INITIAL DESIGN DRAINAGE REPORT
FOR
VALENCIA ROAD –
WADE ROAD TO AJO WAY
PIMA CO. PROJECT NO. 4RTVWE

Location:
T15S, R11E, Sections 12 & 13
T15S, R12E, Sections 7, 8, 9, 16, 17 & 18
Pima County, Arizona

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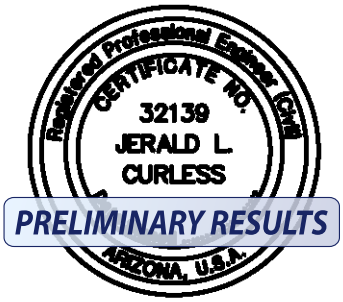

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SECTION 1.0 INTRODUCTION

This Initial Design Phase Drainage Report has been prepared to provide the Pima County Department of Transportation (DOT) with hydrologic and hydraulic engineering information to support new roadway drainage system designs as part of the Valencia Road – Wade Road to Ajo Way roadway improvement project. This report accompanies and complements the roadway widening construction plans that are being prepared by the project prime consultant and civil engineering firm, Kimley-Horn & Associates (KHA). CMG Drainage Engineering, Inc. (CMG) is contracted with KHA as the project drainage design sub-consultant.

1.1 Project Description

The Valencia Road – Wade Road to Ajo Way improvement project is wholly in unincorporated Pima County, Arizona. The roadway alignment is located in Sections 12 and 13, Township 15 South, Range 11 East, and Sections 7, 8, 9, 16, 17 and 18, Gila and Salt River Meridian, Pima County, Arizona. The project consists of widening approximately 2¾ miles of Valencia Road from two lanes to four lanes of traffic from the intersection of Ajo Way (AZ SR86) and matching into the existing 4-lane divided section west of the Valencia and Wade Road intersection. This effort is being pursued to improve safety, reduce congestion, improve operations (with turning lanes to be provided at intersections and cross streets where warranted), increase mobility, and address accessibility/operational issues. Other improvements include a raised landscaped median, multi-use lanes, outside curbs and pavement drainage systems near the SR86 intersection, provisions for pedestrians and other uses, landscaped shoulders, and noise mitigation for adjacent areas where warranted. A vicinity / location map for the project is presented as Figure 1.

1.2 Major Drainage Features

Notable drainage features that impact the project include shallow dispersed sheet flooding within the lower reaches of several watersheds emanating from the Sierrita Mountains to the south. Toward the eastern end of the project limits, the Diablo Channel crosses beneath Valencia Road in an existing culvert. This major channel has a drainage area of approximately 12.5 square miles draining to Valencia Road. It crosses beneath the roadway through an existing 10-cell 58” x 36” corrugated metal pipe-arch culvert with concrete bank protection for inlet and outlet works. Overall, there are 23 points of flow concentration for existing drainage at Valencia Road within the project limits. The majority of these existing crossings occur within at-grade dip crossings and there are 4 existing culvert crossings including the Diablo Channel culvert described above.

The majority of the study area is located within Federal Emergency Management Agency (FEMA) designated flood zones except in isolated locations where adjacent developed areas have been removed from the floodplain through Letters of Map Revisions (LOMRs). Depths of flow associated with the FEMA floodplains varies from one to three feet. The existing FEMA floodplains are shown on Figure 2. The project also lies within the Black Wash critical hydrologic basin as defined by the Pima County Regional Flood Control District (RFCD).

1.3 Proposed Improvements

Drainage improvements along the corridor will include 23 new box and pipe culvert crossings designed to convey the 100-year storm beneath the roadway and replace existing storm drainage crossings, most of which are at-grade dip crossings. The existing roadway profile is being raised in combination with the construction of roadside channels to collect pavement drainage and offsite runoff draining toward the roadway. The new channels will have various erosion control linings, e.g. vegetated earthen, rock riprap, wire-tied riprap or concrete depending on the channel function and site specific needs within the project. Erosion/scour control measures will also be included at culvert inlets and outlets. Inlets of the cross drainage structures will generally be lowered and concrete lined. The existing concrete lined channels within the project limits will be maintained.

At a few locations, new drainage easements from adjacent landowners are required to accommodate some proposed roadway drainage structures. These easements are shown on the right-of-way plan sheets contained in the KHA roadway construction plan set.

1.4 Design Criteria

The drainage design criteria for this project follow the standards outlined in the Pima County *2013 Roadway Design Manual (RDM)*, the Pima County Floodplain Ordinance and in RFCD Technical Policies. These guidance documents establish the hydrologic design frequency for cross drainage structures to be the 100-year return period event. A Drainage Criteria Memorandum that documents the project hydrologic and hydraulic design parameters has been prepared and included in Appendix A.

Hydrology - The large variation in watershed sizes and drainage patterns warrants using different methods to compute discharge rates for differing watersheds. The watersheds are divided into regional and local watersheds. Per scoping meetings held early in the project, FLO-2D (Version 2009.06) was utilized to obtained 100-year peak discharge rates for regional watersheds and

Pima County hydrology method (computer program PC-Hydro Version 5.4.3) was utilized for local watersheds.

Hydraulic Designs – Existing hydraulic conditions (inundation limits, flow depths and velocities) for at-grade crossings in the predominantly sheet flow areas were based on floodplain mapping depths determined by 2-dimensional FLO-2D hydraulic modeling. Headwater depths and ponding limits for all existing culverts were determined using FHWA HY-8 computer software. Proposed culverts were designed to convey 100-year flood flows beneath the roadway. Where practical, given other roadway design constraints, maximum headwater elevations were kept at or below roadway subgrade level. Cross culvert and collector channel alignments were designed to avoid the adjacent Tucson Water 42-inch water main. Where possible, drop inlets and collector channel erosion protection were designed to incorporate "natural" materials, e.g. grouted rock riprap, etc., and/or buried scour protection measures.

Onsite Drainage – For the bulk of the project, onsite or pavement drainage facilities consist of roadside channels that also serve to collect offsite runoff where needed. Roadside collector channels were designed to collect and convey the 100-year flood. In addition, the project does contain a super-elevated segment of roadway on the west end near the connection with Ajo Way. In this segment, catch basins and a storm drain system will be designed along the median per the pavement drainage requirements found in Section 2.10 of the 2013 RDM.

SECTION 2.0 EXISTING CONDITIONS

2.1 Overview

The project site is located within the lower reaches of several watersheds emanating from the Sierrita Mountains southwest of Tucson. These offsite watersheds are broad and unconfined with low topographic relief. Watershed boundaries are poorly defined and numerous upstream locations have been identified where breakout flows occur between watersheds. Contributing runoff drains from southeast to northwest, crosses Valencia Road and eventually drains to the Black Wash. Some residential development has occurred upstream of the roadway, including the Sonoran Ranch Estates I project in the western portion of the project limits and Diablo Village Estates and Wes Star Estates that line the upstream (south) side of the project's eastern half. There is also a newly-platted residential subdivision at the southeast corner of Valencia Road and Vahalla Road called Vahalla Estates that has not been constructed yet. Flows generated from the residential developments tend to be more concentrated when they reach the roadway.

At approximate roadway station 208+80, the Diablo Channel crosses beneath Valencia Road in an existing culvert. The channel was excavated as part of the Diablo Village Estates residential subdivision improvements in the late 1970's or early 1980's. Upstream of its crossing with Valencia Road, the channel is a constructed trapezoidal channel with a 50-foot-wide earthen bottom and unlined banks. The existing culvert beneath Valencia Road is a 10-cell 58" X 36" corrugated metal pipe-arch culvert mitered to the concrete-lined upstream and downstream roadway embankment faces. A concrete drop inlet/grade control structure also exists in the channel upstream of the culvert inlet.

Overall, there are 23 points of flow concentration for existing drainage at Valencia Road within the project limits. The majority of these existing crossings occur within at-grade dip crossings and there are 4 existing culvert crossings including the Diablo Channel culvert described above. The three remaining cross drainage pipes are located adjacent to the Sonoran Ranch Estates subdivision development. These small pipes do not have 100-year capacity. Instead, they were installed as part of the subdivision improvements to pick up lesser, more frequent storm flows within the Right-of Way and convey them under Valencia Road to be discharged into downstream constructed channels.

In addition to the subdivisions upstream (south) of Valencia Road, three residential developments; Sonoran Ranch Estates II, Eagle Point Estates and Tucson Mountain Ranch have developed and constructed to varying degrees downstream (north) of the roadway within the project limits. These

subdivision developments contain platted drainageways (both public and private) that consist of natural flow corridors or constructed concrete-lined channels designed to accept drainage that crosses Valencia Road from south to north and convey it through the subdivisions away from the roadway. The existing drainage crossings are summarized in Table 1.

Table 1: Existing Drainage Crossings

Concentration Point	Roadway Station	Wash Name	Structure Description	100-Year Flow (cfs)
1A	91+05	Unnamed	At Grade Dip Section	47
1B	94+22	Unnamed	At Grade Dip Section	174
2	100+77	Unnamed	At Grade Dip Section	520
3A	114+48	Unnamed	At Grade Dip Section	335
3B	117+95	Unnamed	At Grade Dip Section	557
3C	122+70	Unnamed	At Grade Dip Section	193
4	131+80	Unnamed	At Grade Dip Section	122
5	134+20	Unnamed	At Grade Dip Section	746
6	142+86	Unnamed	At Grade Dip Section	422
7	155+48	Unnamed	1 – 24" CMP	160
8	162+13	Unnamed	1 – 24" CMP	57
9	166+10	Unnamed	At Grade Dip Section	245
10	171+06	Unnamed	1 – 24" CMP	523
11A	175+13	Unnamed	At Grade Dip Section	282
11B	177+98	Unnamed	At Grade Dip Section	228
12	180+35	Unnamed	At Grade Dip Section	200
13	188+28	Unnamed	At Grade Dip Section	666
14A	194+87	Unnamed	At Grade Dip Section	179
14B	198+40	Unnamed	At Grade Dip Section	77
15	200+85	Unnamed	At Grade Dip Section	97
16	208+80	Diablo Channel	10 – 57"x38" CMP Arch	1500
17	219+96	Unnamed	At Grade Dip Section	25
17A Iberia Ave.	219+21, 85 ft Lt	Unnamed	2-36" RCP	134
18	226+38	Unnamed	At Grade Dip Section	126

2.2 Existing Conditions Analyses

There are 23 points of concentration for existing drainage designated in the vicinity of the project site. As noted above in Section 1.4, FLO-2D (Version 2009.06) was utilized to obtained 100-year peak discharge rates for regional watersheds and Pima County hydrology method (computer program PC-Hydro Version 5.4.3) was utilized for local watersheds. The regional watersheds extend much farther south and have no well-defined watershed boundaries, while local watersheds have well-defined watershed boundaries and have watershed sizes less than 50 acres. For regional watersheds, FLO-2D models for both 3-hour type II and 24-hour type I storms were built and the higher discharges from either model were recorded at each concentration point.

Hydrologic cross sections were cut in the FLO-2D models to determine the quantities of flow that would cross Valencia Road at each of the drainage crossings. FLO-2D modeling parameters are summarized in Table 2.

Table 2: FLO-2D Modeling Parameters

FLO-2D Model Parameters	Description
FLO-2D Study Area	• Approximately 54.1 square miles. See Figure 3 for details.
Grid Size	• Overall model: 100 ft grid size with total 150,822 grids. Used for hydrologic analysis. • Detail model: 20 ft grid size with total 253,119 grids. Used for hydraulic analysis and floodplain mapping.
Topographic Data and Aerial Photos	• 2015 or 2008 PAG bare earth LIDAR data and 2015 6-inch aerial photos.
Storm Frequencies Evaluated	• 100-year rainfall events.
Rainfall Data (RAIN.DAT)	• Aerial reduction factor was not applied per PCRFCD TECH-033. • Three representative rainfall point with100-year NOAA 14 (upper 90%) rainfall depths for 3-hour and 24-hour were used. Rainfall depths from these three representative rainfall points, with each covers approximately 1/3 of the FLO-2D study area, were applied to the FLO-2D models. • Compared to the 3-hour Type II model, results from the 24-hr Type I storm model dominate flooding conditions within the study area. Therefore, the results from 24-hr Type I storm model were used for floodplain mapping.
Inflow Hydrographs (INFLOW.DAT)	• No inflow hydrograph for the overall model (100-ft grid). • Inflow hydrographs for the detail model (20-ft grid) were obtained from the overall model.
Infiltration (INFIL.DAT)	• Used the SCS Curve Number method. SCS Curve Numbers were obtained per the procedures in PC-Hydro User Guide (v5). • Soil data were obtained from Hydrologic Soil Groups maps attached to PC-Hydro User Manual. See also Figure 4. • Vegetation cover density is 20%. Desert Brush as the hydrologic cover type for entire watershed. • Impervious cover densities were estimated from latest aerial photos.
Manning's Roughness Coefficient	• Manning's "n"=0.035 for the entire FLO-2D study area to match previous studies in the vicinity. • Manning's values on some grids were calibrated to allow stable and faster FLO-2D simulation.
Limiting Froude Number (FPFROUDE.DAT)	• Limiting Froude Number on pavements (not STREET component) is 1.2. • Limiting Froude Number for all other areas utilized global limiting Froude Number of 0.95 (in CONT.DAT).
Hydraulic Structures (HYSTRUC.DAT)	• The existing culverts underneath Valencia Rd at the Diablo Channel.

The flow concentration point peak discharge rates are summarized in Table 3. The local watershed boundaries and regional FLO-2D hydrologic cross section locations are shown on the Offsite Watershed Map, Figure 5. Hydrologic computation sheets for the local watersheds (PC-Hydro) are provided in Appendix B. The peak discharge information for the regional watersheds can be found in the electronic FLO-2D model files in Appendix F. For the regional watersheds, the 24-hour FLO-2D modeling resulted in the higher discharge rates and are shown in Table 3.

Table 3: Summary of Peak Discharge Values

Concentration Point	Drainage Area (acre)	Q100 (cfs)	Watershed Type	Hydrology Method/Source
CP-1A	6.3	47	Local	PC-Hydro
CP-1B	N/A	174	Regional	FLO-2D (model included future developed conditions parameters for adjacent Pomegranate Farms property)
CP-2	N/A	520	Regional	
CP-3A	N/A	335	Regional	
CP-3B	N/A	557	Regional	
CP-3C	N/A	193	Regional	
CP-4	N/A	122	Regional	
CP-5	N/A	746	Regional	
CP-6	N/A	422	Regional	
CP-7	29.5	160	Local	PC-Hydro
CP-8	7.0	57	Local	PC-Hydro
CP-9	47.7	245	Local	PC-Hydro
CP-10	N/A	523	Regional	FLO-2D (model included future developed conditions parameters for adjacent AZ State Land property)
CP-11A	N/A	282	Regional	
CP-11B	N/A	228	Regional	
CP-12	N/A	200	Regional	
CP-13	N/A	666	Regional	
CP-14A	N/A	179	Regional	
CP-14B	N/A	77	Regional	
CP-15	17.6	97	Local	PC-Hydro
CP-16	N/A	1500	Regional	Previous Study*
CP-17	3.8	25	Local	PC-Hydro
CP-17A Iberia Ave.	25.1	134	Local	PC-Hydro
CP-18	21.2	126	Local	PC-Hydro

* obtained from previous Diablo Village Estates drainage design plans

Existing flooding conditions for this project site are characterized as wide spread sheet flow as nearly the entire land area within the right of way is inundated to some degree during a 100-year flood. FLO-2D was determined to be the most appropriate method for hydraulic modeling in this area. As noted above, the FLO-2D model with the 24-hr storm, compared to the 3-hr storm,

generated flood depths and higher peak discharges. Therefore, only the 24-hr storm FLO-2D models were further evaluated for existing conditions hydraulics and proposed cross drainage designs. The existing conditions flow depths from the 24-hr storm FLO-2D model are shown on Figure 6.

