Appendix M: Pavement Drainage Report & BMP Assessment

THIS PAGE INTENTIONALLY LEFT BLANK.

PAVEMENT DRAINAGE REPORT and PERMANENT BMP ASSESSMENT

KEA‘AU PĀHOA ROAD IMPROVEMENTS PROJECT
Kea‘au Bypass to Pāhoa-Kapoho Road
Project No. STP-0130(27)
Puna District, Island Of Hawai‘i

Submitted to:

State of Hawai‘i
Department of Transportation, Highways Division
Honolulu, Hawai‘i

Submitted By

SSFM INTERNATIONAL, INC.
Project Managers, Planners, & Engineers

501 Sumner Street, Suite 620
Honolulu, Hawai‘i 96817
Phone: (808) 531-1308
Fax: (808) 521-7348
Email: contact_us@ssfm.com

APRIL 2010

Statement of SSFM International, Inc.'s Quality Process

It is the policy of SSFM to have a consistent and systematic approach to the development and review of its reports and other project deliverables.

All projects and products of our service are subject to a quality process and in no case will the quality review be eliminated. The main purpose of this process is to assure:

- ❖ Clarity, completeness, coordination, and accuracy of documents.
- ❖ That the project, study or investigation meets the Client's objectives.
- ❖ That the requirements of our Agreement with the Client have been met, and the Client has received the value of the fee to be paid.

The Preparation of This Report Was The Responsibility of and Completed By:

Robin Barnes	April 29, 2010 Date

The Quality Review of This Report Was The Responsibility of and Completed By:

Signature	May 5, 2010 Date

Contents

I. INTRODUCTION

PROJECT DESCRIPTION AND REPORT PURPOSE

The Kea‘au-Pāhoa Road (State Route 130) is located in the Puna district on the Island of Hawai‘i. The existing highway within the project site is two lanes in width. A vicinity map is shown in Figure 1. This pavement drainage report has been prepared in support of the environmental assessment for several improvement options currently under consideration for the highway. The alternatives are:

- Alternative 1, a “No-build” alternative, which only includes currently programmed actions.
- Alternative 2, a Transportation Systems Management (TSM) alternative, which would make lower-cost improvements along the corridor, including turning lanes, traffic control improvements, such as traffic signals or modern roundabouts, access management, and transit improvements but not entail major construction.
- Alternative 3, which could incorporate some or all of the TSM improvements above, plus widen Kea‘au-Pāhoa Road to four lanes between Kea‘au Bypass and Ainaloa Boulevard, and retain the two lane cross section between Ainaloa Boulevard and Pahoa-Kapoho Road. This alternative includes bike lanes, bus pull-outs, improved shoulders, and median treatments.
- Alternative 4, which could incorporate some or all of the TSM improvements above, plus widen Kea‘au-Pāhoa Road to four lanes between Kea‘au Bypass and Pahoa-Kapoho Road. This alternative includes bike lanes, bus pull-outs, improved shoulders, and median treatments.
- Alternative 5, which could incorporate some or all of the TSM improvements above, plus widen Kea‘au-Pāhoa Road to six lanes between Kea‘au Bypass and Paradise Drive, four lanes between Paradise Drive and Kahakai Boulevard, and retain the two lane cross section between Kahakai Boulevard and Pahoa-Kapoho Road. This alternative includes bike lanes, bus pull-outs, improved shoulders, and median treatments.

SSFM prepared this *Pavement Drainage Report and BMP Assessment* for the project. The purposes of this report are to: first, identify and quantify the necessary pavement drainage improvements to ensure that the project conforms to State Design Standards; and second, to quantify the pre-project and post-project storm water runoff rates and volumes from the right-of-way for use in the retention/detention stormwater analysis. This report also addresses stormwater quality issues and required permanent Best Management Practices.

1.1 PROJECT LOCATION

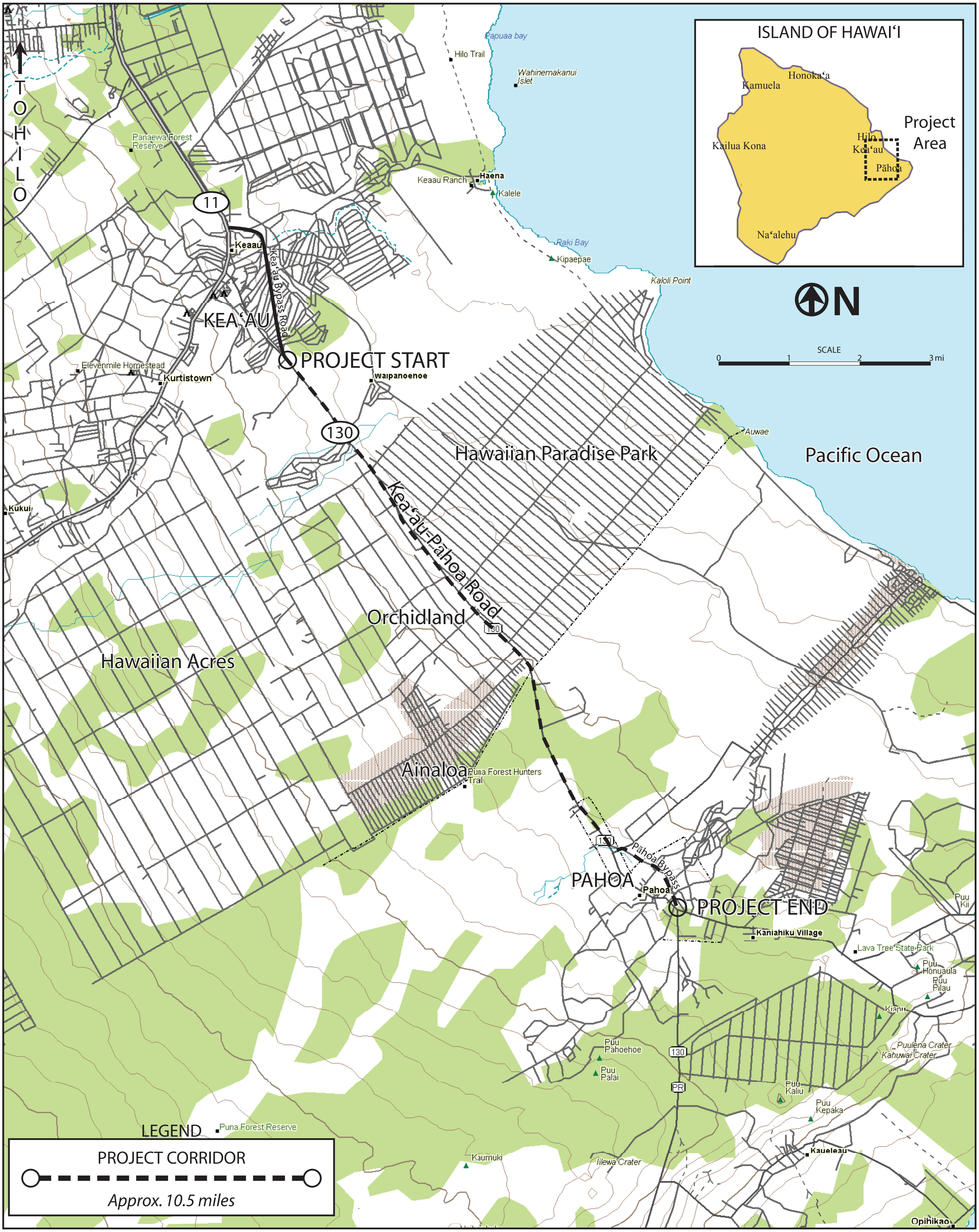
The project site is located as shown in Figure 1 - Location Map

II. SUMMARY OF PROJECT CHANGES

The project improvements for pavement drainage and BMP purposes are summarized in Table 1- Project Changes:

Table 1- Project Changes

	Alternative 2	**Alternative 3**	**Alternative 4**	**Alternative 5**
General Description	Addition of bus pull-outs, turning lanes	32,500 feet. of four-lane road 20,400 feet of two-lane road	four-lane road, entire length	23,500 feet of six-lane road 24,000 feet of four-lane road 5,400 feet of two-lane road
Existing Pavement	266,277 sq. yard	266,277 sq. yard	266,277 sq. yard	266,277 sq. yard
Final Pavement	307,500 sq. yard	460,260 sq. yard	512,269 sq. yard	562,936 sq. yard
Drain Inlets	81	254	254	278
Drywells	20	116	116	116
Perforated storm sewer	20,200 feet	116,460 feet	116,460 feet	116,460 feet



PROJECT LOCATION MAP

Keaʻau-Pāhoa Road Improvements, Keaʻau to Pāhoa, Project No. STP-0130(27)

State of Hawaiʻi, Department of Transportation

Figure 1

Source:
DeLorme 3-D TopoQuads

III. HYDROLOGY

AVAILABLE HYDROLOGIC METHODS

For the purposes of this report, the Rational Method has been employed for the calculation of the peak design flows and storm volumes.

Short-period Precipitation

Short period rainfall intensities are required to apply the Rational Method to small watersheds. The County of Hawaiʻi ("COH") Drainage Standards provide a method to determine the short-duration rainfall depths and intensities for the project site. These maps were taken from the Rainfall Frequency Atlas for the Hawaiian Islands, Technical Paper No 43. The 10-year and 25-year - One-Hour isohyetal maps (i.e., map showing lines of equal rainfall intensity) are attached as Figure 2 and Figure 3 respectively. The hydrologic calculations for the project site have been included as Appendix 1.

HYDROLOGIC CALCULATIONS

For on-site watersheds peak runoff rates and volumes were analyzed using the Rational Method. The runoff calculation input-values were obtained from the *COH Storm Drainage Standards, TP-43* and the HDOT design standards.

On-site Drainage Design

The on-site drainage analysis has been developed based on the average width of pavement within the project site. The on-site right-of-way is varies from approximately 80 feet to over 100 feet at various location along the corridor.

The average width of paving throughout the length of corridor is reasonably constant except at intersections and in the areas of the appurtenant auxiliary lanes related to those the intersections. Therefore, the square footage of proposed pavement per foot of length of the right-of-way remains reasonably constant. For the purposes of this design only, these average areas will be used to determine both the peak flow and the volume of floodwater from the project. This analysis will be adjusted, as needed, during final design to account for the pavement areas at intersections, or auxiliary lanes.

Peak Flow and Runoff

The peak runoff was calculated using the Rational Method. Runoff volume for post-project conditions for the traveled-way was calculated using trapezoidal hydrographs, as defined in the Rational Method. This method is consistent with current industry standards and the ASCE Hydrology Manual.

