	2.89	100	0.6
1A.2b	asphalt	Concentrated Flow, paved (revised with n = 0.0175)	0.0175	0.20	0.017	3.77	30	0.1
1B.1	concrete	Concentrated Flow, paved (revised with n = 0.015)	0.015	0.20	0.006	2.61	169	1.1
1B.2	gutter	Curb,Type G (24")	0.015	0.09	0.046	4.40	195	0.7
1B.3a	asphalt	Concentrated Flow, paved (revised with n = 0.0175)	0.0175	0.20	0.090	8.72	178	0.3
1B.4a	natural hillslope	Concentrated Flow, natural slope	0.025	0.20	0.431	13.35	442	0.6
1B.4a	swale	Curb,Type G (24")	0.015	0.09	0.038	4.00	157	0.7
1B.4b	natural hillslope	Concentrated Flow, natural slope	0.025	0.20	0.396	12.79	359	0.5
1B.5b	natural hillslope	Concentrated Flow, natural slope	0.025	0.20	0.592	15.65	143	0.2
1B.5b	swale	Curb,Type G (24")	0.015	0.09	0.090	6.13	592	1.6
1B.6b.i	grass	Concentrated Flow, grass	0.073	0.20	0.136	2.57	59	0.4
1B.6b.i	swale	Curb,Type G (24")	0.015	0.09	0.044	4.28	639	2.5
1B.6b.ii	grass	Concentrated Flow, grass	0.073	0.20	0.124	2.45	89	0.6
1B.6b.ii	swale	Curb,Type G (24")	0.015	0.09	0.020	2.92	148	0.8
1B.6b.iii	gutter	Curb,Type G (24")	0.015	0.09	0.041	4.16	411	1.6
1B.7b.i	grass	Concentrated Flow, grass	0.073	0.20	0.035	1.31	113	1.4
1B.7b.i	gutter	Curb,Type G (24")	0.015	0.09	0.039	4.02	650	2.7
2.1	gutter	Curb,Type G (24")	0.015	0.09	0.010	2.01	311	2.6
3A.1	gutter	Curb,Type G (24")	0.015	0.09	0.095	6.30	636	1.7
3.1a	gutter	Curb,Type G (24")	0.015	0.09	0.010	2.02	818	6.7
3.1b	gutter	Curb,Type G (24")	0.015	0.09	0.004	1.29	501	6.5
3.2a	gutter	Curb,Type G (24")	0.015	0.09	0.009	1.95	1211	10.3
3.2b	gutter	Curb,Type G (24")	0.015	0.09	0.001	0.65	139	3.6
3.3b	gutter	Curb,Type G (24")	0.015	0.09	0.016	2.60	185	1.2
3.4b	gutter	Curb,Type G (24")	0.015	0.09	0.007	1.71	144	1.4
4.1	gutter	Curb,Type G (24")	0.015	0.09	0.203	9.22	25	0.0
4.1	gutter	Curb,Type G (24")	0.015	0.09	0.011	2.18	88	0.7
4.1	gutter	Curb,Type G (24")	0.015	0.09	0.015	2.52	132	0.9
4.1	swale	Curb,Type G (24")	0.015	0.09	0.010	2.07	98	0.8
4.10a.i	gutter	Curb,Type G (24")	0.015	0.09	0.005	1.49	188	2.1
4.10a.i	sedimentation tank	Concentrated Flow, paved (revised with n = 0.015)	0.015	0.20	0.001	1.07	116	1.8
4.10a.ii	gutter	Curb,Type G (24")	0.015	0.09	0.034	3.78	146	0.6
4.11a.i	gutter	Curb,Type G (24")	0.015	0.09	0.008	1.82	126	1.2