2.3 Summary of Existing Conditions

This study has determined that there are 23 points of concentration for offsite runoff crossing the roadway within the project limits. The contributing watersheds include 8 local watersheds, while the remaining 15 flow crossings are generated from regional watersheds. Peak discharges for the local watersheds were determined by the Pima County Hydrology method (PC-Hydro), and those for regional watersheds were determined by two-dimensional hydrologic modeling with FLO-2D. For regional watersheds, the maximum flow depths and peak discharges from the 24-hr storm were higher than those from the 3-hr storm. Therefore, the 24-hr storm FLO-2D model was utilized for further crossing drainage evaluations.

SECTION 3.0 PROPOSED CROSS DRAINAGE IMPROVEMENTS

3.1 Offsite Drainage Approach

The existing roadway was examined by reviewing the project topography, aerial photography and conducting site visits to determine logical locations for new cross drainage culverts. Along the western 1 mile of the project, which borders the proposed Pomegranate Farms development on the south and Bureau of Land Management (BLM) land on the north, a project goal of fitting all roadway improvements within the existing Right-of-Way (ROW) such that no offsite easements were needed from downstream BLM land, placed an additional constraint on the roadway and cross drainage design efforts. With this constraint it was critical to place proposed culvert outlets at the deepest available watercourse thalweg locations along the north ROW to accept cross drainage discharges. This allowed the cross culverts to be placed as low as possible, which in turn helped keep the overlying roadway profile lower and gave the best opportunity to design adequate slopes on the culverts.

All of the proposed culverts in this section included some form of drop inlets on the south ends to further keep the culvert profiles as low as possible. In addition, because offsite drainage from the Pomegranate Farms property reaches the Valencia Road ROW mostly as dispersed sheet flow, laterally extended drop inlets or collector channels were needed to capture the offsite flow and convey it to the next available downstream culvert inlet. The drop inlets and collector channels were designed to maintain required horizontal and vertical separations from the existing Tucson Water 42-inch diameter water line that runs just inside the existing south ROW.

This aspect of the design was also applicable along the undeveloped Arizona State Land Department (ASLD) property further to the east between the Sonoran Ranch Estates I development and Vahalla Road. Although the Pomegranate Farms and ASLD properties are currently undeveloped, design runoff discharges were determined based on future developed conditions to ensure that the Valencia Road cross drainage system would adequately accommodate future peak discharges from those properties.

Along the remainder of the project limits, existing development projects generally included downstream drainage ways that made logical outlet locations for new cross culverts under Valencia Road. On the upstream (inlet) side along these segments, drainage discharge locations from the adjacent developments were determined and either new culvert inlets were placed directly in line with the incoming flows, or drop inlets or collector channels were designed to laterally capture incoming discharges and convey them to the next available downstream culvert.

3.2 Proposed Conditions Analyses

General drainage patterns are maintained under proposed conditions such that the hydrologic cross sections and watershed boundaries are not significantly altered. The watersheds remain as depicted on Figure 5, Offsite Watershed Map, and for proposed conditions, peak discharges remain unchanged from those listed in Table 3.

As noted in the previous section, for the Pomegranate Farms property, Concentration Points (CPs) 1A through 6, CMG utilized peak discharges that were based on future developed conditions. This was done in cooperation with the RFCD in an effort to ensure that the proposed drainageways and culverts within the development, as well as the proposed downstream culverts under Valencia Road were designed to adequately convey peak discharges once the property is fully developed. The method required by the RFCD involved evaluation of the following two scenarios: 1) 100-year offsite discharge + 10-year onsite discharge; 2)10-year offsite discharge + 100-year onsite discharge. The larger peak discharges produced from the two scenarios were then used for design. The results of the Pomegranate Farms peak discharge determinations were evaluated and then similar increases in discharges were applied to CPs 11A through 14B adjacent to the undeveloped ASLD property east of Sonoran Ranch Estates 1. With the exception of the Diablo Channel (CP-16), the remainder of contributing watersheds consist of previously developed areas that were modeled as such in the PC-Hydro computations. For the Diablo Channel, the proposed discharge rate of 1500 cfs was based on the original channel design discharge from the previous Diablo Village Estates drainage improvement plans.

The proposed discharge rates are summarized in Table 3 and shown on Figures 5 and 7. Hydrologic computation sheets for the local watersheds (PC-Hydro) are provided in Appendix B. The peak discharge information for the regional watersheds can be found in the electronic FLO-2D model files in Appendix F.

Proposed culverts consisted of reinforced concrete box culverts (RCBC), steel pipe arch culverts or circular steel spiral rib pipe (SRP) of varying sizes depending on flow requirements. The proposed culverts were analyzed using the FHWA Culvert Analysis program HY-8, and proposed roadside collector channels were rated by normal depth analyses using Manning's equation found in the FHWA Hydraulic Toolbox computer program. Proposed culvert data are summarized in Table 4 and a summary table of the proposed channel design data is located in Appendix D. Hydraulic computation sheets for the proposed culverts are included in Appendix C and computation sheets for the proposed channels are included in Appendix D.

Table 4: Proposed Cross Drainage Culverts

Concentration Point	Roadway Station	Proposed Structure	Design Flow (cfs)	Outlet Velocity (ft/s)	Design HW Elev.	Approx. Existing WSEL
1A	91+05	3-24" SRP	47	6.6	2435.3	2435.4
1B	94+65	1-8'x4' RCBC	174	8.9	2437.4	2437.3
2	100+77	3-10'x4' RCBC	520	5.3	2438.4	2438.4
3A	114+48	3-8'x4' RCBC	335	3.8	2443.3	2443.3
3B	117+95	4-49"x33" Steel Pipe Arch	557	4.9	2444.7	2444.9
3C	122+70	4-49"x33" Steel Pipe Arch	193	4.5	2444.9	2445.0
4	131+84	2-48" SRP	122	8.9	2447.4	2447.6
5	134+20	3-10'x4' RCBC	746	5.6	2447.3	2447.7
6	142+85	3-10'x4' RCBC	422	5.6	2453.5	2454.0
7	155+48	2-48" SRP	160	14.5	2456.9	2457.1
8	162+13	2-30" SRP	57	11.0	2459.2	2459.5
9	166+10	3-48" SRP	245	13.8	2461.2	2461.2
10	171+00	3-10'x4' RCBC	523	10.1	2461.8	2462.1
11A	175+28	3-8'x4' RCBC	282	8.7	2463.8	2464.2
11B	178+13	3-57"X38" Steel Pipe Arch	228	9.2	2464.9	2465.1
12	180+28	4-49"x33" Steel Pipe Arch	200	8.3	2464.8	2465.5
13	188+26	4-8'x4' RCBC	666	5.2	2466.8	2467.1
14A	194+85	4-36" SRP	179	9.5	2468.8	2469.1
14B	198+40	2-36" SRP	77	9.1	2470.0	2469.9
15	200+70	3-42"x29" Steel Pipe Arch	97	7.5	2470.4	2471.0
16	208+80	4-10'x5' RCBC	1500	12.4	2471.8	2472.0
17	219+96	2-24" SRP	25	7.9	2477.1	2477.6
17A Iberia Ave.	219+21, 85 ft Lt	3-49"x33" Steel Pipe Arch	134	9.3	2473.0	2473.5
18	226+38	3-49"x33" Steel Pipe Arch	126	8.0	2479.6	2480.1

The roadway is generally raised above existing ground to allow 100-year offsite drainage to be conveyed beneath the roadway in the new cross culverts. To minimize the amount of roadway fill, almost all of the proposed culverts were designed to have drop inlets. The drop inlets are proposed to be concrete lined with mainly 2 horizontal to 1 vertical (H:V) drop slopes and 5 foot to 6 foot wide landings at the toe of the drops to both minimize sediment build up and allow maintenance access to the inlets.

The proposed culverts were coded into the proposed conditions FLO-2D (HYSTRUC.DAT). These culverts, along with raised roadway, proposed interceptor channels and a proposed training berm between CP-10 and CP-11A on public ROW, are included in the proposed conditions FLO-2D model (24-hr storm) to simulate hydraulic conditions for the proposed conditions. Proposed conditions flow depth data are shown on Figure 7.

Comparing the flow depths on Figures 6 and 7, the proposed flow depths are generally similar to those in existing conditions at the edge of the ROW. Slight flow depth increases or decreases along the right of way limits are the result of changing dispersed sheet flow conditions into locally concentrated flows by collection and diversion to the proposed culverts. Overall, the proposed roadway has no adverse impact to adjacent properties and therefore no further mitigation measures are provided.

3.2.1 Preliminary Storm Drain

The proposed roadway section does not contain outside curbs, so largely, onsite pavement runoff has been designed to either sheet flow off the ROW or be collected in roadside channels and conveyed to the next logical culvert inlet or downstream watercourse. However, the roadway does contain a super-elevated segment on the west end near the connection with Ajo Way. In this segment, catch basins and a storm drain system will be designed to capture the east-bound pavement drainage and discharge it outside the paved roadway section.

3.3 Sedimentation

The purpose of the sedimentation evaluation was to assess the impact of erosion and sedimentation processes on the ability of the proposed culverts to function as intended, to minimize culvert maintenance requirements, and to minimize the impact of the culverts on upstream and downstream erosion/sedimentation. Achieving these goals is challenging in a moderate sediment load alluvial fan-like environment, where flow can be highly disbursed and unpredictable from event to event.

To minimize the probability of sediment deposition within the culverts, headwater elevations were maintained at or below existing upstream water surface elevations so there will be minimal change in the approach flow velocities. The height of drop inlets were minimized and the inlets designed on 2:1 slopes as opposed to vertical drops. Minimum 0.5% culvert slopes produced cleaning velocities in excess of 3 feet/second within most of the culverts during the estimated 2-year flood event. Smooth bore culverts were utilized to help minimize surface roughness and sediment

deposits. These measures were employed to decrease the likelihood of sediment deposition that could compromise culvert function.

Despite the aforementioned measures to control sediment build up, moderate sediment yields from the undeveloped contributing watersheds dictate that post-flood channel/culvert maintenance be performed at some locations to maintain design capacity. Annual sediment yields vary at different locations, because of differences in soil characteristics, contributing drainage areas, developments, and drainage patterns. Collector channels and roadside swales are also susceptible to future sediment deposition. Annual and post-flood drainage system inspections should be conducted to maintain the system's hydraulic capacities.

3.4 Channelization

New channels have been proposed to redirect drainage to or from the proposed cross drainage system, to prevent offsite runoff from overtopping the roadway, and/or to minimize the need for drainage easements outside of the ROW. The channels were designed to contain the 100-year runoff plus a minimum 1-foot of freeboard. Collector channels were designed with concrete back slopes (upstream) and wire-tied Reno mattress erosion control aprons along the toes of the slope to act as scour prevention splash pads for flows entering the channels over the side. Channels with normal depth velocities in excess of 4 feet per second were designed with additional riprap erosion control linings on the bottoms and fore slopes. A channel design summary table and open channel hydraulic computation sheets have been provided in Appendix D.

3.5 Outlet Protection

Outlet erosion calculations for proposed culvert outlets were required at all crossings on this project. Depending on the outlet flow characteristics (velocity & depth), the outlet protection designs followed US Army Corps of Engineers HEC-14 procedures for at-grade riprap outlet aprons or energy dissipation basins. Table 5 summarizes the parameters for the outlet protection measures at each location requiring such protection. Design computation sheets for outlet erosion protection have been provided in Appendix E.

Table 5: Erosion Control Outlet Protection Summary

Roadway Station / Concentration Point	Proposed Culvert	Outlet Protection Type	Outlet Protection Length (ft)	Outlet Protection Thickness (ft)
91+05 / CP-1A	3-24" SRP	Dumped Riprap Apron (D_{50}=0.5 ft)	8	1.0
94+65 / CP-1B	1-8'x4' RCBC	Dumped Riprap Apron (D_{50}=1.0 ft)	15	2.0
100+77 / CP-2	3-10'x4' RCBC	Dumped Riprap Apron (D_{50}=0.5 ft)	13	1.0
114+48 / CP-3A	3-8'x4' RCBC	Dumped Riprap Apron (D_{50}=0.5 ft)	15	1.0
117+95 / CP-3B	4-49"x33" Steel Pipe Arch	Dumped Riprap Apron (D_{50}=0.5 ft)	11	1.0
122+70 / CP-3C	4-49"x33" Steel Pipe Arch	Dumped Riprap Apron (D_{50}=0.5 ft)	11	1.0
131+84 / CP-4	2-48" SRP	Dumped Riprap Apron (D_{50}=1.0 ft)	13	2.0
134+20 / CP-5	3-10'x4' RCBC	Dumped Riprap Apron (D_{50}=0.5 ft)	15	1.0
142+85 / CP-6	3-10'x4' RCBC	Dumped Riprap Apron (D_{50}=0.5 ft)	10	1.0
178+13 / CP-11B	3-57"X38" Steel Pipe Arch	Dumped Riprap Apron (D_{50}=0.75 ft)	16	1.5
180+28 / CP-12	4-49"x33" Steel Pipe Arch	Dumped Riprap Apron (D_{50}=0.75 ft)	14	1.5
188+26 / CP-13	4-8'x4' RCBC	Dumped Riprap Apron (D_{50}=0.5 ft)	16	1.0
194+85 / CP-14A	4-36" SRP	Dumped Riprap Apron (D_{50}=0.5 ft)	12	1.0
198+40 / CP-14B	2-36" SRP	Dumped Riprap Apron (D_{50}=0.5 ft)	12	1.0
200+70 / CP-15	3-42"x29" Steel Pipe Arch	Dumped Riprap Apron (D_{50}=1.0 ft)	12	2.0
208+80 / CP-16	4-10'x5' RCBC	Wire-tied Riprap Pre-formed Scour Hole Basin	40	1.5
219+96 / CP-17	2-24" SRP	Dumped Riprap Apron (D_{50}=0.5 ft)	8	1.0
219+21 85' Lt / CP-17A	3-49"x33" Steel Pipe Arch	Dumped Riprap Apron (D_{50}=0.5 ft)	11	1.0
226+38 / CP-18	3-49"x33" Steel Pipe Arch	Dumped Riprap Apron (D_{50}=0.5 ft)	11	1.0

3.6 Right-of-Way Requirements

Insufficient right-of-way exists to contain several of the proposed drainage system structures for this project. The roadway right-of-way plans prepared by KHA, which compliment this drainage report, should be consulted for proposed right-of-way limits and/or drainage easements that are proposed for this project.