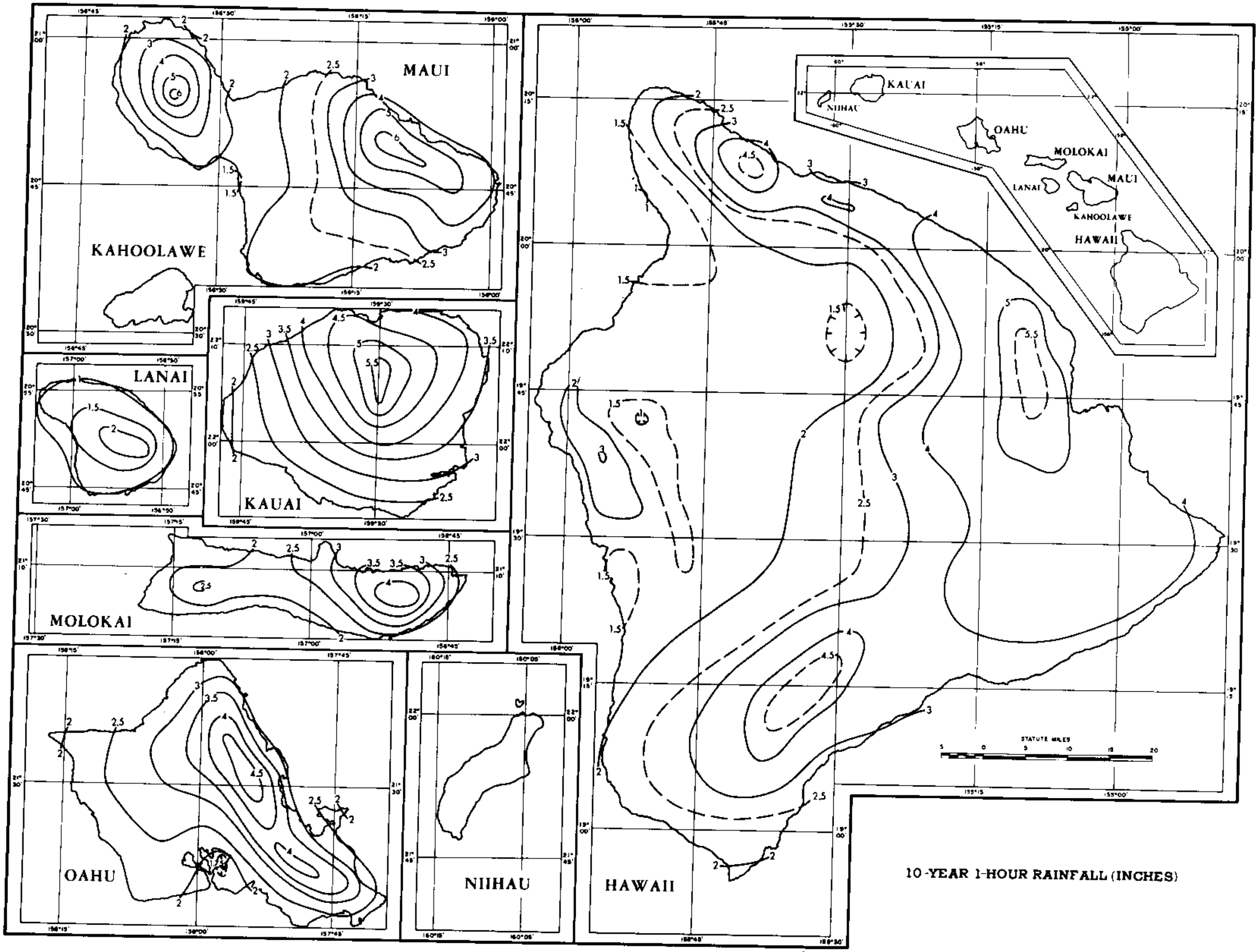


FIGURE 18.—10-yr. 1-hr. rainfall (in.)

Figure 2

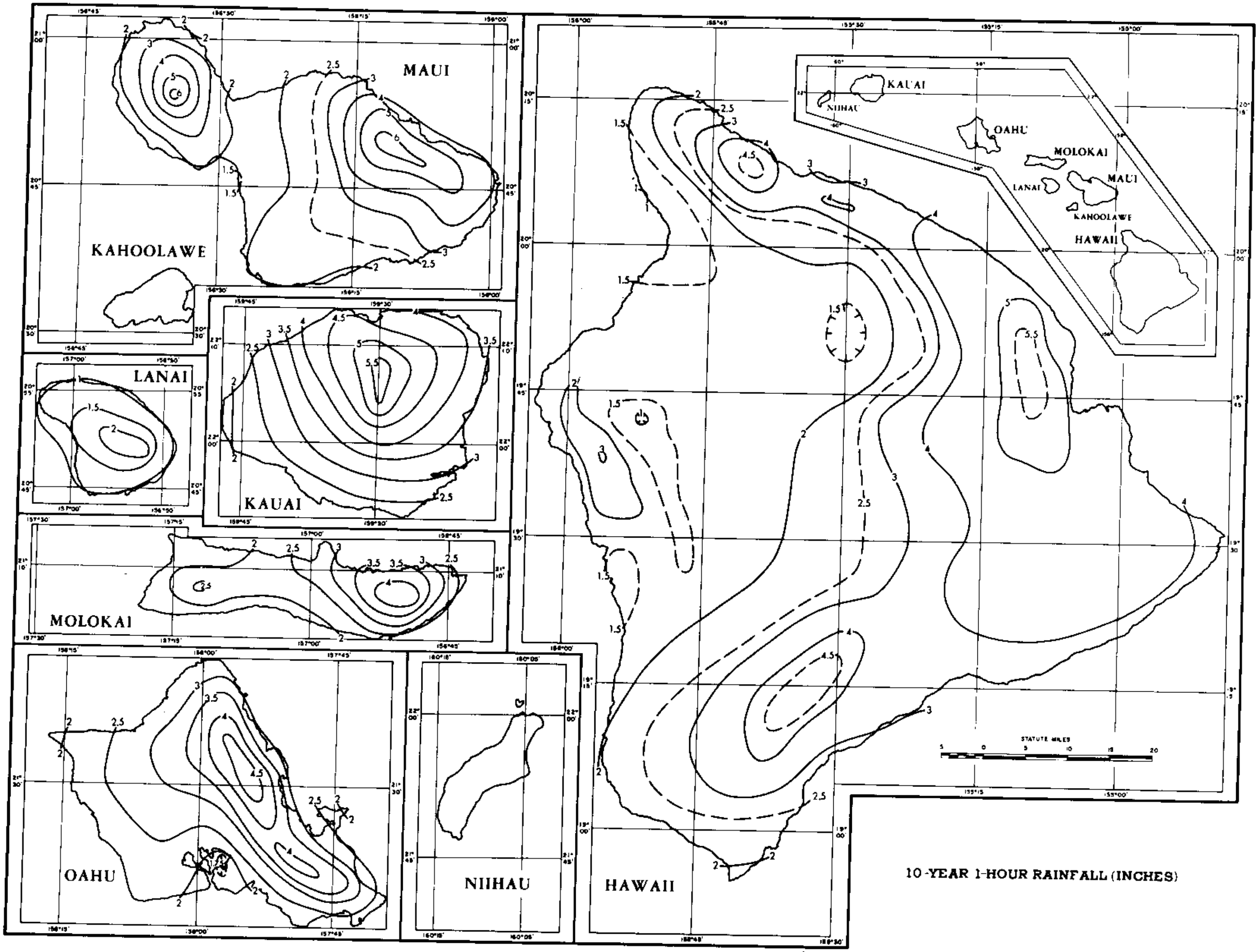


FIGURE 18.—10-yr. 1-hr. rainfall (in.)

Figure 2

Calculated Values

The peak runoff rates were estimated for each of the 3-Build alternatives, as well as Alternative 2, the Transportation Systems Management (TSM) option. A printout of the spreadsheet used to make this calculation is attached within Appendix 1 and summarized in the following tables.

The increased runoff rates and volumes were estimated and presented below based on a segment length of 1,000 feet of roadway construction, for comparison to the existing conditions. These peak runoff rates are used in the design of roadway drainage facilities.

Table 2A –Design Flow for TSM's

25-Year Runoff – Paved Areas			
	Proposed Pahoa-bound Lanes	Proposed Keaau-bound Lanes	Total per 1,000 feet of Roadway
Pavement Width[1&2] (feet)=	22	22	44
Area / 1,000 Feet of Lane (sq. feet) =	22,000	22,000	44,000
Paved Area (acres) =	0.51	0.51	1.02
Runoff Coeff. C =	0.90	0.90	0.90
Peak Runoff / 1,000 Feet (cfs)=	4.5	4.5	9.0

Note: (cfs) = cubic feet per second

Table 2B –Design Flow for Two Lane Road Section

25-Year Runoff – Paved Areas			
	Proposed Pahoa-bound Lanes	Proposed Keaau-bound Lanes	Total per 1,000 feet of Roadway
Pavement Width[1&2] (feet) =	27	27	54
Area / 1,000 Feet of Lane (sq. feet) =	27,000	27,000	54,000
Paved Area (acres) =	0.62	0.62	1.24
Runoff Coeff. C =	0.90	0.90	0.90
Peak Runoff / 1,000 Feet (cfs) =	5.6	5.6	11.2

Table 2C –Design Flow for Four Lane Road Section

25-Year Runoff – Paved Areas			
	Proposed Pahoa-bound Lanes	Proposed Keaau-bound Lanes	Total per 1,000 feet of Roadway
Pavement Width[1&2] (feet) =	37	37	74
Area / 1,000 Feet of Lane (sq. feet) =	37000	37000	74000
Paved Area (acres) =	0.85	0.85	1.7
Runoff Coeff. C =	0.90	0.90	0.9
Peak Runoff / 1,000 Feet (cfs) =	7.6	7.6	15.2

Table 2D –Design Flow for Six Lane Road Section

25-Year Runoff – Paved Areas			
	Proposed Pahoa-bound Lanes	Proposed Keaau-bound Lanes	Total per 1,000 feet of Roadway
Pavement Width[1&2] (feet)=	49	49	98
Area / 1,000 Feet of Lane (sq. feet) =	49,000	49,000	2.24
Paved Area (acres)=	1.12	1.12	2.24
Runoff Coeff. C =	0.90	0.90	0.90
Peak Runoff / 1,000 Feet (cfs) =	10.1	10.1	20.2

Notes:

1. Adjustments to pavement width for intersection, aux. lanes, etc. will be made during final design.

PERMANENT BEST MANAGEMENT PRACTICES

Stormwater Management

The overall goal of storm water management is to mitigate the adverse impact of new construction on the environment. Stormwater management can generally be separated into two areas:

1. <u>Management of the quantity of storm water leaving a project site.</u> This relates to adverse impacts of increased flows and volumes leaving the site on the downstream watercourses. Increased flows and volumes can exacerbate flooding and erosion.