4.11a.ii	gutter	Curb,Type G (24")	0.015	0.09	0.017	2.69	116	0.7
4.12a	gutter	Curb,Type G (24")	0.015	0.09	0.076	5.64	410	1.2
4.13a	swale	Curb,Type G (24")	0.015	0.09	0.032	3.64	822	3.8
4.14a.i	swale	Curb,Type G (24")	0.015	0.09	0.181	8.70	371	0.7
4.14a.iii	natural hillslope	Concentrated Flow, natural slope	0.025	0.20	0.507	14.47	370	0.4
4.2a	gutter	Curb,Type G (24")	0.015	0.09	0.008	1.79	131	1.2
4.2b.i	gutter	Curb,Type G (24")	0.015	0.09	0.001	0.65	147	3.8
4.2b.ii	swale	Curb,Type G (24")	0.015	0.09	0.189	8.90	570	1.1
4.2b.iii	swale	Curb,Type G (24")	0.015	0.09	0.231	9.83	515	0.9
4.2b.iv	swale	Curb,Type G (24")	0.015	0.09	0.014	2.42	72	0.5
4.2b.iv	natural hillslope	Concentrated Flow, natural slope	0.025	0.20	0.425	13.25	271	0.3
4.2b.iv	swale	Curb,Type G (24")	0.015	0.09	0.323	11.63	293	0.4
4.2b.v	swale	Curb,Type G (24")	0.015	0.09	0.007	1.73	140	1.4
4.2c	gutter	Curb,Type G (24")	0.015	0.09	0.037	3.94	864	3.7
4.3a	concrete	Concentrated Flow, paved (revised with n = 0.015)	0.015	0.20	0.050	7.55	101	0.2
4.3b.i	swale	Curb,Type G (24")	0.015	0.09	0.001	0.65	138	3.5
4.3b.iii	gutter	Curb,Type G (24")	0.015	0.09	0.034	3.78	498	2.2
4.4a	asphalt	Concentrated Flow, paved (revised with n = 0.0175)	0.0175	0.20	0.017	3.74	60	0.3
4.5a.i	gutter	Curb,Type G (24")	0.015	0.09	0.007	1.67	151	1.5
4.5a.i	sedimentation tank	Concentrated Flow, paved (revised with n = 0.015)	0.015	0.20	0.001	1.07	105	1.6
4.5a.ii	gutter	Curb,Type G (24")	0.015	0.09	0.013	2.34	76	0.5
4.6a.i	gutter	Curb,Type G (24")	0.015	0.09	0.001	0.65	182	4.7
4.6a.i	sedimentation tank	Concentrated Flow, paved (revised with n = 0.015)	0.015	0.20	0.001	1.07	113	1.8
4.6a.ii	gutter	Curb,Type G (24")	0.015	0.09	0.001	0.65	54	1.4
4.7a.i	gutter	Curb,Type G (24")	0.015	0.09	0.001	0.65	190	4.9
4.7a.i	sedimentation tank	Concentrated Flow, paved (revised with n = 0.015)	0.015	0.20	0.001	1.07	115	1.8
4.7a.ii	gutter	Curb,Type G (24")	0.015	0.09	0.001	0.65	76	1.9
4.8a.i	gutter	Curb,Type G (24")	0.015	0.09	0.005	1.47	193	2.2
4.8a.i	sedimentation tank	Concentrated Flow, paved (revised with n = 0.015)	0.015	0.20	0.001	1.07	116	1.8
4.8a.ii	gutter	Curb,Type G (24")	0.015	0.09	0.001	0.65	99	2.6
4.9a.i	gutter	Curb,Type G (24")	0.015	0.09	0.005	1.42	209	2.5
4.9a.i	sedimentation tank	Concentrated Flow, paved (revised with n = 0.015)	0.015	0.20	0.001	1.07	115	1.8
4.9a.ii	gutter	Curb,Type G (24")	0.015	0.09	0.001	0.65	95	2.5
4.9a.iii	gutter	Curb,Type G (24")	0.015	0.09	0.009	1.98	320	2.7
ON.1	gravel	Concentrated Flow, grass	0.025	0.20	0.017	0.90	120	2.2
ON.2	gutter	Curb,Type G (24")	0.015	0.09	0.012	2.20	433	3.3
OP.1	gutter	Curb,Type G (24")	0.015	0.09	0.046	4.39	65	0.2
OP.1	asphalt	Concentrated Flow, paved (revised with n = 0.0175)	0.0175	0.20	0.098	9.09	113	0.2
OP.2	gutter	Curb,Type G (24")	0.015	0.09	0.110	6.80	429	1.1