3.7 Mitigation Measures

Riparian mapping and mitigation for this project are outside the scope of this report. However, per review of the Pima County RFCD GIS internet website, the proposed cross culverts may impact riparian habitat areas. Mitigation regulated under Section 16.30 of the Pima County Floodplain and Erosion Hazard Management Ordinance could be required if it is determined that the proposed construction impacts more than 1/3 acre of this habitat.

3.8 Permitting Requirements

The Pima County RDM includes a task to address whether or not the project encroaches on regulated floodplains and if a CLOMR and/or LOMR are required in the case of Federal Emergency Management (FEMA) floodplains. The need for a CLOMR is triggered by a greater than 1.0 foot increase in water surface elevation (WSE) outside of the right-of-way. All WSE increases in the Valencia Road FEMA floodplains are less than 1.0 foot, therefore a CLOMR is not required. During the Final PS&E Phase of the project, an evaluation of impacts by the roadway project to the FEMA floodplains will be conducted. This evaluation will determine whether or not a post-construction LOMR is warranted.

A jurisdictional delineation to determine watercourse areas within the project limits, which may be subject to Section 404 Clean Water Act regulations, has been completed by the environmental consultant for this project. All Section 404 permitting for this project is being handled by the environmental consultant and is outside the scope of this study. Drainage system design information will be coordinated with the environmental consultant by CMG and KHA to be used to determine impacts to jurisdictional 404 waters by the proposed roadway drainage improvements.

SECTION 4.0 REFERENCES

1. Natural Resources Conservation Service, Hydrologic Soils Map, Soil Survey 669 – Eastern Pima County, 1999.

2. Pima County Department of Transportation and Flood Control District, *Drainage and Channel Design Standards for Local Drainage*, June 1984.

3. Pima County Regional Flood Control District, *Floodplain and Erosion Hazard Management Ordinance No. 2010-FC5*, May 2010.

4. Pima County Regional Flood Control District, *PC-Hydro V5, Pima County Hydrology Procedures*, March 2007.

5. Pima County Department of Transportation and Flood Control District, *Pima County Storm Drain Design – Guidelines and Standard Plans*, March 23, 1981.

6. Pima County Department of Transportation, *Roadway Design Manual*, Fourth Edition, 2013.

7. United States Federal Highway Administration, *Hydraulic Design Series No. 5*, Hydraulic Design of Highway Culverts, 1985.

8. United States Federal Highway Administration, *Urban Drainage Design Manual*, Hydraulic Engineering Circular No. 22, November 1996.

9. United States Federal Highway Administration, *Hydraulic Design of Energy Dissipators for Culverts and Channels*, Hydraulic Engineering Circular No. 14, July 2006.

FIGURES

APPENDIX A

DRAINAGE CRITERIA MEMORANDUM

CMG DRAINAGE ENGINEERING, INC.

3555 N. MOUNTAIN AVE. • P.O. BOX 64880 (MAIL) • TUCSON, AZ 85728 • PHONE: (520) 882-4244 • FAX: (520) 888-1421

DRAINAGE CRITERIA MEMORANDUM

DATE: February 25, 2016

TO: Paul Bennett, PE – Pima County DOT Project Manager

FROM: Jerry Curless, PE – CMG Drainage Engineering (CMG)

CC: Bill Zimmerman, Evan Canfield – PCRFCD; Rick Solis – Kimley-Horn; Jiankang Wang – CMG

SUBJECT: **Valencia Road: Ajo Highway to Wade Road (4RTVWE)**

Introduction

This memorandum is intended to confirm technical guidelines for the drainage design of the subject Valencia Road widening project, and to document discussions that were held in a February 18, 2016 pre-design meeting at Pima County. The project area is located in unincorporated Pima County and consists of widening approximately 2¾ miles of the Valencia Roadway from two lanes to four lanes of traffic from the intersection of Ajo Highway (AZ 86) and matching into the existing 4-lane divided section west of the Valencia and Wade Road intersection.

The watersheds that contribute stormwater runoff to the project are varied. Undeveloped watersheds originate in the Sierrita Mountains approximately 10 miles south of the project and contribute mainly to the western half of the project limits. The undeveloped watersheds are characterized by low topographic relief, small under fit channels that do not fully contain 100-year flood flows and are distributary in nature. Flow conditions from these watersheds are typified by dispersed sheet flow. Some residential development has occurred upstream of the roadway, including the Sonoran Ranch Estates I project in the western portion of the project limits and various other residential developments that line the upstream (south) side of the project's eastern half. Flows generated from the residential developments tend to be more concentrated in nature when they reach the roadway.

The methodologies and design parameters for the project are listed below.

Hydrology:

1. To remain consistent with the drainage methodology utilized on the previously designed segment of Valencia Road east of this project's site (Mark Rd to Wade Rd), the Pima County Regional Flood Control District (PCRFCD) directed that peak discharges for the entire project length be determined using FLO-2D ver. 2009 software with the same input parameters from the previous Mark Rd to Wade Rd project. The only exception to this is that for contributing watersheds within the Sonoran Ranch Estates I development, Pima Co PC-Hydro methods and software will be used.
2. The FLO-2D model will utilize a 20-foot grid size within the road ROW and in areas approximately ½ mile upstream and 1000 feet downstream of the roadway.

3. CMG will run both 3-hour and 24-hour storm models and use the higher discharges from the two.
4. Watershed delineation will be based on PAG topographic data and aerial photos to be supplied by Pima Co.
5. For the possible post-construction LOMR, peak discharges should match previous adjacent LOMRs as close as possible.

Hydraulic Designs:

Existing hydraulic conditions

1. Existing hydraulic conditions within the project limits will be determined with FLO-2D using the same approach as the previous Wade Rd to Mark Rd project.
2. As applicable, HEC-RAS/Manning's Method/HY-8 will be used in determining the existing hydraulic conditions for channels and culverts.

Proposed Hydraulic Designs

1. Proposed hydraulic conditions within the project limits will be determined with FLO-2D using the same approach as the previous Wade Rd to Mark Rd project.
2. Culvert design criteria:
   - Culverts will be designed to convey full 100-yr flows beneath the roadway;
   - Maximum headwater elevations will be kept at or below roadway subgrade level;
   - It's anticipated that steel spiral rib pipe, with similar hydraulic characteristics to RCP, will be used for pipe culverts in this project. This will be consistent with those used in the Wade Rd to Mark Rd project;
3. Culvert drop inlet and collector channel designs:
   - Roadway design will be for a 4-lane roadway section and collector channel alignments will be designed to avoid the adjacent Tucson Water 42-inch water main;
   - Where possible, drop inlets and collector channel erosion protection will be designed to incorporate "natural" materials, e.g. grouted rock riprap, etc., and/or buried scour protection measures;

If there are any technical methodologies or design parameters that are not covered above, the latest version of PCRFCD's applicable Technical Policies and Standards or the Pima Co Roadway Design Manual will be followed.

APPENDIX B

LOCAL WATERSHED HYDROLOGIC COMPUTATIONS
(PC-HYDRO)

PIMA COUNTY
FLOOD CONTROL

HYDROLOGIC DATA SHEET FOR PIMA COUNTY FLOOD PEAK PROCEDURE

Generated using methonds provided by Pima County Regional Flood Control District

Client:	KHA/Pima County	Prepared by:	BJK
Project Name:	Valencia Rd	Date:	06/24/2016
Concentration Point:	CP-1A	Job #	15-043
Watershed Area:	6.33 Acres	Watershed Type	Medium Density Urbanized

Watercourse Data By Reach

Reach No.	Height (Hi)	Length (Li)	Slope (Si)	Basin Factor (Nb)
1	10.4	762	0.0136	0.035

Length of Watercourse (Lc):	762	feet	Mean Slope:	0.0131	
Length to Cen. of Gravity (Lca):	311	feet	Weighted Basin Fac:	0.035	
Veg. Cover Type(s):	Desert Brush		Veg. Cover Density:	20	

RETURN PERIOD: 100-years

Rainfall Depths: NOAA Atlas 14 (90% UCL) @ Latitude: 32.1316 Longitude: -111.1441

Duration:	5-min	10-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
Point Values (in):	0.86	1.3	1.62	2.18	2.69	2.99	3.12	3.4	3.64	4.35

Soil Type	Percent	Curve # (CN)	Adj. Curve # (CN*)	Runoff Coef. (C)
B	-	-	-	-
C	100	88	90.92	0.661
D	-	-	-	-
Imp.	20	99	99	0.956

Weighted Runoff Coef. (Cw):	0.72	
Time of Concentration:	5	min
Rainfall Intensity (i) @ Tc:	10.32	in/hr
Runoff Supply Rate (q) @ Tc:	7.43	in/hr
PEAK DISCHARGE:	47.4	cfs

Lesser Return Periods

Return Period	Ratio	Qpeak
2-year	0.2	9.5
5-year	0.3	14.2
10-year	0.45	21.3
25-year	0.65	30.8
50-year	0.85	40.3

PIMA COUNTY
FLOOD CONTROL

HYDROLOGIC DATA SHEET FOR PIMA COUNTY FLOOD PEAK PROCEDURE

Generated using methonds provided by Pima County Regional Flood Control District

Client:	KHA/Pima County	Prepared by:	BJK
Project Name:	Valencia Rd	Date:	05/04/2016
Concentration Point:	CP-7	Job #	15-043
Watershed Area:	29.53 Acres	Watershed Type	Medium Density Urbanized

Watercourse Data By Reach

Reach No.	Height (Hi)	Length (Li)	Slope (Si)	Basin Factor (Nb)
1	30	2835	0.0106	0.035

Length of Watercourse (Lc):	2835	feet	Mean Slope:	0.0106	
Length to Cen. of Gravity (Lca):	1344	feet	Weighted Basin Fac:	0.035	
Veg. Cover Type(s):	Desert Brush		Veg. Cover Density:	20	

RETURN PERIOD: 100-years

Rainfall Depths: NOAA Atlas 14 (90% UCL) @ Latitude: 32.1316 Longitude: -111.1441

Duration:	5-min	10-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
Point Values (in):	0.86	1.3	1.62	2.18	2.69	2.99	3.12	3.4	3.64	4.35

Soil Type	Percent	Curve # (CN)	Adj. Curve # (CN*)	Runoff Coef. (C)
B	-	-	-	-
C	100	88	90.92	0.661
D	-	-	-	-
Imp.	35	99	99	0.956

Weighted Runoff Coef. (Cw):	0.764	
Time of Concentration:	12.5	min
Rainfall Intensity (i) @ Tc:	7.01	in/hr
Runoff Supply Rate (q) @ Tc:	5.36	in/hr
PEAK DISCHARGE:	159.5	cfs

Lesser Return Periods

Return Period	Ratio	Qpeak
2-year	.20	31.9
5-year	.30	47.9
10-year	.45	71.8
25-year	.65	103.7
50-year	.85	135.6

PIMA COUNTY
FLOOD CONTROL

HYDROLOGIC DATA SHEET FOR PIMA COUNTY FLOOD PEAK PROCEDURE

Generated using methonds provided by Pima County Regional Flood Control District

Client:	KHA/Pima County	Prepared by:	BJK
Project Name:	Valencia Rd	Date:	05/04/2016
Concentration Point:	CP-8	Job #	15-043
Watershed Area:	7.01 Acres	Watershed Type	Medium Density Urbanized

Watercourse Data By Reach

Reach No.	Height (Hi)	Length (Li)	Slope (Si)	Basin Factor (Nb)
1	16.5	1423	0.0116	0.025

Length of Watercourse (Lc):	1423	feet	Mean Slope:	0.0112	
Length to Cen. of Gravity (Lca):	712	feet	Weighted Basin Fac:	0.025	
Veg. Cover Type(s):	Desert Brush		Veg. Cover Density:	20	

RETURN PERIOD: 100-years

Rainfall Depths: NOAA Atlas 14 (90% UCL) @ Latitude: 32.1316 Longitude: -111.1441

Duration:	5-min	10-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
Point Values (in):	0.86	1.3	1.62	2.18	2.69	2.99	3.12	3.4	3.64	4.35

Soil Type	Percent	Curve # (CN)	Adj. Curve # (CN*)	Runoff Coef. (C)
B	-	-	-	-
C	100	88	90.92	0.661
D	-	-	-	-
Imp.	40	99	99	0.956

Weighted Runoff Coef. (Cw):	0.779	
Time of Concentration:	5	min
Rainfall Intensity (i) @ Tc:	10.31	in/hr
Runoff Supply Rate (q) @ Tc:	8.04	in/hr
PEAK DISCHARGE:	56.8	cfs

Lesser Return Periods

Return Period	Ratio	Qpeak
2-year	.20	11.4
5-year	.30	17
10-year	.45	25.5
25-year	.65	36.9
50-year	.85	48.3

PIMA COUNTY
FLOOD CONTROL

HYDROLOGIC DATA SHEET FOR PIMA COUNTY FLOOD PEAK PROCEDURE

Generated using methonds provided by Pima County Regional Flood Control District

Client:	KHA/Pima County	Prepared by:	BJK
Project Name:	ValencIa Rd	Date:	05/04/2016
Concentration Point:	CP-9	Job #	15-043
Watershed Area:	47.7 Acres	Watershed Type	Medium Density Urbanized

Watercourse Data By Reach

Reach No.	Height (Hi)	Length (Li)	Slope (Si)	Basin Factor (Nb)
1	29	3179	0.0091	0.035

Length of Watercourse (Lc):	3179	feet	Mean Slope:	0.0091	
Length to Cen. of Gravity (Lca):	1365	feet	Weighted Basin Fac:	0.035	
Veg. Cover Type(s):	Desert Brush		Veg. Cover Density:	20	

RETURN PERIOD: 100-years

Rainfall Depths: NOAA Atlas 14 (90% UCL) @ Latitude: 32.1316 Longitude: -111.1441

Duration:	5-min	10-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
Point Values (in):	0.86	1.3	1.62	2.18	2.69	2.99	3.12	3.4	3.64	4.35

Soil Type	Percent	Curve # (CN)	Adj. Curve # (CN*)	Runoff Coef. (C)
B	-	-	-	-
C	100	88	90.92	0.661
D	-	-	-	-
Imp.	35	99	99	0.956

Weighted Runoff Coef. (Cw):	0.764	
Time of Concentration:	14.1	min
Rainfall Intensity (i) @ Tc:	6.66	in/hr
Runoff Supply Rate (q) @ Tc:	5.09	in/hr
PEAK DISCHARGE:	244.6	cfs

Lesser Return Periods

Return Period	Ratio	Qpeak
2-year	.20	48.9
5-year	.30	73.4
10-year	.45	110.1
25-year	.65	159
50-year	.85	207.9