2. Management of the quality of storm water leaving a project site. The construction of urban or impervious facilities increases the probability that runoff leaving site will contain constituents detrimental to the downstream watershed. Included in this list of potential constituents would be silt, trash, hydrocarbons, heavy metals and organic pesticides and herbicides.

Management of the quantity of storm water is referred to as Hydrograph Modification. Management of the quality of storm water is carried out by the installation and maintenance of on-site permanent Best Management Practices (BMP's) facilities to remove and sequester adverse water quality constituents from the runoff.

Hydrograph modification and BMP's are quite often handled by the same facilities. An example of this would be the use of a detention basin or infiltration facility in order to reduce peak flow and also to allow water quality constituents to settle out of the floodwater in the basin prior to discharge from the site.

Stormwater Quantity

The On-site Drainage Design has been developed based on the projected average width of pavement within the project site. The project right-of-way will range from 100 feet for the proposed 2-lane segments to a width of 132 feet for the 6-lane segment.

There are two sub-watersheds within the project site as defined for the purposes of this section of the report only. They are:

- The first sub-watershed is the area comprising the width of the existing pavement.
- The second sub-watershed is the area comprising the proposed ultimate pavement.

Sub-watersheds one and two were analyzed to determine the increase in peak runoff rate and peak runoff volume due to the increase in impervious area. The average width of paving throughout the length of right-of-way was used in this analysis of both the increased peak flow and the increased volume of floodwater from the existing and proposed pavement areas. This analysis will be adjusted, as needed, during final design to account for the pavement areas at intersections and auxiliary lanes etc.

Peak Flow Increase due to Project

The increase in peak flow is a function of the increase in impervious areas associated with the roadway widening project. The impervious area is increased by the construction of new pavement.

Runoff Volume Increase due to Project

Runoff volume for pre-project and post-project conditions for each side of the traveled way were calculated using trapezoidal hydrographs, as defined in the Modified Rational Method. A printout of the spreadsheet used to make these calculations is included within Appendix 1 and summarized in the following Table 3 – Unit Increase in Flow and Volume for Pavement.

This table shows that the total increase in peak outflow for a 1,000 foot section of the right-of-way due to the pavement impact would be 2.8 cfs for the widened 2-lane cross section; 5.5 cfs for the 4-lane road section and 8.8 cfs for the development of a 6-lane road cross section. Similarly, the runoff volume increases by 1653cu-feet for the 2-lane cross section; 3306cu-feet for a 4-lane cross section and 5289cu-feet for a 6-lane cross section, per 1000 feet of roadway. Hydrograph modification facilities were sized to mitigate both of these increases, as discussed later in this report.

Table 3A –Unit Increase in Flow and Volume for Pavement Transportation System Management (TSM's)

25-Year Runoff				
	Existing		Proposed	**Net Increase** (per 1000 feet)
	Unpaved	Paved	Paved	
Pavement Width[1&2] (feet) =	10	34	44	
Area / 1,000 Feet of Road (sq. feet) =	10,000	34,000	44,000	
Area in Acres =	0.22	0.78	1.02	
Runoff Coeff. C =	0.30	0.90	0.90	
Peak Runoff / 1,000 Feet =	0.68	7.0	9.0	**1.4 cfs**
Runoff Volume / 1,000 Feet =	414	4214	5454	**826 cu. feet**

Table 3B –Unit Increase in Flow and Volume for Pavement Two-Lane Cross-section

25-Year Runoff				
	Existing		Proposed	**Net Increase** (per 1000 feet)
	Unpaved	Paved	Paved	
Pavement Width[1&2] (feet)=	20	34	54	
Area / 1,000 Feet of Road (sq. feet) =	20,000	34,000	54,000	
Area in Acres =	0.46	0.78	1.24	
Runoff Coeff. C =	0.30	0.90	0.90	
Peak Runoff / 1,000 Feet =	1.38	7.0	11.2	**2.8 cfs**
Runoff Volume / 1,000 Feet =	826	4214	6694	**1653 cu. feet**

Table 3C –Unit Increase in Flow and Volume for Pavement Four-Lane Cross-section

25-Year Runoff				
	Existing		Proposed	**Net Increase** (per 1000 feet)
	Unpaved	Paved	Paved	
Pavement Width[1&2] (feet) =	40	34	74	
Area / 1,000 Feet of Road (sq. feet) =	40,000	34,000	74,000	
Area in Acres =	0.92	0.78	1.7	
Runoff Coeff. C =	0.30	0.90	0.90	
Peak Runoff / 1,000 Feet =	2.76	7.02	15.2	**5.5 cfs**
Runoff Volume / 1,000 Feet =	1652	4214	9174	**3306 cu. feet**

Table 3D –Unit Increase in Flow and Volume for Pavement Six-Lane Cross-section

25-Year Runoff				
	Existing		Proposed	**Net Increase** (per 1000 feet)
	Unpaved	Paved	Paved	
Pavement Width[1&2] (feet) =	64	34	98	
Area / 1,000 Feet of Road (sq. feet) =	64,000	34,000	98,000	
Area in Acres =	1.46	0.78	2.24	
Runoff Coeff. C =	0.30	0.90	0.90	
Peak Runoff / 1,000 Feet =	4.40	7.0	20.2	**8.8 cfs**
Runoff Volume / 1,000 Feet =	2644	4214	12,148	**5289 cu. feet**

Notes:
1. Adjustments to pavement width for intersection, aux. lanes, etc. will be made during final design.
2. Runoff volume = Area under hydrograph with Tc = 10 min.

Stormwater Quality

Stormwater quality degrades with urban development and increased impervious surfaces, as various pollutants are introduced into the stormwater runoff. Therefore, the quality of storm water runoff leaving the project site is of concern. HDOT requires that the project provide permanent water quality treatment of the roadway runoff prior to discharging off right-of-way. The project would incorporate permanent Best Management Practices (BMP's) in conformance with HDOT and good engineering practice to accomplish this goal.

The first half-inch of runoff during a storm is referred to as the Water Quality Volume (WQV) or the "first-flush" volume (FHWA- HEC-22). This portion of the runoff from a storm contains measurably more suspended solids plus other contaminants per cubic foot than would be expected in runoff occurring later in the storm. Accepted permanent BMP practice is to provide at least for on-site storage and disposal of this first-flush runoff.

The HDOT Storm Water Permanent Best Management Practices Manual, 2007 contains specific equations for calculating the water quality volume and water quality flow. These equations would be used during final design of the project to size permanent BMP's.

Permanent BMP's can be separated into structural BMP's and non-structural BMP's. An example of a nonstructural BMP would be scheduled street sweeping by the state in order to reduce litter and other constituents from collecting on the pavement, thereby avoiding the litter and other materials from being washed into the storm drain system.

Examples of a *structural BMP* would include detention basins, infiltration facilities and/or drywells. Each of these facilities provide temporary storage to control peak flow and would also provide permanent storage and infiltration area in order to control both the increase in storm volume and the first-flush discharge resulting from the project.

A full assessment of all available BMP's would be provided during final design of the project to optimize water quality benefits.

The storm drain system would be designed generally as follows:

1. Surface runoff from the traveled way would be collected within the roadside swales or shallow ditches. Flow from these swales would be collected and conveyed into drain inlets and drywells located within the state right-of-way. Overflow from the drywells, if any, would be directed to the cross culvert's inlet channel or outlet channel.
2. Drywells would be used at intervals along the corridor to intercept the *first-flush* runoff, promote infiltration at-depth, and to contain that runoff in storage for eventual infiltration into the ground. The detailed design of the drywell locations, spacing and capacity should be such that each drywell is able to treat their own drainage area efficiently, and minimize the amount of carry-over to the next drywell. Storm runoff exceeding the capacity of the *first-flush* drywells would bypass the drywell inlet and would then be discharged via the downstream infiltration trenches. To minimize the maintenance concerns with drywell clogging, additional pre-treatment devices such as vortex separators can be added at selected locations along the system to promote and retain sediment or oil/grease deposits.
3. In addition to infiltration from the proposed drywells, the storm sewer collection system would also be designed as a perforated infiltration facility. The perforated storm sewer and drain rock envelope will promote infiltration and inflow from the surface of roadside swale and allow for subsurface storage and infiltration to-ground. This linear method of disposal to-ground allows for more even distribution and infiltration of the stormwater runoff and better mimics the pre-development conditions.

   A confirmation of the suitability of the Permanent BMP facilities will not be known until detailed geotechnical surveys are completed, to establish the porosity and infiltration capability of the existing soils.

Based on the above collection and infiltration system, the proposed permanent BMP facilities will fit entirely within the proposed right of way limits for the two, four and six lane cross sections.

HYDROGRAPH MODIFICATION

Stormwater Quantity

The State Department of Transportation and the County of Hawai'i require that the peak flow and total volume of the storm runoff from the project site remain at or less than pre-project values. The 25-year rainfall was used to determine the increase in flow and volume, as previously detailed.

The areas of existing pavement were compared to the areas of the total post-project pavement in order to estimate the impact of the project on peak flow and on the increase in volume of runoff due to the project. Both peak flow reduction and volume reduction would be accomplished as shown in Table 4 - Conceptual Design - Hydrograph Modification.

The total impact of the project was determined by multiplying the unit rate for the two-lane, four-lane or six lane cross section by the applicable length within each alternative.

In order to mitigate the increase in peak flow it would be necessary to build either a detention area, or a series of drywells and in-pipe storage of sufficient capacity to store a portion of the peak flow leaving the project, thereby reducing that peak flow. To minimize the right-of-way requirements for BMP facilities, a linear storage and infiltration approach was adopted to store and infiltrate the increased flow.

A storage volume was estimated for each alternative to mitigate the increase in peak flow. This mitigation volume was determined using a hydrologic method known as pond routing. The calculations are contained in Appendix 1.

Table 4 - Conceptual Design - Hydrograph Modification

	TSM Alternative	**Two-Lane Cross section**	**Four-Lane Cross Section**	**Six-Lane Cross section**
Pre-Project Flow (per 1,000 feet of roadway	7.71 cfs	8.40 cfs	9.78 cfs	11.43 cfs
Post-Project Flow (per 1,000feet of roadway	9.09 cfs	11.16 cfs	15.29 cfs	20.25 cfs
Detention volume required to mitigate increase in flow rate (per 1,000feet)	3.750 cu. feet	3,900 cu. feet	6,100 cu. feet	8,500 cu. feet
Retention volume required to mitigate increased runoff volume	826 cu. feet	1,653 cu. feet	3,306 cu. feet	5,289 cu. feet
Governing design volume	**3,750 cu. feet**	**3,900 cu. feet**	**6,100 cu. feet**	**8,500 cu. feet**

The proposed linear storage system includes 30-inch diameter pipes, within a clear drain rock trench, along both sides of the roadway to serve as a conveyance and infiltration system. In addition, drywells are planned at intervals of 1,000 feet to provide additional storage, and promote infiltration at depth in the event that the porosity of shallow soils is not adequate. The in-situ permeability must be confirmed during the future preliminary and detailed design tasks.