Figure 15–4 Velocity versus slope for shallow concentrated flow



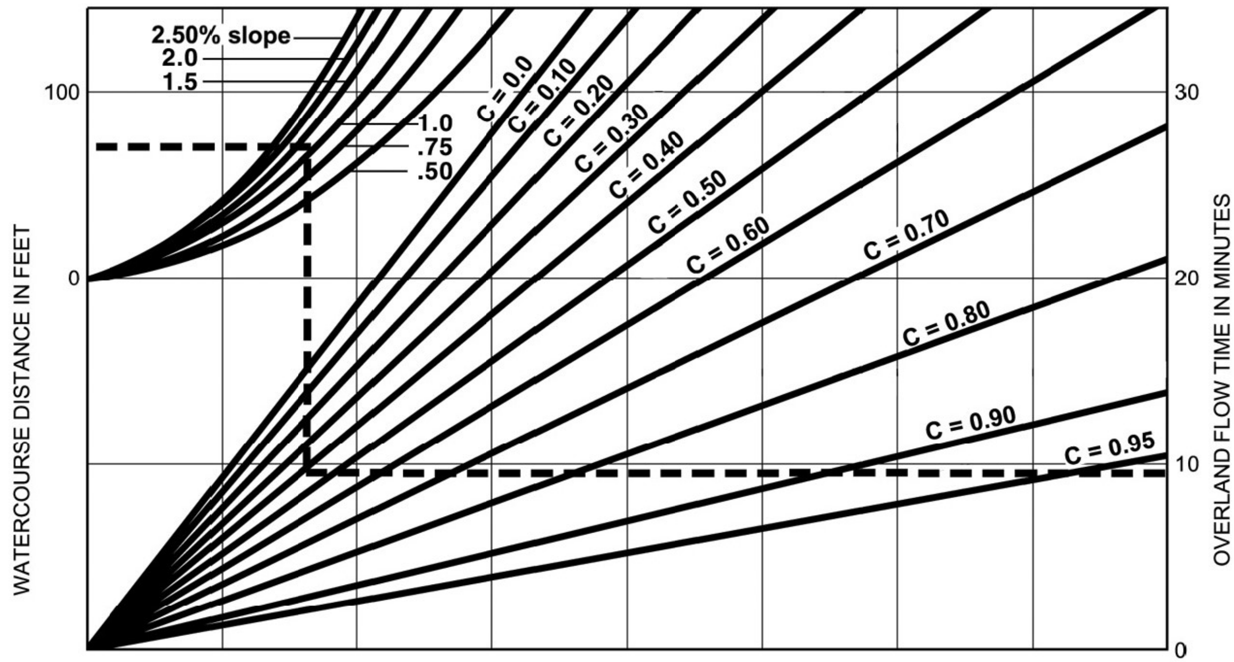
-*Pavement and small upland gullies* equation used for concentrated flow on eastern hillslopes
-*Short-grass pasture* equation used for concentrated flow on cemetery lawn
-*Pavement and small upland gullies* equation with revised Manning's n used for concentrated flow on:
Concrete pavement, n = 0.015: $V = 33.88(s)^{0.5}$
Asphalt pavement, n = 0.0175: $V = 29.04(s)^{0.5}$

Table 15–3 Equations and assumptions developed from figure 15–4

Flow type	Depth (ft)	Manning's *n*	Velocity equation (ft/s)
Pavement and small upland gullies	0.2	0.025	$V = 20.328(s)^{0.5}$
Grassed waterways	0.4	0.050	$V = 16.135(s)^{0.5}$
Nearly bare and untilled (overland flow); and alluvial fans in western mountain regions	0.2	0.051	$V = 9.965(s)^{0.5}$
Cultivated straight row crops	0.2	0.058	$V = 8.762(s)^{0.5}$
Short-grass pasture	0.2	0.073	$V = 6.962(s)^{0.5}$
Minimum tillage cultivation, contour or strip-cropped, and woodlands	0.2	0.101	$V = 5.032(s)^{0.5}$
Forest with heavy ground litter and hay meadows	0.2	0.202	$V = 2.516(s)^{0.5}$