PIMA COUNTY
FLOOD CONTROL

HYDROLOGIC DATA SHEET FOR PIMA COUNTY FLOOD PEAK PROCEDURE

Generated using methonds provided by Pima County Regional Flood Control District

Client:	KHA/Pima County	Prepared by:	BJK
Project Name:	Valencia Rd	Date:	05/04/2016
Concentration Point:	CP-15	Job #	15-043
Watershed Area:	17.61 Acres	Watershed Type	Medium Density Urbanized

Watercourse Data By Reach

Reach No.	Height (Hi)	Length (Li)	Slope (Si)	Basin Factor (Nb)
1	10	1337	0.0075	0.035

Length of Watercourse (Lc):	1337 feet	Mean Slope:	0.0075
Length to Cen. of Gravity (Lca):	620 feet	Weighted Basin Fac:	0.035
Veg. Cover Type(s):	Desert Brush	Veg. Cover Density:	20

RETURN PERIOD: 100-years

Rainfall Depths: NOAA Atlas 14 (90% UCL) @ Latitude: 32.1316 Longitude: -111.1441

Duration:	5-min	10-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
Point Values (in):	0.86	1.3	1.62	2.18	2.69	2.99	3.12	3.4	3.64	4.35

Soil Type	Percent	Curve # (CN)	Adj. Curve # (CN*)	Runoff Coef. (C)
B	-	-	-	-
C	100	88	90.92	0.661
D	-	-	-	-
Imp.	5	99	99	0.956

Weighted Runoff Coef. (Cw):	0.676	
Time of Concentration:	9	min
Rainfall Intensity (i) @ Tc:	8.08	in/hr
Runoff Supply Rate (q) @ Tc:	5.46	in/hr
PEAK DISCHARGE:	96.8	cfs

Lesser Return Periods

Return Period	Ratio	Qpeak
2-year	.20	19.4
5-year	.30	29.1
10-year	.45	43.6
25-year	.65	63
50-year	.85	82.3

PIMA COUNTY
FLOOD CONTROL

HYDROLOGIC DATA SHEET FOR PIMA COUNTY FLOOD PEAK PROCEDURE

Generated using methonds provided by Pima County Regional Flood Control District

Client:	KHA/Pima County	Prepared by:	RMS
Project Name:	Valencia Rd	Date:	07/21/2016
Concentration Point:	CP-17	Job #	15-043
Watershed Area:	3.8 Acres	Watershed Type	Medium Density Urbanized

Watercourse Data By Reach

Reach No.	Height (Hi)	Length (Li)	Slope (Si)	Basin Factor (Nb)
1	4.1	1104	0.0037	0.025

Length of Watercourse (Lc):	1104 feet	Mean Slope:	0.0036
Length to Cen. of Gravity (Lca):	592 feet	Weighted Basin Fac:	0.025
Veg. Cover Type(s):	Desert Brush	Veg. Cover Density:	20

RETURN PERIOD: 100-years

Rainfall Depths: NOAA Atlas 14 (90% UCL) @ Latitude: 32.1316 Longitude: -111.1441

Duration:	5-min	10-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
Point Values (in):	0.86	1.3	1.62	2.18	2.69	2.99	3.12	3.4	3.64	4.35

Soil Type	Percent	Curve # (CN)	Adj. Curve # (CN*)	Runoff Coef. (C)
B	-	-	-	-
C	100	88	90.92	0.661
D	-	-	-	-
Imp.	30	99	99	0.956

Weighted Runoff Coef. (Cw):	0.749	
Time of Concentration:	7.5	min
Rainfall Intensity (i) @ Tc:	8.65	in/hr
Runoff Supply Rate (q) @ Tc:	6.48	in/hr
PEAK DISCHARGE:	24.8	cfs

Lesser Return Periods

Return Period	Ratio	Qpeak
2-year	.20	5
5-year	.30	7.4
10-year	.45	11.2
25-year	.65	16.1
50-year	.85	21.1

PIMA COUNTY
FLOOD CONTROL

HYDROLOGIC DATA SHEET FOR PIMA COUNTY FLOOD PEAK PROCEDURE

Generated using methonds provided by Pima County Regional Flood Control District

Client:	KHA/Pima County	Prepared by:	RMS/jlc
Project Name:	Valencia Rd	Date:	07/21/2016
Concentration Point:	CP-17A	Job #	15-043
Watershed Area:	25.1 Acres	Watershed Type	Medium Density Urbanized

Watercourse Data By Reach

Reach No.	Height (Hi)	Length (Li)	Slope (Si)	Basin Factor (Nb)
1	35	3793	0.0092	0.025

Length of Watercourse (Lc):	3793 feet	Mean Slope:	0.0092
Length to Cen. of Gravity (Lca):	2345 feet	Weighted Basin Fac:	0.025
Veg. Cover Type(s):	Desert Brush	Veg. Cover Density:	20

RETURN PERIOD: 100-years

Rainfall Depths: NOAA Atlas 14 (90% UCL) @ Latitude: 32.1316 Longitude: -111.1441

Duration:	5-min	10-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
Point Values (in):	0.86	1.3	1.62	2.18	2.69	2.99	3.12	3.4	3.64	4.35

Soil Type	Percent	Curve # (CN)	Adj. Curve # (CN*)	Runoff Coef. (C)
B	-	-	-	-
C	100	88	90.92	0.661
D	-	-	-	-
Imp.	30	99	99	0.956

Weighted Runoff Coef. (Cw):	0.749	
Time of Concentration:	12.2	min
Rainfall Intensity (i) @ Tc:	7.09	in/hr
Runoff Supply Rate (q) @ Tc:	5.31	in/hr
PEAK DISCHARGE:	134.4	cfs

Lesser Return Periods

Return Period	Ratio	Qpeak
2-year	0.2	26.9
5-year	0.3	40.3
10-year	0.45	60.5
25-year	0.65	87.4
50-year	0.85	114.3

PIMA COUNTY
FLOOD CONTROL

HYDROLOGIC DATA SHEET FOR PIMA COUNTY FLOOD PEAK PROCEDURE

Generated using methonds provided by Pima County Regional Flood Control District

Client:	KHA/Pima County	Prepared by:	RMS
Project Name:	Valencia Rd	Date:	07/21/2016
Concentration Point:	CP-18	Job #	15-043
Watershed Area:	21.2 Acres	Watershed Type	Medium Density Urbanized

Watercourse Data By Reach

Reach No.	Height (Hi)	Length (Li)	Slope (Si)	Basin Factor (Nb)
1	27.5	3037	0.0091	0.025

Length of Watercourse (Lc):	3037	feet	Mean Slope:	0.0089	
Length to Cen. of Gravity (Lca):	1561	feet	Weighted Basin Fac:	0.025	
Veg. Cover Type(s):	Desert Brush		Veg. Cover Density:	20	

RETURN PERIOD: 100-years

Rainfall Depths: NOAA Atlas 14 (90% UCL) @ Latitude: 32.1316 Longitude: -111.1441

Duration:	5-min	10-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
Point Values (in):	0.86	1.3	1.62	2.18	2.69	2.99	3.12	3.4	3.64	4.35

Soil Type	Percent	Curve # (CN)	Adj. Curve # (CN*)	Runoff Coef. (C)
B	-	-	-	-
C	100	88	90.92	0.661
D	-	-	-	-
Imp.	30	99	99	0.956

Weighted Runoff Coef. (Cw):	0.749	
Time of Concentration:	9.8	min
Rainfall Intensity (i) @ Tc:	7.84	in/hr
Runoff Supply Rate (q) @ Tc:	5.88	in/hr
PEAK DISCHARGE:	125.6	cfs

Lesser Return Periods

Return Period	Ratio	Qpeak
2-year	.20	25.1
5-year	.30	37.7
10-year	.45	56.5
25-year	.65	81.6
50-year	.85	106.8

APPENDIX C

PROPOSED CROSS CULVERT HYDRAULIC COMPUTATIONS

HY-8 Culvert Analysis Report
Valencia Rd – Wade Rd to Ajo Way
8-3-16

Table 1 - Summary of Culvert Flows at Crossing: CP-1A 91+05 [8-2-16]

Headwater Elevation (ft)	Total Discharge (cfs)	3 - 24 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
2432.38	0.00	0.00	0.00	1
2435.10	4.70	4.70	0.00	1
2435.13	9.40	9.40	0.00	1
2435.16	14.10	14.10	0.00	1
2435.18	18.80	18.80	0.00	1
2435.20	23.50	23.50	0.00	1
2435.22	28.00	28.00	0.00	1
2435.23	32.90	32.90	0.00	1
2435.25	37.60	37.60	0.00	1
2435.27	42.30	42.30	0.00	1
2435.28	47.00	47.00	0.00	1
2437.50	91.81	91.81	0.00	Overtopping

Table 2 - Culvert Summary Table: 3 - 24

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	2432.38	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
4.70	4.70	2435.10	2.722	0.0*	5-S2n	0.400	0.430	0.400	0.458	3.563	1.910
9.40	9.40	2435.13	2.752	0.0*	5-S2n	0.572	0.615	0.572	0.667	4.239	2.350
14.10	14.10	2435.16	2.776	0.190	5-S2n	0.709	0.760	0.711	0.825	4.687	2.639
18.80	18.80	2435.18	2.798	0.385	5-S2n	0.828	0.886	0.828	0.957	5.095	2.861
23.50	23.50	2435.20	2.818	0.586	5-S2n	0.941	0.996	0.941	1.071	5.394	3.042
28.00	28.00	2435.22	2.836	0.783	5-S2n	1.043	1.088	1.045	1.169	5.622	3.191
32.90	32.90	2435.23	2.854	1.014	5-S2n	1.154	1.184	1.154	1.266	5.848	3.333
37.60	37.60	2435.25	2.871	1.250	5-S2n	1.259	1.270	1.259	1.352	6.019	3.454
42.30	42.30	2435.27	2.888	2.075	7-M2c	1.371	1.349	1.349	1.431	6.255	3.564
47.00	47.00	2435.28	2.903	2.217	7-M2c	1.490	1.422	1.422	1.506	6.556	3.665

* Full Flow Headwater elevation is below inlet invert.

****

Straight Culvert

Inlet Elevation (invert): 2432.38 ft, Outlet Elevation (invert): 2431.72 ft

Culvert Length: 132.00 ft, Culvert Slope: 0.0050

Inlet Throat Elevation: 2432.38 ft, Inlet Crest Elevation: 2435.05 ft

****

Site Data - 3 - 24

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 2434.90 ft

Outlet Station: 132.00 ft

Outlet Elevation: 2431.72 ft

Number of Barrels: 3

Culvert Data Summary - 3 - 24

Barrel Shape: Circular

Barrel Diameter: 2.00 ft

Barrel Material: Corrugated Steel

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Beveled Edge (1:1)

Inlet Depression: Yes

Table 3 - Summary of Culvert Flows at Crossing: CP-1B 94+65 Single-Angled Culv

Headwater Elevation (ft)	Total Discharge (cfs)	1-8'x4' RCBC Discharge (cfs)	Roadway Discharge (cfs)	Iterations
2431.63	0.00	0.00	0.00	1
2436.79	17.40	17.40	0.00	1
2436.88	34.80	34.80	0.00	1
2436.96	52.20	52.20	0.00	1
2437.03	69.60	69.60	0.00	1
2437.09	87.00	87.00	0.00	1
2437.15	104.40	104.40	0.00	1
2437.21	121.80	121.80	0.00	1
2437.26	139.20	139.20	0.00	1
2437.31	156.60	156.60	0.00	1
2437.36	174.00	174.00	0.00	1
2438.00	293.77	293.77	0.00	Overtopping

Table 4 - Culvert Summary Table: 1-8'x4' RCBC

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	2431.63	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
17.40	17.40	2436.79	5.162	0.847	7-M2c	0.609	0.528	0.528	0.603	4.122	2.442
34.80	34.80	2436.88	5.254	1.344	7-M2c	0.964	0.838	0.838	0.895	5.193	3.065
52.20	52.20	2436.96	5.330	1.761	7-M2c	1.263	1.098	1.098	1.122	5.945	3.480
69.60	69.60	2437.03	5.399	2.134	7-M2c	1.535	1.330	1.330	1.314	6.543	3.799
87.00	87.00	2437.09	5.462	2.478	7-M2c	1.788	1.543	1.543	1.483	7.048	4.061
104.40	104.40	2437.15	5.521	2.800	7-M2c	2.026	1.742	1.742	1.635	7.490	4.284
121.80	121.80	2437.21	5.576	3.106	7-M2c	2.257	1.931	1.931	1.774	7.885	4.479
139.20	139.20	2437.26	5.629	3.397	7-M2c	2.480	2.111	2.111	1.904	8.244	4.654
156.60	156.60	2437.31	5.680	3.679	7-M2c	2.697	2.283	2.283	2.024	8.574	4.813
174.00	174.00	2437.36	5.729	3.952	7-M2c	2.911	2.449	2.449	2.138	8.881	4.958

****

Straight Culvert

Inlet Elevation (invert): 2431.63 ft, Outlet Elevation (invert): 2430.61 ft

Culvert Length: 203.00 ft, Culvert Slope: 0.0050

Inlet Throat Elevation: 2431.63 ft, Inlet Crest Elevation: 2436.64 ft

****

Site Data - 1-8'x4' RCBC

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 2436.30 ft

Outlet Station: 203.00 ft

Outlet Elevation: 2430.61 ft

Number of Barrels: 1

Culvert Data Summary - 1-8'x4' RCBC

Barrel Shape: Concrete Box

Barrel Span: 8.00 ft

Barrel Rise: 4.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0200

Culvert Type: Straight

Inlet Configuration: 1.5:1 Bevel (90º) Headwall

Inlet Depression: Yes

Table 5 - Summary of Culvert Flows at Crossing: CP-2 100+77 [8-2-16]

Headwater Elevation (ft)	Total Discharge (cfs)	3-10'x4' RCBC Discharge (cfs)	Roadway Discharge (cfs)	Iterations
2432.17	0.00	0.00	0.00	1
2438.03	52.00	52.00	0.00	1
2438.08	104.00	104.00	0.00	1
2438.13	156.00	156.00	0.00	1
2438.18	208.00	208.00	0.00	1
2438.22	260.00	260.00	0.00	1
2438.25	312.00	312.00	0.00	1
2438.29	364.00	364.00	0.00	1
2438.32	416.00	416.00	0.00	1
2438.35	468.00	468.00	0.00	1
2438.38	520.00	520.00	0.00	1
2439.00	1313.71	1313.71	0.00	Overtopping

Table 6 - Culvert Summary Table: 3-10'x4' RCBC

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	2432.17	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
52.00	52.00	2438.03	5.857	0.0*	5-JS1t	0.287	0.454	0.823	1.053	2.107	3.754
104.00	104.00	2438.08	5.915	0.185	5-JS1t	0.467	0.720	1.307	1.537	2.652	4.630
156.00	156.00	2438.13	5.963	0.575	5-JS1t	0.608	0.943	1.676	1.906	3.103	5.207
208.00	208.00	2438.18	6.006	0.913	5-JS1t	0.744	1.143	1.983	2.213	3.496	5.649
260.00	260.00	2438.22	6.046	1.219	5-JS1t	0.850	1.326	2.250	2.480	3.851	6.010
312.00	312.00	2438.25	6.083	1.506	5-JS1t	0.957	1.498	2.489	2.719	4.178	6.318
364.00	364.00	2438.29	6.118	1.781	5-JS1t	1.064	1.660	2.707	2.937	4.482	6.589
416.00	416.00	2438.32	6.151	2.046	5-JS1t	1.158	1.814	2.907	3.137	4.770	6.831
468.00	468.00	2438.35	6.183	2.307	5-JS1t	1.249	1.962	3.094	3.324	5.042	7.050
520.00	520.00	2438.38	6.214	2.565	5-JS1t	1.339	2.105	3.269	3.499	5.303	7.251

* Full Flow Headwater elevation is below inlet invert.