Based on the above linear storage, each build alternative is provided with 9,800 cu. feet of storage per 1,000 feet of length. This available storage exceeds the required storage volume, under each of the build alternatives.

IV. HYDRAULICS

4.1 GENERAL

The project is subject to HDOT design standards. Stormwater inlets and drywells would be located during final design to meet collection and conveyance standards of the DOT. For conceptual design and estimating purposes, the roadside swale capacity has been estimated using a channel roughness coefficient of 0.030, and an average slope of 1.0%. The drain inlet spacing was then selected to ensure that the roadway runoff for the 25-year design event did not exceed the hydraulic capacity of the swale. The preliminary swale cross sections, and drain inlet spacing have been presented within Appendix 2.

V. LIMITATIONS

This report was prepared to comply with the guidelines established by: the State Department of Health; the State HDOT; and County of Hawai‘i. Evaluation of the appropriateness of these guidelines and the accuracy of their data used to develop those guidelines was beyond the scope of work for this project.

Usage of the report is limited to address the purpose and scope previously defined. SSFM International, Inc. shall not be held responsible for any unauthorized application of this report and the contents herein.

The opinions presented in this report have been derived in accordance with current standards of civil engineering practice. No other warranty is expressed or implied.

VI. BIBLIOGRAPHY

1. Rainfall Frequency Atlas of the Hawaiian Islands, Technical Paper No. 43, U.S. Weather Bureau
2. Storm Drainage Standard, Department of Public Works, County of Hawai‘i, October 1970
3. Soil Map from National Resources Conservation Service (NRCS)
4. Soil Survey of Island of Hawai‘i, State of Hawai‘i, United States Department of Agriculture, Soil Conservation Service, December 1973
5. Hydrology Handbook, Second Edition, American Society of Civil Engineers, 1996.
6. FHWA-HEC-22
7. HDOT, Storm Water Permanent Best Management Practices Manual, 2007
8. HDOT, Design criteria for Highway Drainage, 2006

APPENDIX 1

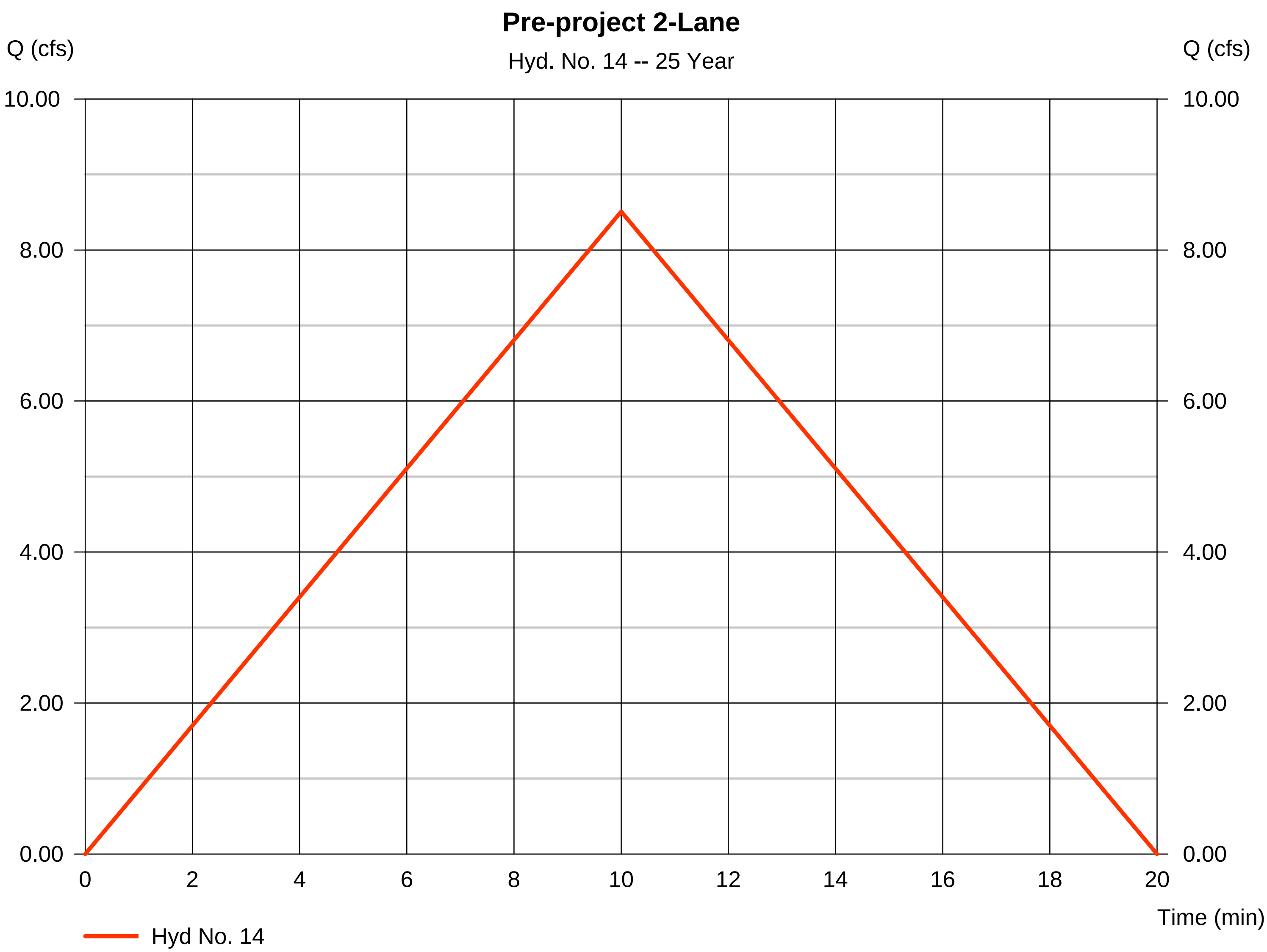
HYDROLOGIC ANALYSES

Hydrograph Report

Hyd. No. 14

Pre-project 2-Lane

Hydrograph type	= Rational	Peak discharge	= 8.508 cfs
Storm frequency	= 25 yrs	Time to peak	= 10 min
Time interval	= 1 min	Hyd. volume	= 5,105 cuft
Drainage area	= 1.240 ac	Runoff coeff.	= 0.68
Intensity	= 10.091 in/hr	Tc by User	= 10.00 min
IDF Curve	= K-P IDF 5.0 Inches.IDF	Asc/Rec limb fact	= 1/1



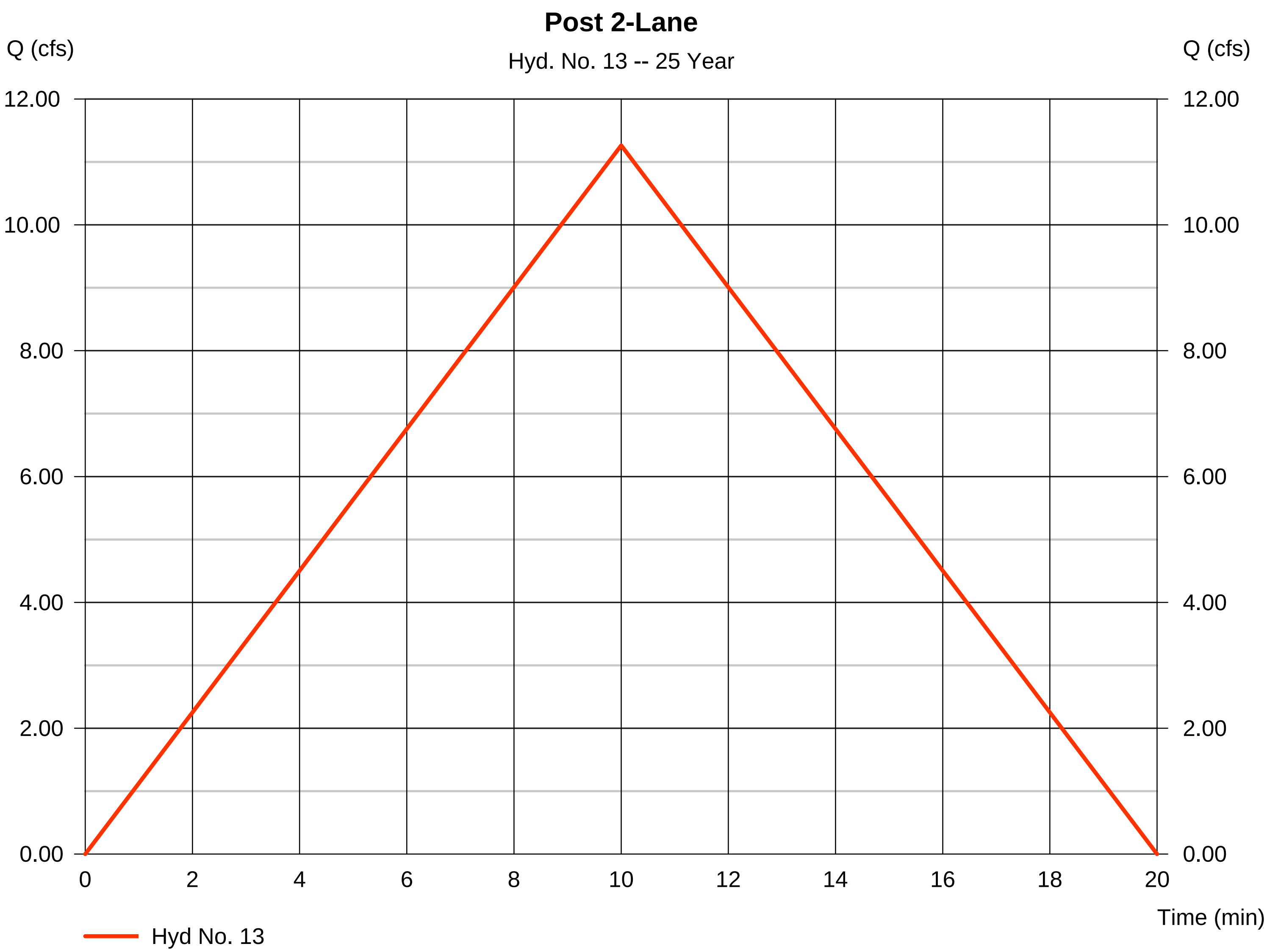
Hydrograph Report

Hydraflow Hydrographs by Intelisolve v9.25 | Friday, Feb 19, 2010

Hyd. No. 13

Post 2-Lane

Hydrograph type	= Rational	Peak discharge	= 11.26 cfs
Storm frequency	= 25 yrs	Time to peak	= 10 min
Time interval	= 1 min	Hyd. volume	= 6,757 cuft
Drainage area	= 1.240 ac	Runoff coeff.	= 0.9
Intensity	= 10.091 in/hr	Tc by User	= 10.00 min
IDF Curve	= K-P IDF 5.0 Inches.IDF	Asc/Rec limb fact	= 1/1