Initial Time of Concentration Calculations

Subarea	Land Use	$T_i = [1.8\ (1.1\text{-}C) D^{1/2}]/s^{(1/3)}$			
		Runoff Coeff. (Soil Type = D) (C) [--]	Overland Flow Length (D) [ft.]	Overland Slope (s) [%]	Initial T_c (T_i) [min.]
1A.1a	General Industrial	0.87	27	27	0.7
1A.2b	General Industrial	0.87	70	0.7	3.9
1B.1	General Industrial	0.87	51	18	1.1
1B.3a	General Industrial	0.87	70	7.1	1.8
1B.4a	Permanent Open Space	0.35	103	23	4.8
1B.4b	Permanent Open Space	0.35	104	29	4.5
1B.5b	Permanent Open Space	0.35	107	39	4.1
1B.6b.i	Residential, 1 DU/A or less	0.41	101	14	5.2
1B.6b.ii	Residential, 1 DU/A or less	0.41	101	15	5.1
1B.7b.i	Residential, 1 DU/A or less	0.41	100	5.0	7.3
3.2b	General Industrial	0.87	64	0.1	7.1
3.4b	General Industrial	0.87	55	1.8	2.5
4.1	General Industrial	0.87	63	8.0	1.6
4.10a.i	General Industrial	0.87	50	0.1	6.3
4.10a.ii	General Industrial	0.87	103	23	1.5
4.11a.i	General Industrial	0.87	100	0.5	5.2
4.11a.ii	General Industrial	0.87	102	21	1.5
4.13a	Permanent Open Space	0.35	58	104	2.2
4.14a.i	Permanent Open Space	0.35	77	98	2.6
4.14a.iii	Permanent Open Space	0.35	102	22	4.9
4.2b.i	General Industrial	0.87	25	4.0	1.3
4.2b.ii	Permanent Open Space	0.35	57	81	2.4
4.2b.iii	Permanent Open Space	0.35	108	68	3.4
4.2b.iv	Permanent Open Space	0.35	104	29	4.5
4.2b.v	Permanent Open Space	0.35	134	89	3.5
4.2c	General Industrial	0.87	25	4.0	1.3
4.3a	General Industrial	0.87	91	32	1.2
4.3b.i	Permanent Open Space	0.35	48	114	1.9
4.5a.i	General Commercial	0.87	50	0.1	6.3
4.5a.ii	General Industrial	0.87	113	27	1.5
4.6a.i	General Industrial	0.87	50	0.1	6.3
4.6a.ii	General Industrial	0.87	114	24	1.5
4.7a.i	General Industrial	0.87	50	0.1	6.3
4.7a.ii	General Industrial	0.87	120	27	1.5
4.8a.i	General Industrial	0.87	50	0.1	6.3
4.8a.ii	General Industrial	0.87	120	21	1.6
4.9a.i	General Industrial	0.87	50	0.1	6.3
4.9a.ii	General Industrial	0.87	98	26	1.4
4.9a.iii	General Industrial	0.87	25	0.1	4.5
ON.1	General Industrial	0.87	70	4.3	2.1
ON.2	General Industrial	0.87	35	64	0.6
OP.1	General Industrial	0.87	58	83	0.7
OP.2	General Industrial	0.87	34	5.9	1.3



EXAMPLE:

Given: Watercourse Distance (D) = 70 Feet
Slope (s) = 1.3%
Runoff Coefficient (C) = 0.41
Overland Flow Time (**T**) = 9.5 Minutes

$$T = \frac{1.8\,(1.1-C)\sqrt{D}}{\sqrt[3]{s}}$$

SOURCE: Airport Drainage, Federal Aviation Administration, 1965

Rational Formula - Overland Time of Flow Nomograph

FIGURE

3-3

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Appendix C:
Exhibits

LEGEND

- ▲ Drainage Collection Sites
- • Drainage Inlet
- Drainge Area
- Drainage Subarea
- Offsite - North
- Offsite - Pacific
- Site 1A
- Site 1B
- Site 2
- Site 3A
- Site 3
- Site 4
- Contours (2 ft)