****

Straight Culvert

Inlet Elevation (invert): 2432.17 ft, Outlet Elevation (invert): 2431.03 ft

Culvert Length: 114.01 ft, Culvert Slope: 0.0100

Inlet Throat Elevation: 2432.17 ft, Inlet Crest Elevation: 2437.93 ft

****

Site Data - 3-10'x4' RCBC

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 2437.20 ft

Outlet Station: 114.00 ft

Outlet Elevation: 2431.03 ft

Number of Barrels: 3

Culvert Data Summary - 3-10'x4' RCBC

Barrel Shape: Concrete Box

Barrel Span: 10.00 ft

Barrel Rise: 4.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: 1.5:1 Bevel (90º) Headwall

Inlet Depression: Yes

Table 7 - Summary of Culvert Flows at Crossing: C-3A 114+48 [8-2-16]

Headwater Elevation (ft)	Total Discharge (cfs)	3-8x4 RCBC Discharge (cfs)	Roadway Discharge (cfs)	Iterations
2438.55	0.00	0.00	0.00	1
2443.00	33.50	33.50	0.00	1
2443.05	67.00	67.00	0.00	1
2443.10	100.50	100.50	0.00	1
2443.13	134.00	134.00	0.00	1
2443.17	167.50	167.50	0.00	1
2443.20	201.00	201.00	0.00	1
2443.24	234.50	234.50	0.00	1
2443.27	268.00	268.00	0.00	1
2443.29	301.50	301.50	0.00	1
2443.32	335.00	335.00	0.00	1
2444.00	650.04	650.04	0.00	Overtopping

Table 8 - Culvert Summary Table: 3-8x4 RCBC

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	2438.55	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
33.50	33.50	2443.00	4.451	0.698	5-S1t	0.331	0.393	1.165	1.275	1.198	2.977
67.00	67.00	2443.05	4.502	1.237	5-S1t	0.512	0.623	1.686	1.796	1.656	3.590
100.50	100.50	2443.10	4.546	1.648	5-S1t	0.677	0.817	2.070	2.180	2.023	3.995
134.00	134.00	2443.13	4.585	1.992	5-S1t	0.815	0.989	2.383	2.493	2.343	4.306
167.50	167.50	2443.17	4.621	2.292	5-S1t	0.941	1.148	2.653	2.763	2.631	4.562
201.00	201.00	2443.20	4.654	2.563	5-S1t	1.067	1.296	2.892	3.002	2.896	4.781
234.50	234.50	2443.24	4.686	2.811	5-S1t	1.179	1.437	3.108	3.218	3.144	4.974
268.00	268.00	2443.27	4.716	3.042	5-S1t	1.287	1.570	3.305	3.415	3.378	5.147
301.50	301.50	2443.29	4.745	3.259	5-S1t	1.396	1.699	3.489	3.599	3.601	5.303
335.00	335.00	2443.32	4.773	3.464	5-S1t	1.499	1.822	3.660	3.770	3.814	5.448

****

Straight Culvert

Inlet Elevation (invert): 2438.55 ft, Outlet Elevation (invert): 2438.01 ft

Culvert Length: 108.00 ft, Culvert Slope: 0.0050

Inlet Throat Elevation: 2438.55 ft, Inlet Crest Elevation: 2442.91 ft

****

Site Data - 3-8x4 RCBC

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 2442.47 ft

Outlet Station: 108.00 ft

Outlet Elevation: 2438.01 ft

Number of Barrels: 3

Culvert Data Summary - 3-8x4 RCBC

Barrel Shape: Concrete Box

Barrel Span: 8.00 ft

Barrel Rise: 4.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: 1.5:1 Bevel (90º) Headwall

Inlet Depression: Yes

Table 9 - Summary of Culvert Flows at Crossing: C-3B 117+95 [8-3-16]

Headwater Elevation (ft)	Total Discharge (cfs)	4-49"x33" Steel Pipe Arch Discharge (cfs)	Roadway Discharge (cfs)	Iterations
2440.35	0.00	0.00	0.00	1
2442.45	55.70	0.00	55.67	3
2442.99	111.40	0.00	111.32	4
2443.41	167.10	0.01	166.60	16
2443.69	222.80	12.18	210.19	8
2443.72	238.00	21.56	216.37	4
2443.88	334.20	99.85	234.76	4
2444.13	389.90	94.87	295.57	6
2444.27	445.60	167.10	297.18	18
2444.47	501.30	167.10	336.90	11
2444.67	557.00	167.10	392.15	9
2441.40	0.00	0.00	0.00	Overtopping

Table 10 - Culvert Summary Table: 4-49"x33" Steel Pipe Arch

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	2440.35	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
55.70	0.00	2442.45	0.000	1.067	6-FFt	0.000	0.000	1.607	1.717	0.000	3.197
111.40	0.00	2442.99	0.000	1.737	6-FFt	0.000	0.000	2.277	2.387	0.000	3.836
167.10	0.01	2443.41	3.316	2.227	3-M1f	0.000	0.000	2.750	2.877	0.000	4.261
222.80	12.18	2443.69	3.364	2.630	5-S1f	0.323	0.369	2.750	3.276	0.355	4.587
238.00	21.56	2443.72	3.387	2.736	5-S1f	0.440	0.505	2.750	3.374	0.628	4.665
334.20	99.85	2443.88	3.514	3.529	4-FFf	1.036	1.202	2.750	3.920	2.907	5.086
389.90	94.87	2444.13	3.507	3.777	4-FFf	1.005	1.168	2.750	4.193	2.762	5.289
445.60	167.10	2444.27	3.595	4.519	4-FFf	1.439	1.602	2.750	4.443	4.865	5.472
501.30	167.10	2444.47	3.595	4.751	4-FFf	1.439	1.602	2.750	4.675	4.865	5.637
557.00	167.10	2444.67	3.595	4.967	4-FFf	1.439	1.602	2.750	4.891	4.865	5.789

****

Straight Culvert

Inlet Elevation (invert): 2440.35 ft, Outlet Elevation (invert): 2439.81 ft

Culvert Length: 108.00 ft, Culvert Slope: 0.0050

Inlet Throat Elevation: 2440.35 ft, Inlet Crest Elevation: 2443.67 ft

****

Site Data - 4-49"x33" Steel Pipe Arch

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 2443.40 ft

Outlet Station: 108.00 ft

Outlet Elevation: 2439.81 ft

Number of Barrels: 4

Culvert Data Summary - 4-49"x33" Steel Pipe Arch

Barrel Shape: Pipe Arch

Barrel Span: 49.00 in

Barrel Rise: 33.00 in

Barrel Material: Steel or Aluminum

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Headwall

Inlet Depression: Yes

Table 11 - Summary of Culvert Flows at Crossing: C-3C 122+70 [8-3-16]

Headwater Elevation (ft)	Total Discharge (cfs)	4-49"x33" Steel Pipe Arch Discharge (cfs)	Roadway Discharge (cfs)	Iterations
2441.45	0.00	0.00	0.00	1
2444.60	19.30	11.57	7.56	16
2444.65	38.60	26.73	11.74	6
2444.69	57.90	42.18	15.50	4
2444.73	77.20	57.65	19.43	4
2444.76	96.50	72.96	23.37	3
2444.79	114.00	86.89	27.10	3
2444.82	135.10	103.84	31.83	2
2444.85	154.40	118.36	36.02	3
2444.87	173.70	133.21	40.45	3
2444.90	193.00	147.98	44.96	3
2444.30	0.00	0.00	0.00	Overtopping

Table 12 - Culvert Summary Table: 4-49"x33" Steel Pipe Arch

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	2441.45	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
19.30	11.57	2444.60	3.153	0.153	5-JS1t	0.315	0.359	0.689	0.799	1.303	3.264
38.60	26.73	2444.65	3.202	0.517	5-JS1t	0.503	0.569	1.039	1.149	1.842	3.978
57.90	42.18	2444.69	3.243	0.806	5-S2n	0.631	0.732	0.642	1.410	5.183	4.448
77.20	57.65	2444.73	3.280	1.062	5-JS1t	0.756	0.873	1.516	1.626	2.605	4.807
96.50	72.96	2444.76	3.313	1.301	5-S2n	0.859	1.003	0.866	1.812	6.231	5.102
114.00	86.89	2444.79	3.340	1.797	5-S1t	0.953	1.110	1.853	1.963	3.219	5.332
135.10	103.84	2444.82	3.373	2.009	5-S1t	1.060	1.229	2.018	2.128	3.551	5.576
154.40	118.36	2444.85	3.399	2.191	5-S1t	1.147	1.321	2.156	2.266	3.836	5.774
173.70	133.21	2444.87	3.424	2.377	5-S1t	1.237	1.408	2.285	2.395	4.114	5.954
193.00	147.98	2444.90	3.449	2.561	5-S1t	1.325	1.494	2.405	2.515	4.425	6.119

****

Straight Culvert

Inlet Elevation (invert): 2441.45 ft, Outlet Elevation (invert): 2440.91 ft

Culvert Length: 108.00 ft, Culvert Slope: 0.0050

Inlet Throat Elevation: 2441.45 ft, Inlet Crest Elevation: 2444.54 ft

****

Site Data - 4-49"x33" Steel Pipe Arch

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 2444.30 ft

Outlet Station: 108.00 ft

Outlet Elevation: 2440.91 ft

Number of Barrels: 4

Culvert Data Summary - 4-49"x33" Steel Pipe Arch

Barrel Shape: Pipe Arch

Barrel Span: 49.00 in

Barrel Rise: 33.00 in

Barrel Material: Steel or Aluminum

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Headwall

Inlet Depression: Yes

Table 13 - Summary of Culvert Flows at Crossing: C-4 131+84 [8-3-16]

Headwater Elevation (ft)	Total Discharge (cfs)	2 - 48 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
2441.85	0.00	0.00	0.00	1
2447.18	12.20	12.20	0.00	1
2447.22	24.40	24.40	0.00	1
2447.26	36.60	36.60	0.00	1
2447.29	48.80	48.80	0.00	1
2447.33	61.00	61.00	0.00	1
2447.36	73.20	73.20	0.00	1
2447.38	85.40	85.40	0.00	1
2447.41	97.60	97.60	0.00	1
2447.43	109.80	109.80	0.00	1
2447.46	122.00	122.00	0.00	1
2447.50	142.80	142.80	0.00	Overtopping

Table 14 - Culvert Summary Table: 2 - 48

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	2441.85	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
12.20	12.20	2447.18	5.327	0.179	5-S2n	0.616	0.713	0.641	0.536	4.600	2.371
24.40	24.40	2447.22	5.373	0.500	5-S2n	0.882	1.016	0.901	0.793	5.698	2.967
36.60	36.60	2447.26	5.411	0.766	5-S2n	1.101	1.252	1.107	0.992	6.467	3.362
48.80	48.80	2447.29	5.445	1.013	5-S2n	1.269	1.456	1.286	1.160	6.965	3.666
61.00	61.00	2447.33	5.476	1.244	5-S2n	1.437	1.633	1.449	1.307	7.424	3.914
73.20	73.20	2447.36	5.506	1.479	5-S2n	1.582	1.801	1.600	1.440	7.788	4.127
85.40	85.40	2447.38	5.533	1.710	5-S2n	1.724	1.954	1.743	1.561	8.114	4.313
97.60	97.60	2447.41	5.560	1.939	5-S2n	1.862	2.092	1.880	1.674	8.405	4.479
109.80	109.80	2447.43	5.585	2.174	5-S2n	1.993	2.225	2.013	1.779	8.665	4.630
122.00	122.00	2447.46	5.609	2.416	5-S2n	2.124	2.352	2.143	1.877	8.901	4.767

****

Straight Culvert

Inlet Elevation (invert): 2441.85 ft, Outlet Elevation (invert): 2441.31 ft

Culvert Length: 108.00 ft, Culvert Slope: 0.0050

Inlet Throat Elevation: 2441.85 ft, Inlet Crest Elevation: 2447.10 ft

****

Site Data - 2 - 48

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 2446.50 ft

Outlet Station: 108.00 ft

Outlet Elevation: 2441.31 ft

Number of Barrels: 2

Culvert Data Summary - 2 - 48

Barrel Shape: Circular

Barrel Diameter: 4.00 ft

Barrel Material: Corrugated Steel

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Beveled Edge (1:1)

Inlet Depression: Yes

Table 15 - Summary of Culvert Flows at Crossing: C-5 134+20 [8-3-16]

Headwater Elevation (ft)	Total Discharge (cfs)	3-10X4 RCBC Discharge (cfs)	Roadway Discharge (cfs)	Iterations
2442.48	0.00	0.00	0.00	1
2446.76	74.60	5.72	68.17	41
2446.93	149.20	66.27	81.73	7
2447.00	223.80	135.94	88.17	3
2447.06	298.40	204.60	93.59	3
2447.11	373.00	273.24	98.78	3
2447.16	447.60	343.65	103.92	4
2447.20	522.20	413.27	108.89	4
2447.25	596.80	482.95	113.81	4
2447.29	671.40	550.98	118.57	3
2447.33	746.00	622.39	123.56	4
2445.00	0.00	0.00	0.00	Overtopping

Table 16 - Culvert Summary Table: 3-10X4 RCBC

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	2442.48	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
74.60	5.72	2446.76	4.358	0.628	5-S1t	0.045	0.104	1.186	1.306	0.161	3.929
149.20	66.27	2446.93	4.450	1.208	5-S1t	0.439	0.533	1.714	1.834	1.289	4.739
223.80	135.94	2447.00	4.521	1.675	5-S1t	0.706	0.861	2.101	2.221	2.157	5.274
298.40	204.60	2447.06	4.579	2.072	5-S1t	0.911	1.130	2.417	2.537	2.821	5.685
373.00	273.24	2447.11	4.631	2.426	5-S1t	1.107	1.371	2.689	2.809	3.387	6.023
447.60	343.65	2447.16	4.680	2.755	5-S1t	1.280	1.597	2.930	3.050	3.910	6.313
522.20	413.27	2447.20	4.725	3.061	5-S1t	1.451	1.806	3.147	3.267	4.377	6.568
596.80	482.95	2447.25	4.768	3.350	5-S1t	1.605	2.004	3.346	3.466	4.811	6.797
671.40	550.98	2447.29	4.807	3.622	5-S1t	1.755	2.188	3.531	3.651	5.202	7.005
746.00	622.39	2447.33	4.847	3.891	5-S1t	1.905	2.373	3.703	3.823	5.602	7.196