Hydrograph Report

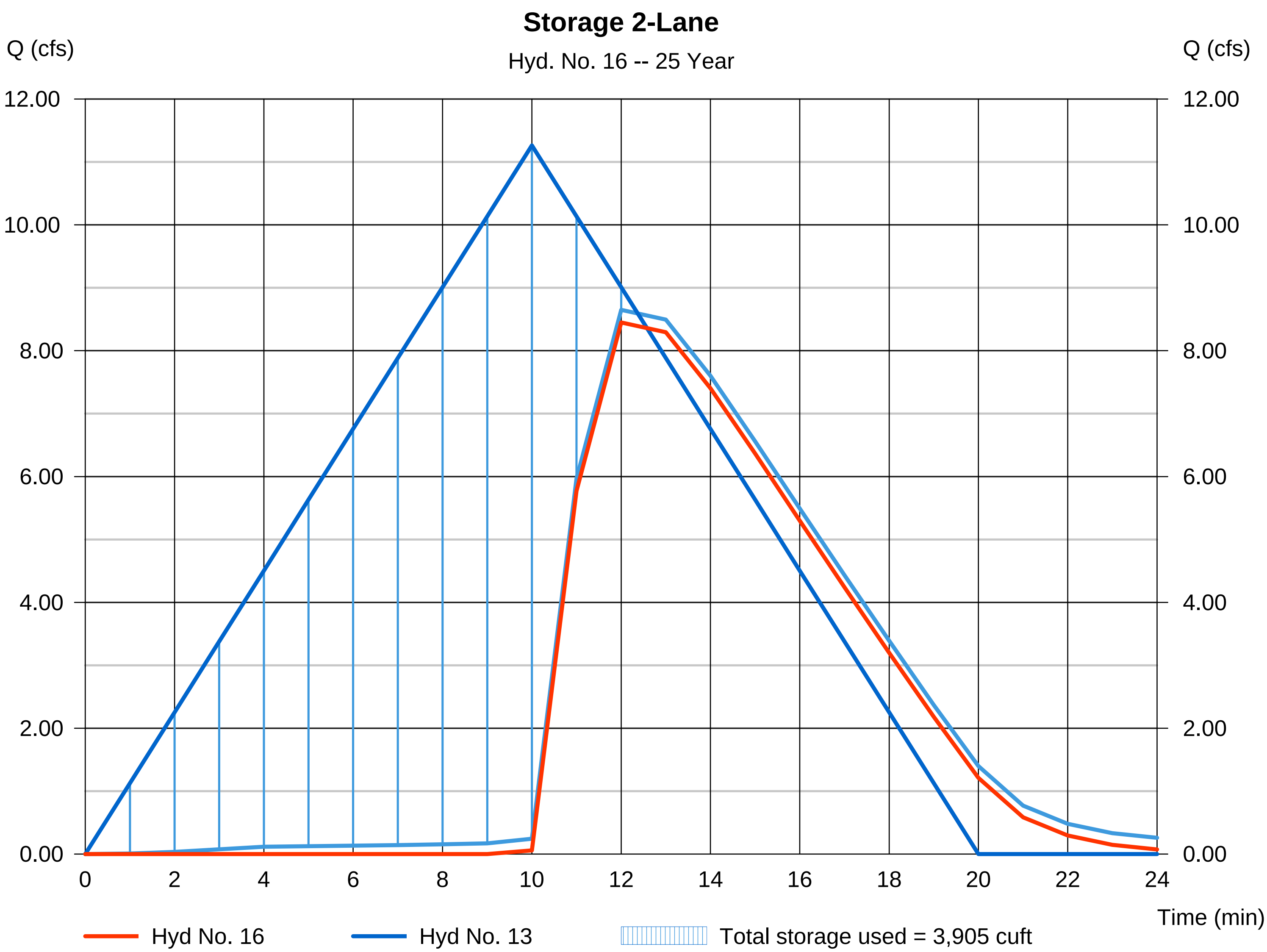
Hydraflow Hydrographs by Intelisolve v9.25 | Friday, Feb 19, 2010

Hyd. No. 16

Storage 2-Lane

Hydrograph type	= Reservoir	Peak discharge	= 8.449 cfs
Storm frequency	= 25 yrs	Time to peak	= 12 min
Time interval	= 1 min	Hyd. volume	= 3,218 cuft
Inflow hyd. No.	= 13 - Post 2-Lane	Max. Elevation	= 25.22 ft
Reservoir name	= 2-Lane	Max. Storage	= 3,905 cuft

Storage Indication method used. Exfiltration extracted from Outflow.



Keauu-Pahoa Road Improvement Project
Change in Unit Runoff due to Ultimate Pavement
Hydrograph Modification

Two lane highway

	25-year Rainfall
Time of Concentration	Intensity ("/Hr)
1-Hour *	5
10-Minute**	10

*COH Hydrology Std-- Plate 1 (See Figure 3) & TP-43 for 25-yr value

**COH Hydrology Std-- Plate 4

25-Year Runoff Calculation - Pahoa-bound Lanes

	Existing		Proposed	Net Increase Due to Project per 1,000 ft of Road	
	Unpaved	Paved	Paved		
Pavement Width[1&2] =	10	17	27	10	
Area / 1,000 Feet of Road =	10000	17000	27000	10000	
Area in Acres =	0.23	0.39	0.62	0.23	
Runoff Coeff. C =	0.30	0.90	0.90	0.9	
A*C =	0.07	0.35	0.56	0.21	
Peak Runoff / 1,000 Ft =	0.69	3.5	5.6	1.38	CFS
Runoff Volume[3] / 1,000 Ft =	413	2107	3347	826	Cu-Ft.

25-Year Runoff Calculation - Keaau-bound Lanes

	Existing		Proposed	Net Increase Due to Project per 1,000 ft of Road	
	Unpaved	Paved	Paved		
Pavement Width[1&2] =	10	17	27	10	
Area /1,000 Feet =	10000	17000	27000	10000	
Area in Acres =	0.23	0.39	0.62	0.23	
Runoff Coeff C =	0.30	0.9	0.9	0.9	
A*C =	0.07	0.35	0.56	0.21	
Peak Runoff / 1,000 Ft =	0.69	3.5	5.6	1.38	CFS
Runoff Volume[3] / 1,000 Ft =	413	2107	3347	826	Cu-Ft.

Notes:

1. Adjustments to pavement width for intersection, aux. lanes, etc. will be made during final design
2. Runoff volume = Area under hydrograph with Tc = 10 min

Varible Description	Existing		Proposed	Increase	Unit
	Unpaved	Paved	Paved		
Flow Inc. per 1,000' of ROW =	1.38	7.02	11.16	**2.8**	**CFS**
Vol. Inc. per 1,000' of ROW =	826	4215	6694	**1653**	**Cu-Ft.**

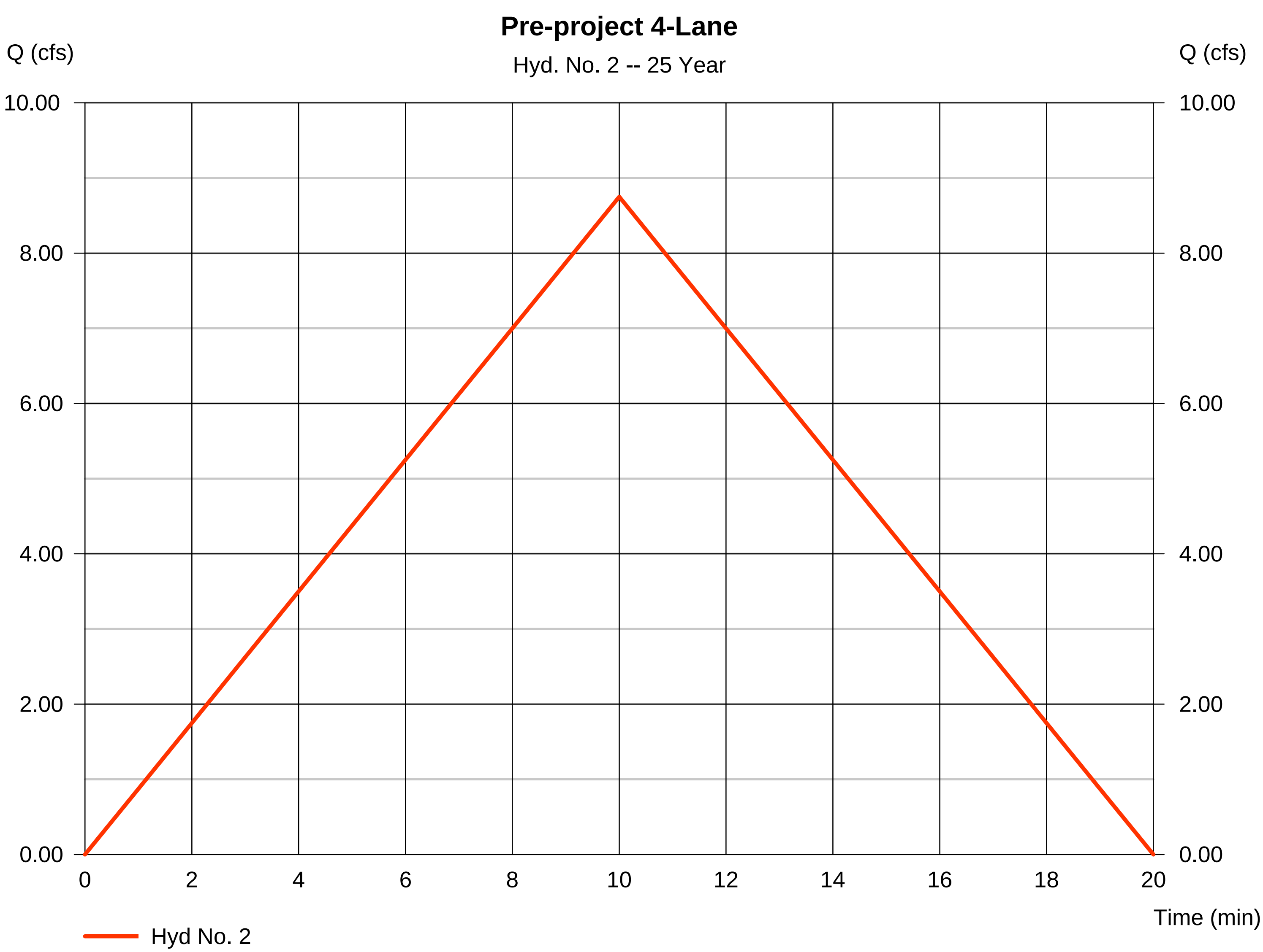
Composite C (existing) =			
Total flow/1000 =	8.40	CFS	
Total area/1000 =	1.24	Ac	
I =	10	at 10 min	(25yr)
Composite C =	0.68	Q/(A*I)	