0 Feet 200

Drainage Subarea	Area (ac)	DCV (ft³)		Peak (cfs)	
		Storm 1	Storm 2	Storm 1	Storm 2
1A.1a	0.39	684	717	0.048	0.050
1A.1b	0.39	675	704	0.047	0.049
1A.2b	0.38	655	682	0.045	0.047
1B.1	0.67	1,170	1,219	0.081	0.085
1B.2	0.24	421	439	0.029	0.030
1B.3a	0.75	1,302	1,357	0.090	0.094
1B.4a	1.56	1,088	1,134	0.075	0.079
1B.4b	1.38	965	1,006	0.067	0.070
1B.5b	8.29	5,795	6,040	0.399	0.419
1B.6b.i	3.09	2,532	2,639	0.175	0.183
1B.6b.ii	1.48	1,208	1,259	0.083	0.087
1B.6b.iii	1.50	2,462	2,566	0.170	0.178
1B.7b.i	4.91	4,016	4,186	0.277	0.290
2.1	0.92	1,593	1,660	0.110	0.115
3A.1	1.64	2,847	2,967	0.196	0.206
3.1a	0.86	1,488	1,550	0.103	0.108
3.1b	0.32	557	580	0.038	0.040
3.2a	2.72	4,732	4,931	0.326	0.342
3.2b	0.31	534	556	0.037	0.039
3.3b	0.16	273	285	0.019	0.020
3.4b	0.35	615	641	0.042	0.044
4.1	1.97	3,420	3,565	0.236	0.247
4.10a.i	0.73	1,261	1,314	0.087	0.091
4.10a.ii	0.39	671	699	0.046	0.049
4.11a.i	0.48	827	862	0.057	0.060
4.11a.ii	0.36	633	660	0.044	0.046
4.12a	0.65	1,130	1,178	0.078	0.082
4.13a	0.88	616	642	0.042	0.045
4.14a.i	0.50	348	363	0.024	0.025
4.14a.iii	0.52	360	376	0.025	0.026
4.2a	0.24	167	174	0.011	0.012
4.2b.i	0.12	212	221	0.015	0.015
4.2b.ii	0.71	1,226	1,278	0.084	0.089
4.2b.iii	1.35	941	980	0.065	0.068
4.2b.iv	3.03	2,121	2,210	0.146	0.153
4.2b.v	0.74	518	540	0.036	0.037
4.2c	0.66	463	483	0.032	0.034
4.3a	0.78	1,362	1,419	0.094	0.099
4.3b.i	0.14	245	256	0.017	0.018
4.3b.iii	2.11	1,472	1,535	0.101	0.106
4.4a	0.07	46	48	0.003	0.003
4.5a.i	0.48	836	871	0.058	0.060
4.5a.ii	0.39	669	697	0.046	0.048
4.6a.i	0.66	1,147	1,195	0.079	0.083
4.6a.ii	0.32	563	587	0.039	0.041
4.7a.i	0.73	1,267	1,321	0.087	0.092
4.7a.ii	0.46	796	830	0.055	0.058
4.8a.i	0.70	1,208	1,259	0.083	0.087
4.8a.ii	0.47	822	857	0.057	0.059
4.9a.i	0.80	1,395	1,454	0.096	0.101
4.9a.ii	0.40	696	726	0.048	0.050
4.9a.iii	0.36	626	652	0.043	0.045
OCH.1	0.11	187	195	0.013	0.014
ON.1	0.36	627	654	0.043	0.045
ON.2	0.98	806	840	0.056	0.058
OP.1	0.88	1,520	1,585	0.105	0.110
OP.2	0.78	1,362	1,420	0.094	0.099

HYDROLOGY
EXISTING CONDITIONS
EXIHIBIT 1

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