****

Straight Culvert

Inlet Elevation (invert): 2442.48 ft, Outlet Elevation (invert): 2441.92 ft

Culvert Length: 112.00 ft, Culvert Slope: 0.0050

Inlet Throat Elevation: 2442.48 ft, Inlet Crest Elevation: 2446.82 ft

****

Site Data - 3-10X4 RCBC

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 2446.39 ft

Outlet Station: 112.00 ft

Outlet Elevation: 2441.92 ft

Number of Barrels: 3

Culvert Data Summary - 3-10X4 RCBC

Barrel Shape: Concrete Box

Barrel Span: 10.00 ft

Barrel Rise: 4.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: 1.5:1 Bevel (90º) Headwall

Inlet Depression: Yes

Table 17 - Summary of Culvert Flows at Crossing: C-6 142+85 [8-3-16]

Headwater Elevation (ft)	Total Discharge (cfs)	3-10X4 RCBC Discharge (cfs)	Roadway Discharge (cfs)	Iterations
2448.66	0.00	0.00	0.00	1
2453.19	42.20	42.20	0.00	1
2453.24	84.40	84.40	0.00	1
2453.28	126.60	126.60	0.00	1
2453.32	168.80	168.80	0.00	1
2453.35	211.00	211.00	0.00	1
2453.38	253.20	253.20	0.00	1
2453.41	295.40	295.40	0.00	1
2453.44	337.60	337.60	0.00	1
2453.47	379.80	379.80	0.00	1
2453.50	422.00	422.00	0.00	1
2454.00	1051.96	1051.96	0.00	Overtopping

Table 18 - Culvert Summary Table: 3-10X4 RCBC

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	2448.66	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
42.20	42.20	2453.19	4.528	0.013	5-JS1t	0.330	0.395	0.641	0.771	2.196	4.448
84.40	84.40	2453.24	4.578	0.388	5-JS1t	0.509	0.626	1.006	1.136	2.796	5.540
126.60	126.60	2453.28	4.620	0.684	5-JS1t	0.670	0.821	1.288	1.418	3.276	6.264
168.80	168.80	2453.32	4.657	0.942	5-JS1t	0.807	0.994	1.525	1.655	3.691	6.818
211.00	211.00	2453.35	4.692	1.175	5-JS1t	0.929	1.154	1.732	1.862	4.061	7.271
253.20	253.20	2453.38	4.724	1.393	5-JS1t	1.052	1.303	1.918	2.048	4.401	7.659
295.40	295.40	2453.41	4.754	1.602	5-JS1t	1.161	1.444	2.088	2.218	4.716	7.998
337.60	337.60	2453.44	4.783	1.803	5-JS1t	1.265	1.578	2.245	2.375	5.013	8.301
379.80	379.80	2453.47	4.811	1.999	5-JS1t	1.369	1.707	2.391	2.521	5.294	8.576
422.00	422.00	2453.50	4.838	2.192	5-JS1t	1.471	1.832	2.529	2.659	5.562	8.827

****

Straight Culvert

Inlet Elevation (invert): 2448.66 ft, Outlet Elevation (invert): 2448.03 ft

Culvert Length: 126.00 ft, Culvert Slope: 0.0050

Inlet Throat Elevation: 2448.66 ft, Inlet Crest Elevation: 2453.10 ft

****

Site Data - 3-10X4 RCBC

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 2452.70 ft

Outlet Station: 126.00 ft

Outlet Elevation: 2448.03 ft

Number of Barrels: 3

Culvert Data Summary - 3-10X4 RCBC

Barrel Shape: Concrete Box

Barrel Span: 10.00 ft

Barrel Rise: 4.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: 1.5:1 Bevel (90º) Headwall

Inlet Depression: Yes

Table 19 - Summary of Culvert Flows at Crossing: C-7 155+48 [8-3-16]

Headwater Elevation (ft)	Total Discharge (cfs)	2 - 48 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
2452.22	0.00	0.00	0.00	1
2456.20	16.00	16.00	0.00	1
2456.30	32.00	32.00	0.00	1
2456.38	48.00	48.00	0.00	1
2456.46	64.00	64.00	0.00	1
2456.53	80.00	80.00	0.00	1
2456.59	96.00	96.00	0.00	1
2456.65	112.00	112.00	0.00	1
2456.71	128.00	128.00	0.00	1
2456.77	144.00	144.00	0.00	1
2456.82	160.00	160.00	0.00	1
2557.00	1323.77	1323.77	0.00	Overtopping

Table 20 - Culvert Summary Table: 2 - 48

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	2452.22	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
16.00	16.00	2456.20	3.979	0.0*	1-S2n	0.490	0.820	0.529	0.254	7.840	2.084
32.00	32.00	2456.30	4.080	0.0*	5-S2n	0.729	1.170	0.750	0.385	9.854	2.737
48.00	48.00	2456.38	4.164	0.0*	5-S2n	0.875	1.444	0.921	0.491	10.869	3.207
64.00	64.00	2456.46	4.239	0.0*	5-S2n	1.021	1.676	1.071	0.584	11.811	3.585
80.00	80.00	2456.53	4.308	0.0*	5-S2n	1.148	1.888	1.210	0.667	12.425	3.909
96.00	96.00	2456.59	4.373	0.0*	5-S2n	1.258	2.075	1.339	0.745	12.980	4.193
112.00	112.00	2456.65	4.434	0.082	5-S2n	1.368	2.247	1.462	0.817	13.472	4.449
128.00	128.00	2456.71	4.492	0.412	5-S2n	1.475	2.411	1.580	0.885	13.843	4.682
144.00	144.00	2456.77	4.548	0.751	5-S2n	1.568	2.561	1.694	0.950	14.203	4.896
160.00	160.00	2456.82	4.602	1.108	5-S2n	1.661	2.707	1.802	1.012	14.561	5.096

* Full Flow Headwater elevation is below inlet invert.

****

Straight Culvert

Inlet Elevation (invert): 2452.22 ft, Outlet Elevation (invert): 2449.51 ft

Culvert Length: 135.63 ft, Culvert Slope: 0.0200

Inlet Throat Elevation: 2452.22 ft, Inlet Crest Elevation: 2456.03 ft

****

Site Data - 2 - 48

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 2455.60 ft

Outlet Station: 135.60 ft

Outlet Elevation: 2449.51 ft

Number of Barrels: 2

Culvert Data Summary - 2 - 48

Barrel Shape: Circular

Barrel Diameter: 4.00 ft

Barrel Material: Corrugated Steel

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Beveled Edge (1:1)

Inlet Depression: Yes

Table 21 - Summary of Culvert Flows at Crossing: C-8 162+13 [8-3-16]

Headwater Elevation (ft)	Total Discharge (cfs)	2 - 30 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
2455.33	0.00	0.00	0.00	1
2458.99	5.70	5.70	0.00	1
2459.02	11.40	11.40	0.00	1
2459.04	17.10	17.10	0.00	1
2459.06	22.80	22.80	0.00	1
2459.08	28.50	28.50	0.00	1
2459.10	34.20	34.20	0.00	1
2459.11	39.90	39.90	0.00	1
2459.13	45.60	45.60	0.00	1
2459.15	51.30	51.30	0.00	1
2459.16	57.00	57.00	0.00	1
2460.00	90.43	90.43	0.00	Overtopping

Table 22 - Culvert Summary Table: 2 - 30

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	2455.33	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
5.70	5.70	2458.99	3.661	0.0*	5-S2n	0.372	0.549	0.385	0.111	5.795	1.706
11.40	11.40	2459.02	3.688	0.0*	5-S2n	0.536	0.786	0.545	0.168	7.139	2.248
17.10	17.10	2459.04	3.711	0.0*	5-S2n	0.667	0.971	0.667	0.214	8.113	2.639
22.80	22.80	2459.06	3.732	0.0*	5-S2n	0.770	1.131	0.770	0.255	8.844	2.957
28.50	28.50	2459.08	3.751	0.0*	5-S2n	0.869	1.271	0.869	0.291	9.379	3.229
34.20	34.20	2459.10	3.768	0.0*	5-S2n	0.959	1.393	0.982	0.325	9.539	3.468
39.90	39.90	2459.11	3.785	0.0*	5-S2n	1.043	1.511	1.043	0.357	10.276	3.684
45.60	45.60	2459.13	3.801	0.0*	5-S2n	1.127	1.621	1.132	0.387	10.552	3.883
51.30	51.30	2459.15	3.816	0.0*	5-S2n	1.205	1.721	1.205	0.415	10.954	4.066
57.00	57.00	2459.16	3.831	0.0*	5-S2n	1.282	1.818	1.306	0.442	10.982	4.236

* Full Flow Headwater elevation is below inlet invert.

****

Straight Culvert

Inlet Elevation (invert): 2455.33 ft, Outlet Elevation (invert): 2451.70 ft

Culvert Length: 242.03 ft, Culvert Slope: 0.0150

Inlet Throat Elevation: 2455.33 ft, Inlet Crest Elevation: 2458.94 ft

****

Site Data - 2 - 30

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 2458.70 ft

Outlet Station: 242.00 ft

Outlet Elevation: 2451.70 ft

Number of Barrels: 2

Culvert Data Summary - 2 - 30

Barrel Shape: Circular

Barrel Diameter: 2.50 ft

Barrel Material: Corrugated Steel

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Beveled Edge (1:1)

Inlet Depression: Yes

Table 23 - Summary of Culvert Flows at Crossing: C-9 166+10 [8-3-16]

Headwater Elevation (ft)	Total Discharge (cfs)	3 - 48 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
2455.63	0.00	0.00	0.00	1
2460.94	24.50	24.50	0.00	1
2460.97	49.00	49.00	0.00	1
2461.00	73.50	73.50	0.00	1
2461.03	98.00	98.00	0.00	1
2461.05	122.50	122.50	0.00	1
2461.07	147.00	147.00	0.00	1
2461.09	171.50	171.50	0.00	1
2461.11	196.00	196.00	0.00	1
2461.13	220.50	220.50	0.00	1
2461.15	245.00	245.00	0.00	1
2461.50	358.92	358.92	0.00	Overtopping

Table 24 - Culvert Summary Table: 3 - 48

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	2455.63	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
24.50	24.50	2460.94	5.307	0.0*	5-S2n	0.533	0.828	0.533	0.275	7.920	1.971
49.00	49.00	2460.97	5.341	0.0*	5-S2n	0.781	1.183	0.781	0.416	9.385	2.591
73.50	73.50	2461.00	5.371	0.0*	5-S2n	0.953	1.460	0.984	0.531	10.135	3.039
98.00	98.00	2461.03	5.397	0.0*	5-S2n	1.116	1.695	1.116	0.631	11.415	3.401
122.50	122.50	2461.05	5.421	0.0*	5-S2n	1.246	1.909	1.286	0.722	11.655	3.710
147.00	147.00	2461.07	5.443	0.0*	5-S2n	1.376	2.096	1.419	0.806	12.260	3.984
171.50	171.50	2461.09	5.464	0.0*	5-S2n	1.498	2.271	1.547	0.884	12.729	4.229
196.00	196.00	2461.11	5.484	0.238	5-S2n	1.608	2.436	1.669	0.958	13.142	4.453
220.50	220.50	2461.13	5.504	0.618	5-S2n	1.718	2.588	1.784	1.028	13.554	4.661
245.00	245.00	2461.15	5.522	1.021	5-S2n	1.827	2.735	1.899	1.095	13.886	4.853

* Full Flow Headwater elevation is below inlet invert.

****

Straight Culvert

Inlet Elevation (invert): 2455.63 ft, Outlet Elevation (invert): 2452.57 ft

Culvert Length: 204.02 ft, Culvert Slope: 0.0150

Inlet Throat Elevation: 2455.63 ft, Inlet Crest Elevation: 2460.88 ft

****

Site Data - 3 - 48

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 2460.40 ft

Outlet Station: 204.00 ft

Outlet Elevation: 2452.57 ft

Number of Barrels: 3

Culvert Data Summary - 3 - 48

Barrel Shape: Circular

Barrel Diameter: 4.00 ft

Barrel Material: Corrugated Steel

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Beveled Edge (1:1)

Inlet Depression: Yes

Table 25 - Summary of Culvert Flows at Crossing: C-10 171+00 [8-3-16]

Headwater Elevation (ft)	Total Discharge (cfs)	3-10X4 RCBC Discharge (cfs)	Roadway Discharge (cfs)	Iterations
2455.90	0.00	0.00	0.00	1
2461.21	52.30	52.30	0.00	1
2461.30	104.60	104.60	0.00	1
2461.38	156.90	156.90	0.00	1
2461.45	209.20	209.20	0.00	1
2461.51	261.50	261.50	0.00	1
2461.57	313.80	313.80	0.00	1
2461.63	366.10	366.10	0.00	1
2461.68	418.40	418.40	0.00	1
2461.73	470.70	470.70	0.00	1
2461.78	523.00	523.00	0.00	1
2462.70	1382.74	1382.74	0.00	Overtopping

Table 26 - Culvert Summary Table: 3-10X4 RCBC

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	2455.90	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
52.30	52.30	2461.21	5.311	0.0*	5-S2n	0.385	0.455	0.385	0.497	4.525	3.238
104.60	104.60	2461.30	5.403	0.0*	5-S2n	0.585	0.723	0.585	0.754	5.958	4.235
156.90	156.90	2461.38	5.480	0.0*	5-S2n	0.771	0.947	0.771	0.962	6.783	4.947
209.20	209.20	2461.45	5.548	0.219	5-S2n	0.922	1.147	0.938	1.144	7.434	5.517
261.50	261.50	2461.51	5.612	0.448	5-S2n	1.074	1.331	1.074	1.308	8.118	6.001
313.80	313.80	2461.57	5.670	0.676	5-S2n	1.205	1.503	1.217	1.460	8.592	6.424
366.10	366.10	2461.63	5.726	0.905	5-S2n	1.333	1.666	1.352	1.602	9.029	6.803
418.40	418.40	2461.68	5.779	1.136	5-S2n	1.461	1.821	1.479	1.736	9.430	7.146
470.70	470.70	2461.73	5.830	1.371	5-S2n	1.576	1.970	1.601	1.863	9.801	7.462
523.00	523.00	2461.78	5.880	1.611	5-S2n	1.690	2.113	1.722	1.985	10.126	7.754

* Full Flow Headwater elevation is below inlet invert.