Hydrograph Report

Hyd. No. 2

Pre-project 4-Lane

Hydrograph type	= Rational	Peak discharge	= 8.749 cfs
Storm frequency	= 25 yrs	Time to peak	= 10 min
Time interval	= 1 min	Hyd. volume	= 5,249 cuft
Drainage area	= 1.700 ac	Runoff coeff.	= 0.51
Intensity	= 10.091 in/hr	Tc by User	= 10.00 min
IDF Curve	= K-P IDF 5.0 Inches.IDF	Asc/Rec limb fact	= 1/1

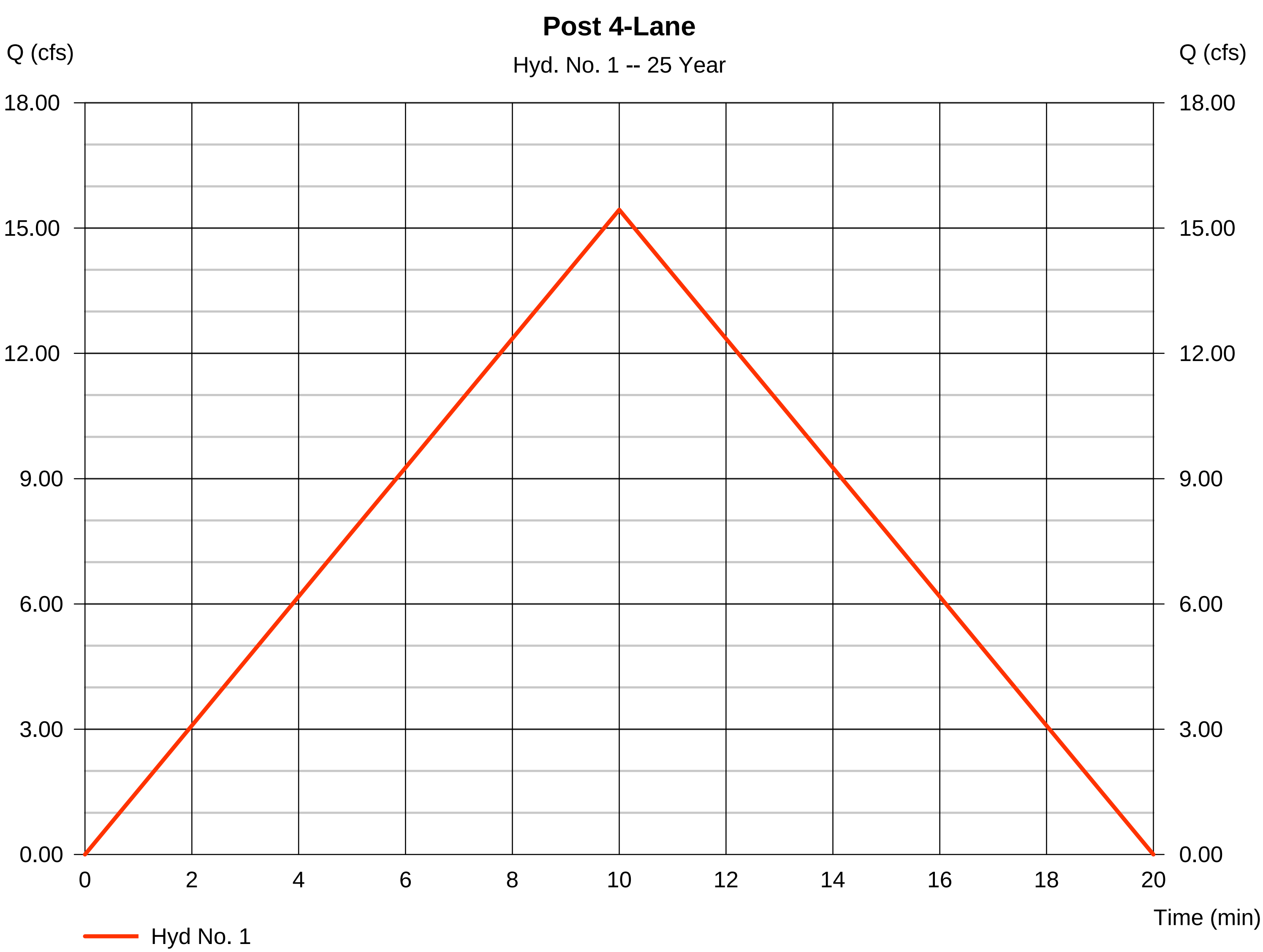


Hydrograph Report

Hyd. No. 1

Post 4-Lane

Hydrograph type	= Rational	Peak discharge	= 15.44 cfs
Storm frequency	= 25 yrs	Time to peak	= 10 min
Time interval	= 1 min	Hyd. volume	= 9,263 cuft
Drainage area	= 1.700 ac	Runoff coeff.	= 0.9
Intensity	= 10.091 in/hr	Tc by User	= 10.00 min
IDF Curve	= K-P IDF 5.0 Inches.IDF	Asc/Rec limb fact	= 1/1



Hydrograph Report

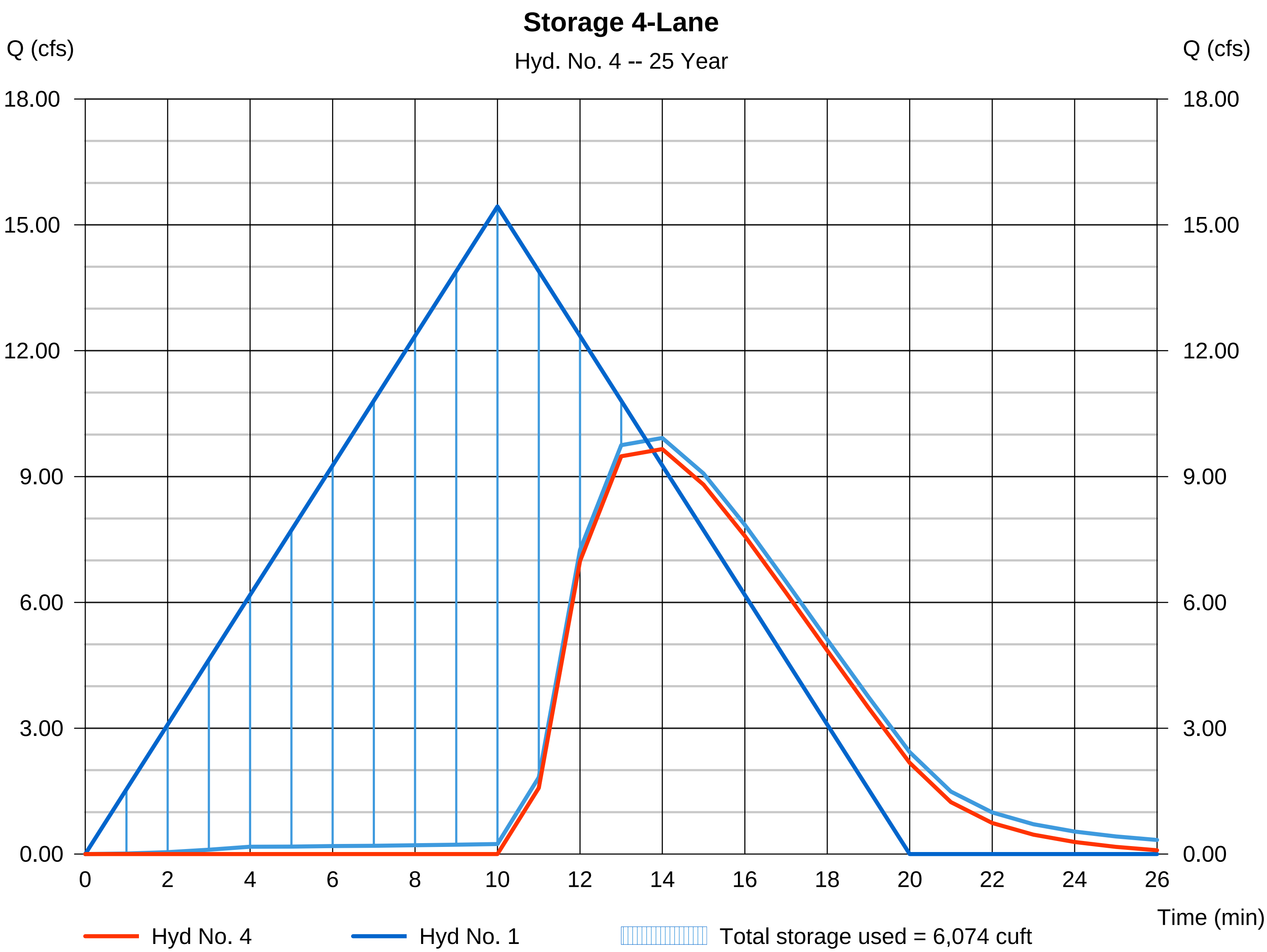
Hydraflow Hydrographs by Intelisolve v9.25 Friday, Feb 19, 2010

Hyd. No. 4

Storage 4-Lane

Hydrograph type	= Reservoir	Peak discharge	= 9.652 cfs
Storm frequency	= 25 yrs	Time to peak	= 14 min
Time interval	= 1 min	Hyd. volume	= 3,836 cuft
Inflow hyd. No.	= 1 - Post 4-Lane	Max. Elevation	= 25.30 ft
Reservoir name	= 4-Lane	Max. Storage	= 6,074 cuft

Storage Indication method used. Exfiltration extracted from Outflow.