****

Straight Culvert

Inlet Elevation (invert): 2455.90 ft, Outlet Elevation (invert): 2454.89 ft

Culvert Length: 201.00 ft, Culvert Slope: 0.0050

Inlet Throat Elevation: 2455.90 ft, Inlet Crest Elevation: 2461.06 ft

****

Site Data - 3-10X4 RCBC

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 2460.70 ft

Outlet Station: 201.00 ft

Outlet Elevation: 2454.89 ft

Number of Barrels: 3

Culvert Data Summary - 3-10X4 RCBC

Barrel Shape: Concrete Box

Barrel Span: 10.00 ft

Barrel Rise: 4.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: 1.5:1 Bevel (90º) Headwall

Inlet Depression: Yes

Table 27 - Summary of Culvert Flows at Crossing: C-11A 175+28 [8-3-16]

Headwater Elevation (ft)	Total Discharge (cfs)	3-8x4 RCBC Discharge (cfs)	Roadway Discharge (cfs)	Iterations
2461.28	0.00	0.00	0.00	1
2462.42	28.20	28.20	0.00	1
2462.51	56.40	56.40	0.00	1
2462.59	84.60	84.60	0.00	1
2462.67	112.80	112.80	0.00	1
2462.87	141.00	141.00	0.00	1
2463.08	169.20	169.20	0.00	1
2463.27	197.40	197.40	0.00	1
2463.46	225.60	225.60	0.00	1
2463.64	253.80	253.80	0.00	1
2463.81	282.00	282.00	0.00	1
2464.50	405.82	405.82	0.00	Overtopping

Table 28 - Culvert Summary Table: 3-8x4 RCBC

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	2461.28	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
28.20	28.20	2462.42	1.136	0.0*	1-S2n	0.279	0.350	0.279	0.537	4.205	2.095
56.40	56.40	2462.51	1.232	0.0*	1-S2n	0.461	0.556	0.461	0.811	5.100	2.715
84.60	84.60	2462.59	1.313	0.0*	1-S2n	0.600	0.728	0.600	1.031	5.877	3.149
112.80	112.80	2462.67	1.385	0.108	1-S2n	0.736	0.882	0.736	1.222	6.385	3.492
141.00	141.00	2462.87	1.594	0.269	1-S2n	0.843	1.023	0.843	1.393	6.971	3.779
169.20	169.20	2463.08	1.800	0.451	1-S2n	0.949	1.156	0.964	1.550	7.316	4.027
197.40	197.40	2463.27	1.995	0.626	1-S2n	1.056	1.281	1.064	1.697	7.727	4.247
225.60	225.60	2463.46	2.181	0.797	1-S2n	1.152	1.400	1.163	1.834	8.079	4.446
253.80	253.80	2463.64	2.360	0.964	1-S2n	1.244	1.514	1.261	1.964	8.388	4.627
282.00	282.00	2463.81	2.532	1.130	1-S2n	1.335	1.625	1.353	2.088	8.684	4.795

* Full Flow Headwater elevation is below inlet invert.

****

Straight Culvert

Inlet Elevation (invert): 2461.28 ft, Outlet Elevation (invert): 2460.47 ft

Culvert Length: 163.00 ft, Culvert Slope: 0.0050

Inlet Throat Elevation: 2461.28 ft, Inlet Crest Elevation: 2462.25 ft

****

Site Data - 3-8x4 RCBC

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 2462.21 ft

Outlet Station: 163.00 ft

Outlet Elevation: 2460.47 ft

Number of Barrels: 3

Culvert Data Summary - 3-8x4 RCBC

Barrel Shape: Concrete Box

Barrel Span: 8.00 ft

Barrel Rise: 4.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: 1.5:1 Bevel (90º) Headwall

Inlet Depression: Yes

Table 29 - Summary of Culvert Flows at Crossing: C-11B 178+13 [8-3-16]

Headwater Elevation (ft)	Total Discharge (cfs)	3-57"x38" Steel Pipe Arch Discharge (cfs)	Roadway Discharge (cfs)	Iterations
2461.08	0.00	0.00	0.00	1
2464.61	22.80	22.80	0.00	1
2464.66	45.60	45.60	0.00	1
2464.71	68.40	68.40	0.00	1
2464.75	91.20	91.20	0.00	1
2464.78	114.00	114.00	0.00	1
2464.82	136.80	136.80	0.00	1
2464.85	159.60	159.60	0.00	1
2464.88	182.40	182.40	0.00	1
2464.91	205.20	205.20	0.00	1
2464.94	228.00	228.00	0.00	1
2466.00	304.02	304.02	0.00	Overtopping

Table 30 - Culvert Summary Table: 3-57"x38" Steel Pipe Arch

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	2461.08	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
22.80	22.80	2464.61	3.531	0.0*	5-S2n	0.494	0.575	0.510	0.473	4.460	1.933
45.60	45.60	2464.66	3.584	0.140	5-S2n	0.717	0.844	0.729	0.715	5.669	2.510
68.40	68.40	2464.71	3.628	0.426	5-S2n	0.903	1.058	0.903	0.909	6.549	2.915
91.20	91.20	2464.75	3.667	0.722	5-S2n	1.062	1.255	1.068	1.078	7.124	3.235
114.00	114.00	2464.78	3.704	1.020	5-S2n	1.215	1.425	1.215	1.229	7.669	3.505
136.80	136.80	2464.82	3.737	1.328	5-S2n	1.361	1.577	1.370	1.369	8.031	3.739
159.60	159.60	2464.85	3.770	1.655	5-S2n	1.506	1.719	1.515	1.498	8.390	3.946
182.40	182.40	2464.88	3.800	2.006	5-S2n	1.651	1.857	1.660	1.620	8.697	4.133
205.20	205.20	2464.91	3.829	2.379	5-S2n	1.800	1.989	1.807	1.735	8.964	4.304
228.00	228.00	2464.94	3.858	0.465	5-S2n	1.952	2.111	1.952	1.845	9.214	4.462

* Full Flow Headwater elevation is below inlet invert.

****

Straight Culvert

Inlet Elevation (invert): 2461.08 ft, Outlet Elevation (invert): 2460.32 ft

Culvert Length: 152.00 ft, Culvert Slope: 0.0050

Inlet Throat Elevation: 2461.08 ft, Inlet Crest Elevation: 2464.52 ft

****

Site Data - 3-57"x38" Steel Pipe Arch

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 2464.30 ft

Outlet Station: 152.00 ft

Outlet Elevation: 2460.32 ft

Number of Barrels: 3

Culvert Data Summary - 3-57"x38" Steel Pipe Arch

Barrel Shape: Pipe Arch

Barrel Span: 57.00 in

Barrel Rise: 38.00 in

Barrel Material: Steel or Aluminum

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Headwall

Inlet Depression: Yes

Table 31 - Summary of Culvert Flows at Crossing: C-12 180+28 [8-3-16]

Headwater Elevation (ft)	Total Discharge (cfs)	4-49"X33" Steel Pipe Arch Discharge (cfs)	Roadway Discharge (cfs)	Iterations
2461.76	0.00	0.00	0.00	1
2464.51	20.00	20.00	0.00	1
2464.55	40.00	40.00	0.00	1
2464.59	60.00	60.00	0.00	1
2464.62	80.00	80.00	0.00	1
2464.64	100.00	100.00	0.00	1
2464.67	120.00	120.00	0.00	1
2464.69	140.00	140.00	0.00	1
2464.72	160.00	160.00	0.00	1
2464.74	180.00	180.00	0.00	1
2464.81	200.00	200.00	0.00	1
2466.00	280.12	280.12	0.00	Overtopping

Table 32 - Culvert Summary Table: 4-49"X33" Steel Pipe Arch

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	2461.76	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
20.00	20.00	2464.51	2.752	0.0*	5-S2n	0.421	0.485	0.421	0.380	4.196	2.126
40.00	40.00	2464.55	2.792	0.153	5-S2n	0.613	0.711	0.613	0.575	5.213	2.768
60.00	60.00	2464.59	2.826	0.386	5-S2n	0.772	0.890	0.772	0.732	5.890	3.221
80.00	80.00	2464.62	2.855	0.629	5-S2n	0.906	1.058	0.913	0.868	6.413	3.582
100.00	100.00	2464.64	2.883	0.870	5-S2n	1.036	1.203	1.042	0.990	6.869	3.887
120.00	120.00	2464.67	2.908	1.116	5-S2n	1.157	1.331	1.165	1.103	7.243	4.151
140.00	140.00	2464.69	2.933	1.370	5-S2n	1.277	1.446	1.284	1.208	7.562	4.387
160.00	160.00	2464.72	2.956	1.643	5-S2n	1.397	1.560	1.403	1.307	7.857	4.600
180.00	180.00	2464.74	2.978	1.935	5-S2n	1.517	1.670	1.523	1.401	8.091	4.795
200.00	200.00	2464.81	3.051	0.630	5-S2n	1.643	1.775	1.645	1.490	8.319	4.975

* Full Flow Headwater elevation is below inlet invert.

****

Straight Culvert

Inlet Elevation (invert): 2461.76 ft, Outlet Elevation (invert): 2461.16 ft

Culvert Length: 120.00 ft, Culvert Slope: 0.0050

Inlet Throat Elevation: 2461.76 ft, Inlet Crest Elevation: 2464.44 ft

****

Site Data - 4-49"X33" Steel Pipe Arch

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 2464.27 ft

Outlet Station: 120.00 ft

Outlet Elevation: 2461.16 ft

Number of Barrels: 4

Culvert Data Summary - 4-49"X33" Steel Pipe Arch

Barrel Shape: Pipe Arch

Barrel Span: 49.00 in

Barrel Rise: 33.00 in

Barrel Material: Steel or Aluminum

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Headwall

Inlet Depression: Yes

Table 33 - Summary of Culvert Flows at Crossing: C-13 188+26 [8-3-16]

Headwater Elevation (ft)	Total Discharge (cfs)	4-8x4 RCBC Discharge (cfs)	Roadway Discharge (cfs)	Iterations
2461.51	0.00	0.00	0.00	1
2466.56	66.60	66.60	0.00	1
2466.61	133.20	133.20	0.00	1
2466.65	199.80	199.80	0.00	1
2466.69	266.40	266.40	0.00	1
2466.72	333.00	333.00	0.00	1
2466.75	399.60	399.60	0.00	1
2466.78	466.20	466.20	0.00	1
2466.81	532.80	532.80	0.00	1
2466.84	599.40	599.40	0.00	1
2466.86	666.00	666.00	0.00	1
2467.00	1010.31	1010.31	0.00	Overtopping

Table 34 - Culvert Summary Table: 4-8x4 RCBC

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	2461.51	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
66.60	66.60	2466.56	5.054	0.0*	5-JS1t	0.349	0.512	0.977	1.457	2.130	3.180
133.20	133.20	2466.61	5.102	0.518	5-JS1t	0.530	0.813	1.623	2.103	2.565	3.884
199.80	199.80	2466.65	5.142	1.035	5-JS1t	0.703	1.066	2.107	2.587	2.963	4.348
266.40	266.40	2466.69	5.178	1.480	5-JS1t	0.842	1.291	2.507	2.987	3.320	4.703
333.00	333.00	2466.72	5.212	1.884	5-JS1t	0.975	1.498	2.854	3.334	3.646	4.994
399.60	399.60	2466.75	5.243	2.263	5-JS1t	1.106	1.692	3.163	3.643	3.949	5.242
466.20	466.20	2466.78	5.272	2.626	5-JS1t	1.220	1.875	3.442	3.922	4.232	5.460
532.80	532.80	2466.81	5.300	2.979	5-JS1t	1.334	2.050	3.700	4.180	4.500	5.656
599.40	599.40	2466.84	5.327	3.327	5-JS1t	1.448	2.217	3.939	4.419	4.756	5.833
666.00	666.00	2466.86	5.353	3.793	5-S1f	1.552	2.378	4.000	4.642	5.203	5.996

* Full Flow Headwater elevation is below inlet invert.

****

Straight Culvert

Inlet Elevation (invert): 2461.51 ft, Outlet Elevation (invert): 2460.38 ft

Culvert Length: 113.01 ft, Culvert Slope: 0.0100

Inlet Throat Elevation: 2461.51 ft, Inlet Crest Elevation: 2466.48 ft

****

Site Data - 4-8x4 RCBC

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 2465.90 ft

Outlet Station: 113.00 ft

Outlet Elevation: 2460.38 ft

Number of Barrels: 4

Culvert Data Summary - 4-8x4 RCBC

Barrel Shape: Concrete Box

Barrel Span: 8.00 ft

Barrel Rise: 4.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: 1.5:1 Bevel (90º) Headwall

Inlet Depression: Yes

Table 35 - Summary of Culvert Flows at Crossing: C-14A 194+85 [8-3-16]

Headwater Elevation (ft)	Total Discharge (cfs)	4 - 36 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
2465.04	0.00	0.00	0.00	1
2468.39	17.90	17.90	0.00	1
2468.46	35.80	35.80	0.00	1
2468.51	53.70	53.70	0.00	1
2468.56	71.60	71.60	0.00	1
2468.61	89.50	89.50	0.00	1
2468.65	107.40	107.40	0.00	1
2468.70	125.30	125.30	0.00	1
2468.74	143.20	143.20	0.00	1
2468.77	161.10	161.10	0.00	1
2468.81	179.00	179.00	0.00	1
2469.50	235.35	235.35	0.00	Overtopping

Table 36 - Culvert Summary Table: 4 - 36

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	2465.04	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
17.90	17.90	2468.39	3.347	0.0*	5-S2n	0.541	0.657	0.541	0.470	5.150	2.257
35.80	35.80	2468.46	3.416	0.109	5-S2n	0.758	0.941	0.770	0.702	6.207	2.865
53.70	53.70	2468.51	3.473	0.390	5-S2n	0.935	1.163	0.950	0.884	6.962	3.276
71.60	71.60	2468.56	3.524	0.665	5-S2n	1.096	1.354	1.107	1.040	7.563	3.594
89.50	89.50	2468.61	3.571	0.940	5-S2n	1.233	1.521	1.252	1.177	7.999	3.857
107.40	107.40	2468.65	3.615	1.221	5-S2n	1.370	1.672	1.387	1.302	8.401	4.082
125.30	125.30	2468.70	3.656	1.517	5-S2n	1.496	1.812	1.520	1.417	8.718	4.279
143.20	143.20	2468.74	3.696	1.825	5-S2n	1.623	1.941	1.647	1.524	9.009	4.455
161.10	161.10	2468.77	3.734	2.151	5-S2n	1.748	2.064	1.772	1.624	9.276	4.616
179.00	179.00	2468.81	3.770	2.490	5-S2n	1.872	2.177	1.896	1.718	9.509	4.762

* Full Flow Headwater elevation is below inlet invert.