Keaau-Pahoa Road Improvement Project
Change in Unit Runoff due to Ultimate Pavement
Hydrograph Modification

Four lane Roadway

	25-year Rainfall
Time of Concentration	Intensity ("/Hr)
1-Hour *	5
10-Minute**	10

*COH Hydrology Std-- Plate 1 (See Figure 3) & TP-43 for 25-yr value

**COH Hydrology Std-- Plate 4

25-Year Runoff Calculation - Pahoa-bound Lanes					
	Existing		Proposed	Net Increase Due to Project per 1,000 ft of Road	
	Unpaved	Paved	Paved		
Pavement Width[1&2] =	20	17	37	20	
Area / 1,000 Feet of Road =	20000	17000	37000	20000	
Area in Acres =	0.46	0.39	0.85	0.46	
Runoff Coeff. C =	0.30	0.90	0.90	0.9	
A*C =	0.14	0.35	0.76	0.41	
Peak Runoff / 1,000 Ft =	1.38	3.5	7.6	2.75	CFS
Runoff Volume[3] / 1,000 Ft =	826	2107	4587	1653	Cu-Ft.

25-Year Runoff Calculation - Keaau-bound Lanes					
	Existing		Proposed	Net Increase Due to Project per 1,000 ft of Road	
	Unpaved	Paved	Paved		
Pavement Width[1&2] =	20	17	37	20	
Area /1,000 Feet =	20000	17000	37000	20000	
Area in Acres =	0.46	0.39	0.85	0.46	
Runoff Coeff C =	0.30	0.9	0.9	0.9	
A*C =	0.14	0.35	0.76	0.41	
Peak Runoff / 1,000 Ft =	1.38	3.5	7.6	2.75	CFS
Runoff Volume[3] / 1,000 Ft =	826	2107	4587	1653	Cu-Ft.

Notes:

1. Adjustments to pavement width for intersection, aux. lanes, etc. will be made during final design
2. Runoff volume = Area under hydrograph with Tc = 10 min

Varible Description	Existing		Proposed	Increase	Unit
	Unpaved	Paved	Paved		
Flow Inc. per 1,000' of ROW =	2.75	7.02	15.29	**5.5**	**CFS**
Vol. Inc. per 1,000' of ROW =	1653	4215	9174	**3306**	**Cu-Ft.**

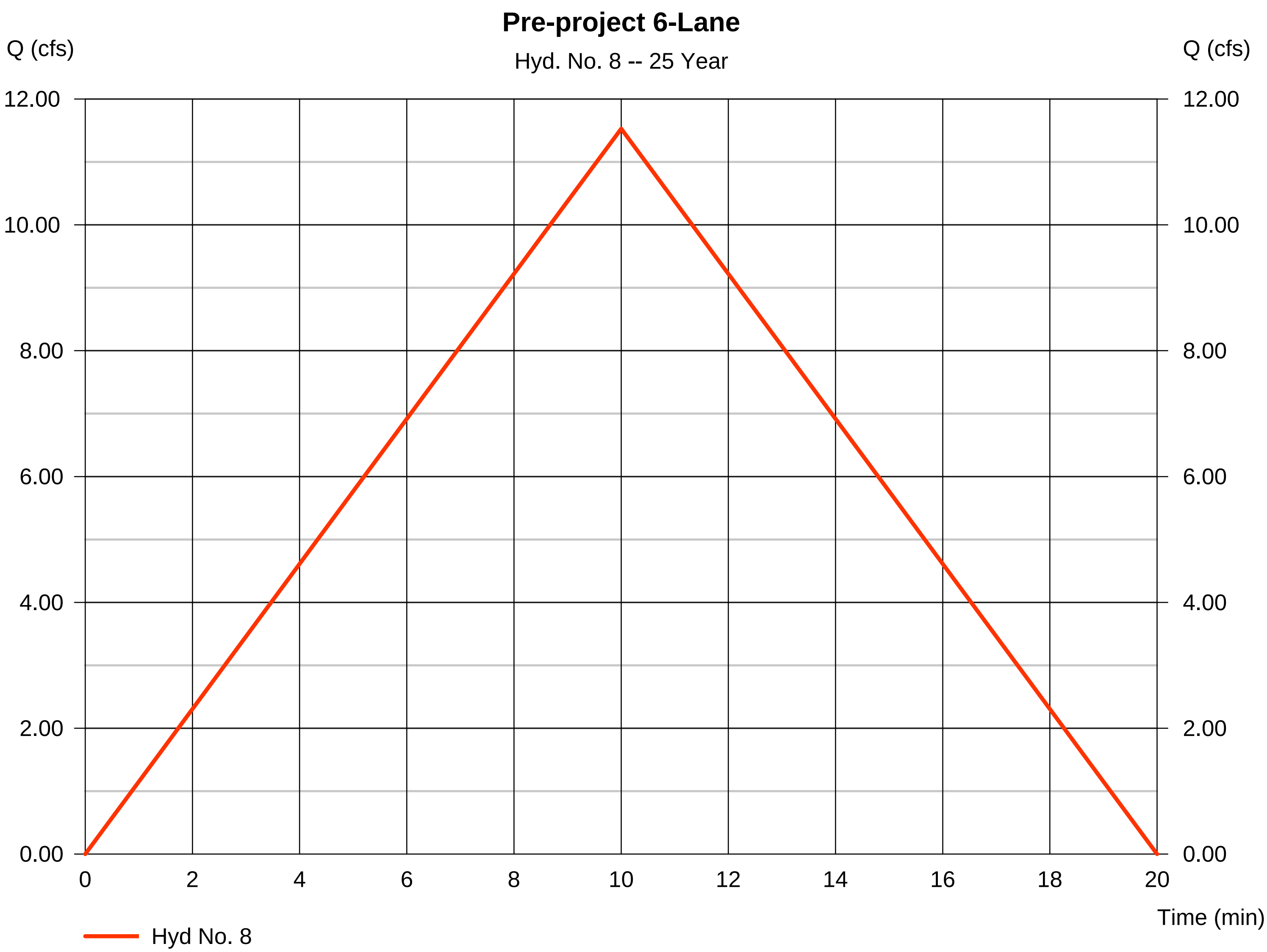
Composite C (existing) =			
Total flow/1000 =	9.78	CFS	
Total area/1000 =	1.70	Ac	
I =	10	at 10 min	(25yr)
Composite C =	0.58	Q/(A*I)	

Hydrograph Report

Hyd. No. 8

Pre-project 6-Lane

Hydrograph type	= Rational	Peak discharge	= 11.53 cfs
Storm frequency	= 25 yrs	Time to peak	= 10 min
Time interval	= 1 min	Hyd. volume	= 6,917 cuft
Drainage area	= 2.240 ac	Runoff coeff.	= 0.51
Intensity	= 10.091 in/hr	Tc by User	= 10.00 min
IDF Curve	= K-P IDF 5.0 Inches.IDF	Asc/Rec limb fact	= 1/1

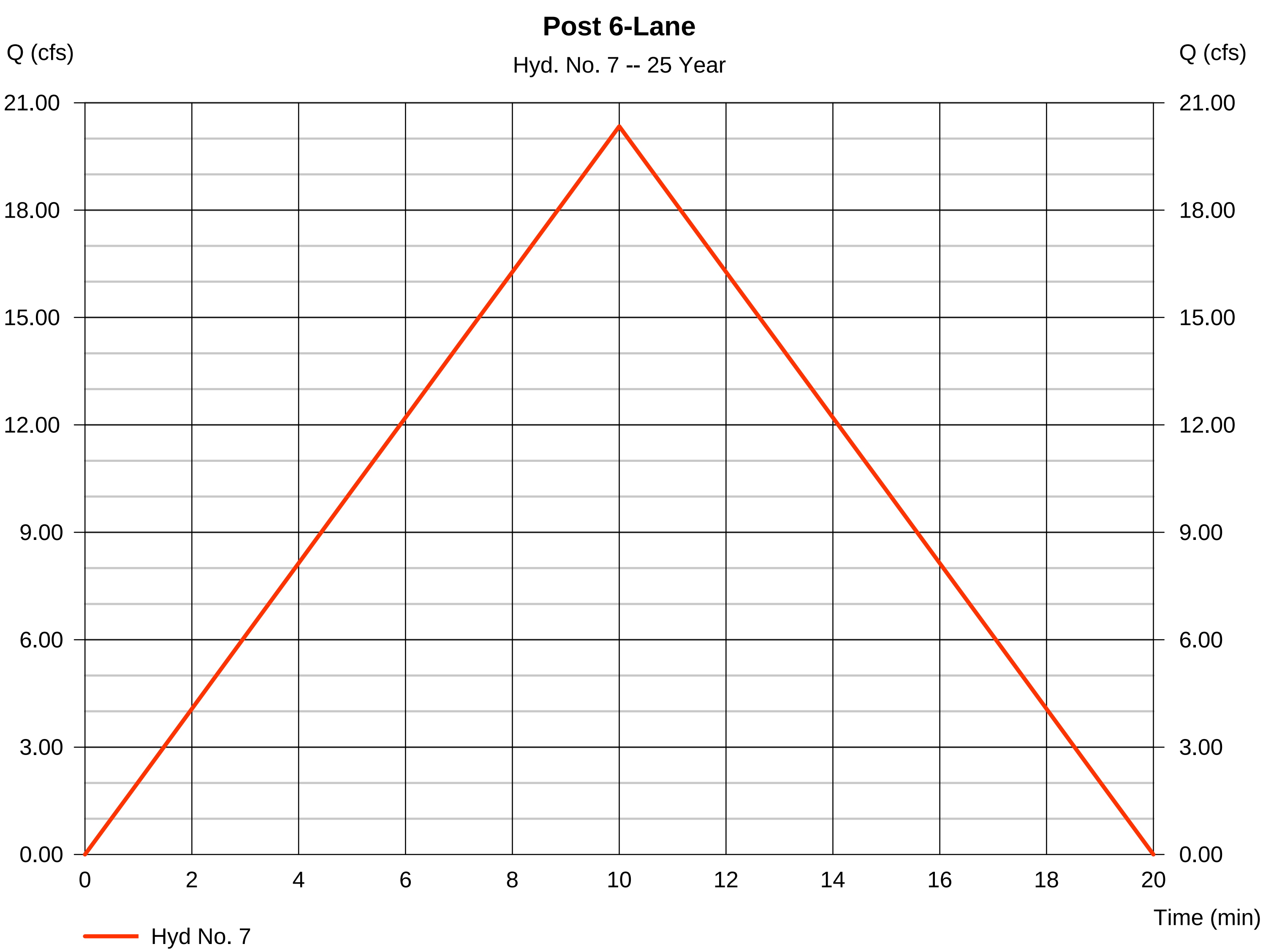


Hydrograph Report

Hyd. No. 7

Post 6-Lane

Hydrograph type	= Rational	Peak discharge	= 20.34 cfs
Storm frequency	= 25 yrs	Time to peak	= 10 min
Time interval	= 1 min	Hyd. volume	= 12,206 cuft
Drainage area	= 2.240 ac	Runoff coeff.	= 0.9
Intensity	= 10.091 in/hr	Tc by User	= 10.00 min
IDF Curve	= K-P IDF 5.0 Inches.IDF	Asc/Rec limb fact	= 1/1



Hydrograph Report

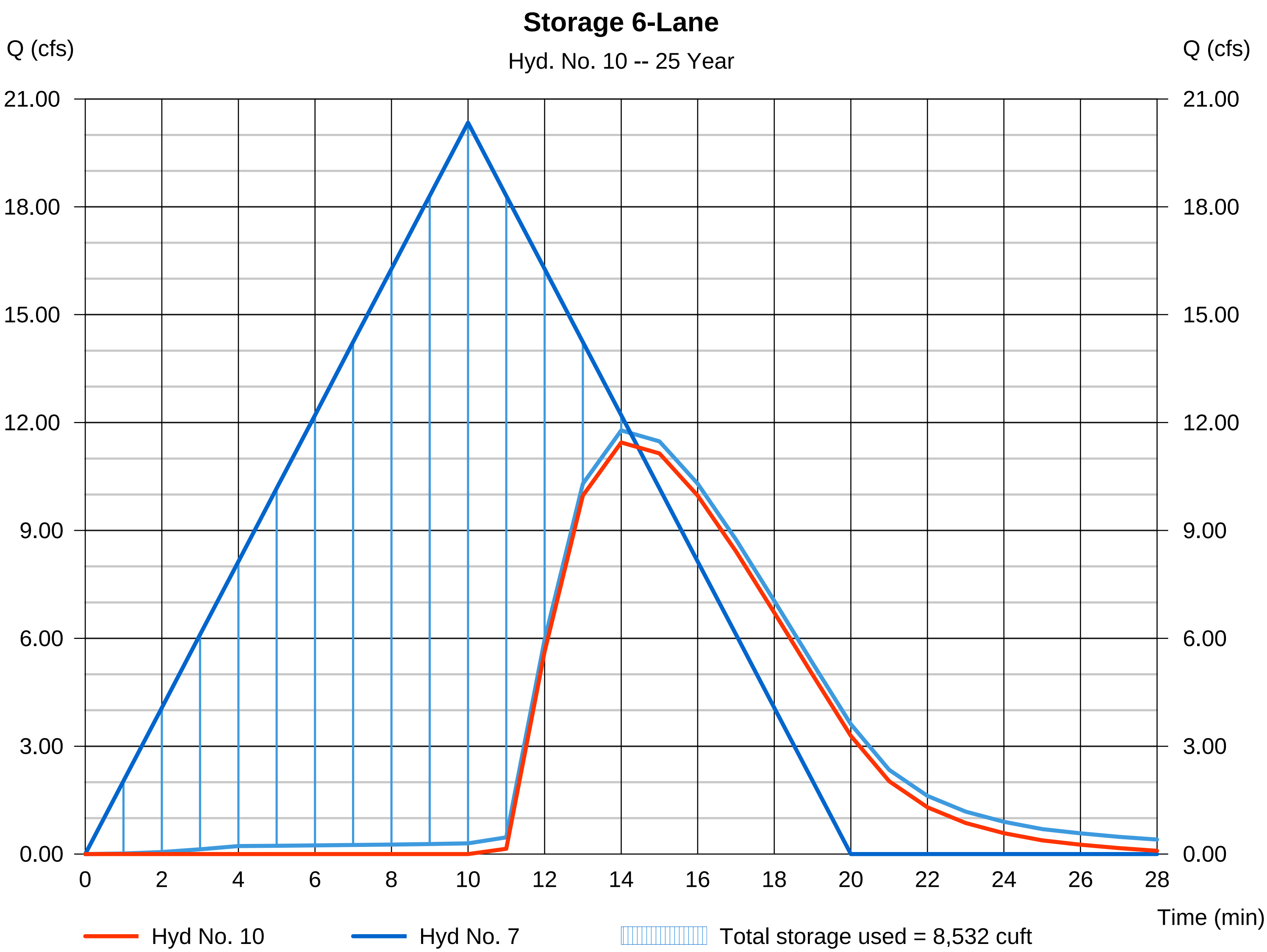
Hydraflow Hydrographs by Intelisolve v9.25 | Friday, Feb 19, 2010

Hyd. No. 10

Storage 6-Lane

Hydrograph type	= Reservoir	Peak discharge	= 11.45 cfs
Storm frequency	= 25 yrs	Time to peak	= 14 min
Time interval	= 1 min	Hyd. volume	= 4,651 cuft
Inflow hyd. No.	= 7 - Post 6-Lane	Max. Elevation	= 25.70 ft
Reservoir name	= Sample	Max. Storage	= 8,532 cuft

Storage Indication method used. Exfiltration extracted from Outflow.



Keaau-Pahoa Road Improvement Project
Change in Unit Runoff due to Ultimate Pavement
Hydrograph Modification

Six Lane Highway

	25-year Rainfall
Time of Concentration	Intensity ("/Hr)
1-Hour *	5
10-Minute**	10

*COH Hydrology Std-- Plate 1 (See Figure 3) & TP-43 for 25-yr value

**COH Hydrology Std-- Plate 4

25-Year Runoff Calculation - Pahoa-bound Lanes					
	Existing		Proposed	Net Increase Due to Project per 1,000 ft of Road	
	Unpaved	Paved	Paved		
Pavement Width[1&2] =	32	17	49	32	
Area / 1,000 Feet of Road =	32000	17000	49000	32000	
Area in Acres =	0.73	0.39	1.12	0.73	
Runoff Coeff. C =	0.30	0.90	0.90	0.9	
A*C =	0.22	0.35	1.01	0.66	
Peak Runoff / 1,000 Ft =	2.20	3.5	10.1	4.41	CFS
Runoff Volume[3] / 1,000 Ft =	1322	2107	6074	2645	Cu-Ft.

25-Year Runoff Calculation - Keaau-bound Lanes					
	Existing		Proposed	Net Increase Due to Project per 1,000 ft of Road	
	Unpaved	Paved	Paved		
Pavement Width[1&2] =	32	17	49	32	
Area /1,000 Feet =	32000	17000	49000	32000	
Area in Acres =	0.73	0.39	1.12	0.73	
Runoff Coeff C =	0.30	0.9	0.9	0.9	
A*C =	0.22	0.35	1.01	0.66	
Peak Runoff / 1,000 Ft =	2.20	3.5	10.1	4.41	CFS
Runoff Volume[3] / 1,000 Ft =	1322	2107	6074	2645	Cu-Ft.

Notes:
1. Adjustments to pavement width for intersection, aux. lanes, etc. will be made during final design
2. Runoff volume = Area under hydrograph with Tc = 10 min

Varible Description	Existing		Proposed	Increase	Unit
	Unpaved	Paved	Paved		
Flow Inc. per 1,000' of ROW =	4.41	7.02	20.25	**8.8**	**CFS**
Vol. Inc. per 1,000' of ROW =	2645	4215	12149	**5289**	**Cu-Ft.**

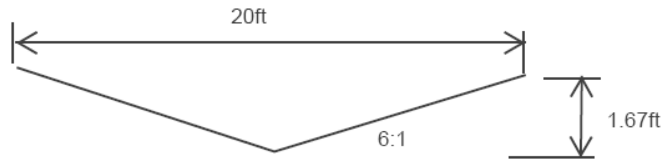
Composite C (existing) =			
Total flow/1000 =	11.43	CFS	
Total area/1000 =	2.25	Ac	
I =	10	at 10 min	(25yr)
Composite C =	0.51	Q/(A*I)	

APPENDIX 2

HYDRAULIC ANALYSES

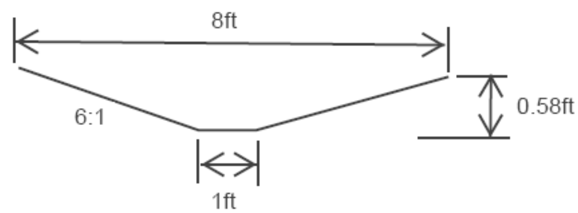
Roadside Swale Capacity

Two Lane Road Section



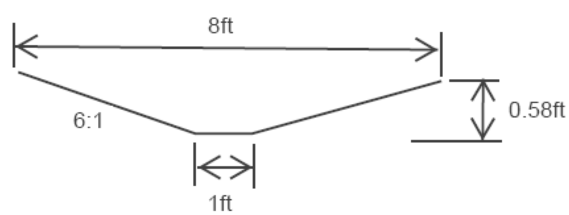
Use n=0.03
S=1.0% Q_{full} = 65.6cfs

Four - Lane Road Section



Use n=0.03
S=1.0% Q_{full} = 6.0cfs

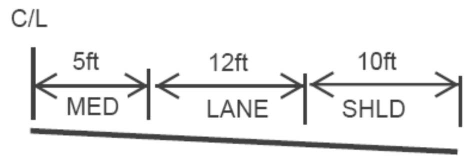
Six - Lane Road Section



Use n=0.03
S=1.0% Q_{full} = 6.0cfs

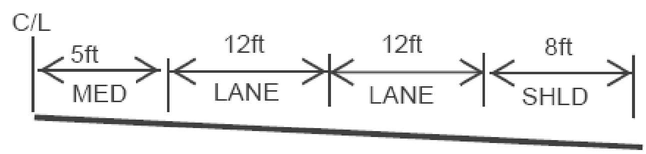
Drain Inlet Spacing

Two Lane Road Section



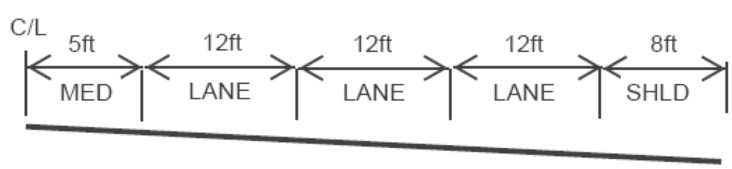
Width = 27ft
Length = 500ft
Area= 0.31ac
Q_{25}= 0.95x10.5x0.31
Q_{25}=3.1cfs (< swale capacity)

Four- Lane Road Section



Width = 37ft
Length = 500ft
Area= 0.425ac
Q_{25}= 0.95x10.5x0.425
Q_{25}=4.2cfs (< swale capacity)

Six- Lane Road Section



Width = 49ft
Length = 400ft
Area= 0.45ac
Q_{25}= 0.95x10.5x0.45
Q_{25}=4.5cfs (< swale capacity)

THIS PAGE INTENTIONALLY LEFT BLANK.