****

Straight Culvert

Inlet Elevation (invert): 2465.04 ft, Outlet Elevation (invert): 2464.16 ft

Culvert Length: 117.00 ft, Culvert Slope: 0.0075

Inlet Throat Elevation: 2465.04 ft, Inlet Crest Elevation: 2468.27 ft

****

Site Data - 4 - 36

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 2468.01 ft

Outlet Station: 117.00 ft

Outlet Elevation: 2464.16 ft

Number of Barrels: 4

Culvert Data Summary - 4 - 36

Barrel Shape: Circular

Barrel Diameter: 3.00 ft

Barrel Material: Corrugated Steel

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Beveled Edge (1:1)

Inlet Depression: Yes

Table 37 - Summary of Culvert Flows at Crossing: C-14B 198+40 [8-3-16]

Headwater Elevation (ft)	Total Discharge (cfs)	2 - 36 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
2466.06	0.00	0.00	0.00	1
2469.68	7.70	7.70	0.00	1
2469.72	15.40	15.40	0.00	1
2469.76	23.10	23.10	0.00	1
2469.80	30.80	30.80	0.00	1
2469.83	38.50	38.50	0.00	1
2469.86	46.20	46.20	0.00	1
2469.89	53.90	53.90	0.00	1
2469.92	61.60	61.60	0.00	1
2469.94	69.30	69.30	0.00	1
2469.97	77.00	77.00	0.00	1
2470.30	112.30	112.30	0.00	Overtopping

Table 38 - Culvert Summary Table: 2 - 36

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	2466.06	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
7.70	7.70	2469.68	3.615	0.0*	5-S2n	0.492	0.608	0.492	0.359	5.007	3.159
15.40	15.40	2469.72	3.662	0.005	5-S2n	0.698	0.869	0.698	0.521	6.108	3.887
23.10	23.10	2469.76	3.702	0.253	5-S2n	0.867	1.073	0.878	0.644	6.687	4.366
30.80	30.80	2469.80	3.737	0.491	5-S2n	1.007	1.249	1.020	0.746	7.251	4.733
38.50	38.50	2469.83	3.769	0.730	5-S2n	1.138	1.407	1.153	0.834	7.687	5.034
46.20	46.20	2469.86	3.799	0.967	5-S2n	1.257	1.546	1.275	0.913	8.064	5.290
53.90	53.90	2469.89	3.828	1.212	5-S2n	1.374	1.675	1.391	0.985	8.408	5.516
61.60	61.60	2469.92	3.855	1.464	5-S2n	1.483	1.793	1.504	1.051	8.682	5.717
69.30	69.30	2469.94	3.882	1.731	5-S2n	1.592	1.909	1.615	1.112	8.936	5.901
77.00	77.00	2469.97	3.907	2.006	5-S2n	1.700	2.014	1.723	1.170	9.173	6.068

* Full Flow Headwater elevation is below inlet invert.

****

Straight Culvert

Inlet Elevation (invert): 2466.06 ft, Outlet Elevation (invert): 2465.16 ft

Culvert Length: 120.00 ft, Culvert Slope: 0.0075

Inlet Throat Elevation: 2466.06 ft, Inlet Crest Elevation: 2469.59 ft

****

Site Data - 2 - 36

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 2469.30 ft

Outlet Station: 120.00 ft

Outlet Elevation: 2465.16 ft

Number of Barrels: 2

Culvert Data Summary - 2 - 36

Barrel Shape: Circular

Barrel Diameter: 3.00 ft

Barrel Material: Corrugated Steel

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Beveled Edge (1:1)

Inlet Depression: Yes

Table 39 - Summary of Culvert Flows at Crossing: C-15 200+70 [8-3-16]

Headwater Elevation (ft)	Total Discharge (cfs)	3-42"x29" Steel Pipe Arch Discharge (cfs)	Roadway Discharge (cfs)	Iterations
2467.89	0.00	0.00	0.00	1
2470.16	9.70	9.70	0.00	1
2470.18	19.40	19.40	0.00	1
2470.20	29.10	29.10	0.00	1
2470.22	38.80	38.80	0.00	1
2470.24	48.50	48.50	0.00	1
2470.25	58.20	58.20	0.00	1
2470.26	67.90	67.90	0.00	1
2470.28	77.60	77.60	0.00	1
2470.29	87.30	87.30	0.00	1
2470.39	97.00	97.00	0.00	1
2471.60	147.79	147.79	0.00	Overtopping

Table 40 - Culvert Summary Table: 3-42"x29" Steel Pipe Arch

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	2467.89	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
9.70	9.70	2470.16	2.271	0.0*	1-S2n	0.355	0.404	0.355	0.349	3.766	3.071
19.40	19.40	2470.18	2.294	0.0*	1-S2n	0.519	0.591	0.519	0.521	4.652	3.891
29.10	29.10	2470.20	2.313	0.188	1-S2n	0.655	0.743	0.655	0.657	5.244	4.445
38.80	38.80	2470.22	2.330	0.384	1-S2n	0.767	0.881	0.772	0.772	5.733	4.871
48.50	48.50	2470.24	2.345	0.581	1-S2n	0.878	1.003	0.878	0.874	6.161	5.223
58.20	58.20	2470.25	2.360	0.781	1-S2n	0.978	1.111	0.995	0.967	6.395	5.524
67.90	67.90	2470.26	2.374	0.987	1-S2n	1.077	1.209	1.082	1.052	6.781	5.788
77.60	77.60	2470.28	2.387	1.202	1-S2n	1.176	1.299	1.176	1.131	7.067	6.025
87.30	87.30	2470.29	2.400	1.434	1-S2n	1.275	1.390	1.275	1.205	7.286	6.239
97.00	97.00	2470.39	2.498	0.385	5-S2n	1.376	1.479	1.376	1.275	7.473	6.435

* Full Flow Headwater elevation is below inlet invert.

****

Straight Culvert

Inlet Elevation (invert): 2467.89 ft, Outlet Elevation (invert): 2467.26 ft

Culvert Length: 127.00 ft, Culvert Slope: 0.0050

Inlet Throat Elevation: 2467.89 ft, Inlet Crest Elevation: 2470.12 ft

****

Site Data - 3-42"x29" Steel Pipe Arch

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 2470.00 ft

Outlet Station: 127.00 ft

Outlet Elevation: 2467.26 ft

Number of Barrels: 3

Culvert Data Summary - 3-42"x29" Steel Pipe Arch

Barrel Shape: Pipe Arch

Barrel Span: 42.00 in

Barrel Rise: 29.00 in

Barrel Material: Steel or Aluminum

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Headwall

Inlet Depression: Yes

Table 41 - Summary of Culvert Flows at Crossing: C-16 208+80 [8-3-16]

Headwater Elevation (ft)	Total Discharge (cfs)	4-10X5 RCBC Discharge (cfs)	Roadway Discharge (cfs)	Iterations
2466.34	0.00	0.00	0.00	1
2469.50	150.00	150.00	0.00	1
2469.65	300.00	300.00	0.00	1
2469.78	450.00	450.00	0.00	1
2469.90	600.00	600.00	0.00	1
2470.00	750.00	750.00	0.00	1
2470.24	900.00	900.00	0.00	1
2470.43	969.00	969.00	0.00	1
2471.05	1200.00	1200.00	0.00	1
2471.44	1350.00	1350.00	0.00	1
2471.82	1500.00	1500.00	0.00	1
2473.00	1954.59	1954.59	0.00	Overtopping

Table 42 - Culvert Summary Table: 4-10X5 RCBC

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	2466.34	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
150.00	150.00	2469.50	3.162	0.221	1-S2n	0.610	0.759	0.610	0.917	6.152	4.996
300.00	300.00	2469.65	3.314	0.704	1-S2n	0.972	1.204	0.990	1.376	7.573	6.389
450.00	450.00	2469.78	3.442	1.141	1-S2n	1.264	1.578	1.301	1.740	8.646	7.342
600.00	600.00	2469.90	3.557	1.562	1-S2n	1.529	1.912	1.586	2.053	9.457	8.084
750.00	750.00	2470.00	3.662	1.981	1-S2n	1.780	2.218	1.853	2.331	10.118	8.698
900.00	900.00	2470.24	3.897	2.406	1-S2n	2.010	2.505	2.107	2.584	10.681	9.225
969.00	969.00	2470.43	4.091	2.604	1-S2n	2.114	2.632	2.221	2.694	10.906	9.446
1200.00	1200.00	2471.05	4.710	3.286	1-S2n	2.450	3.035	2.583	3.036	11.615	10.105
1350.00	1350.00	2471.44	5.096	3.746	5-S2n	2.660	3.283	2.812	3.242	12.004	10.483
1500.00	1500.00	2471.82	5.478	4.223	5-S2n	2.863	3.522	3.030	3.436	12.376	10.830

****

Straight Culvert

Inlet Elevation (invert): 2466.34 ft, Outlet Elevation (invert): 2465.79 ft

Culvert Length: 110.00 ft, Culvert Slope: 0.0050

Inlet Throat Elevation: 2466.34 ft, Inlet Crest Elevation: 2469.24 ft

****

Site Data - 4-10X5 RCBC

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 2469.00 ft

Outlet Station: 110.00 ft

Outlet Elevation: 2465.79 ft

Number of Barrels: 4

Culvert Data Summary - 4-10X5 RCBC

Barrel Shape: Concrete Box

Barrel Span: 10.00 ft

Barrel Rise: 5.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: 1.5:1 Bevel (90º) Headwall

Inlet Depression: Yes

Table 43 - Summary of Culvert Flows at Crossing: C-17 220+01 [8-3-16]

Headwater Elevation (ft)	Total Discharge (cfs)	2-24 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
2472.20	0.00	0.00	0.00	1
2477.01	2.50	2.50	0.00	1
2477.03	5.00	5.00	0.00	1
2477.04	7.50	7.50	0.00	1
2477.06	10.00	10.00	0.00	1
2477.07	12.50	12.50	0.00	1
2477.08	15.00	15.00	0.00	1
2477.10	17.50	17.50	0.00	1
2477.11	20.00	20.00	0.00	1
2477.12	22.50	22.50	0.00	1
2477.13	25.00	25.00	0.00	1
2477.50	66.88	66.88	0.00	Overtopping

Table 44 - Culvert Summary Table: 2-24

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	2472.20	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
2.50	2.50	2477.01	4.809	0.0*	5-S2n	0.293	0.382	0.293	0.200	4.245	1.181
5.00	5.00	2477.03	4.828	0.0*	5-S2n	0.423	0.546	0.423	0.301	5.105	1.523
7.50	7.50	2477.04	4.844	0.0*	5-S2n	0.526	0.673	0.526	0.382	5.676	1.762
10.00	10.00	2477.06	4.859	0.0*	5-S2n	0.608	0.783	0.608	0.452	6.176	1.950
12.50	12.50	2477.07	4.872	0.0*	5-S2n	0.685	0.884	0.685	0.514	6.557	2.106
15.00	15.00	2477.08	4.884	0.0*	5-S2n	0.757	0.974	0.757	0.571	6.900	2.241
17.50	17.50	2477.10	4.896	0.133	5-S2n	0.822	1.054	0.828	0.624	7.111	2.360
20.00	20.00	2477.11	4.907	0.297	5-S2n	0.888	1.126	0.895	0.674	7.340	2.467
22.50	22.50	2477.12	4.918	0.474	5-S2n	0.949	1.199	0.949	0.721	7.661	2.565
25.00	25.00	2477.13	4.928	0.0*	5-S2n	1.010	1.269	1.016	0.766	7.798	2.655

* Full Flow Headwater elevation is below inlet invert.

****

Straight Culvert

Inlet Elevation (invert): 2472.20 ft, Outlet Elevation (invert): 2470.98 ft

Culvert Length: 122.01 ft, Culvert Slope: 0.0100

Inlet Throat Elevation: 2472.20 ft, Inlet Crest Elevation: 2476.98 ft

****

Site Data - 2-24

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 2476.50 ft

Outlet Station: 122.00 ft

Outlet Elevation: 2470.98 ft

Number of Barrels: 2

Culvert Data Summary - 2-24

Barrel Shape: Circular

Barrel Diameter: 2.00 ft

Barrel Material: Corrugated Steel

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Beveled Edge (1:1)

Inlet Depression: Yes

Table 45 - Summary of Culvert Flows at Crossing: C-17A Iberia Ave [8-3-16]

Headwater Elevation (ft)	Total Discharge (cfs)	3-49"x33" Steel Pipe Arch Discharge (cfs)	Roadway Discharge (cfs)	Iterations
2470.24	0.00	0.00	0.00	1
2470.92	13.40	13.40	0.00	1
2471.25	26.80	26.80	0.00	1
2471.52	40.20	40.20	0.00	1
2471.77	53.60	53.60	0.00	1
2471.99	67.00	67.00	0.00	1
2472.21	80.40	80.40	0.00	1
2472.41	93.80	93.80	0.00	1
2472.61	107.20	107.20	0.00	1
2472.81	120.60	120.60	0.00	1
2473.02	134.00	134.00	0.00	1
2474.50	211.16	211.16	0.00	Overtopping

Table 46 - Culvert Summary Table: 3-49"x33" Steel Pipe Arch

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	2470.24	0.000	0.000	0-NF	0.000	0.000	0.540	0.000	0.000	0.000
13.40	13.40	2470.92	0.679	0.398	1-JS1t	0.338	0.455	0.970	0.430	1.333	2.345
26.80	26.80	2471.25	1.008	0.634	1-JS1t	0.503	0.666	1.184	0.644	2.117	2.987
40.20	40.20	2471.52	1.278	0.841	1-JS1t	0.614	0.837	1.353	0.813	2.738	3.424
53.60	53.60	2471.77	1.525	1.038	1-JS1t	0.724	0.991	1.498	0.958	3.271	3.762
67.00	67.00	2471.99	1.754	1.234	1-JS1t	0.818	1.129	1.627	1.087	3.760	4.041
80.40	80.40	2472.21	1.967	1.433	1-JS1t	0.908	1.251	1.743	1.203	4.205	4.281
93.80	93.80	2472.41	2.170	1.639	1-JS1t	0.998	1.361	1.851	1.311	4.639	4.491
107.20	107.20	2472.61	2.371	1.851	1-JS1t	1.079	1.462	1.951	1.411	5.046	4.680
120.60	120.60	2472.81	2.574	2.073	1-S2n	1.159	1.564	1.237	1.505	9.062	4.851
134.00	134.00	2473.02	2.783	2.305	5-S2n	1.240	1.663	1.326	1.595	9.335	5.007

****

Straight Culvert

Inlet Elevation (invert): 2470.24 ft, Outlet Elevation (invert): 2469.66 ft

Culvert Length: 65.00 ft, Culvert Slope: 0.0089

****

Site Data - 3-49"x33" Steel Pipe Arch

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 2470.24 ft

Outlet Station: 65.00 ft

Outlet Elevation: 2469.66 ft

Number of Barrels: 3

Culvert Data Summary - 3-49"x33" Steel Pipe Arch

Barrel Shape: Pipe Arch

Barrel Span: 49.00 in

Barrel Rise: 33.00 in

Barrel Material: Steel or Aluminum

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Headwall

Inlet Depression: NONE

Table 47 - Summary of Culvert Flows at Crossing: C-18 226+38 [8-3-16]

Headwater Elevation (ft)	Total Discharge (cfs)	3-49"x33" Steel Pipe Arch Discharge (cfs)	Roadway Discharge (cfs)	Iterations
2475.27	0.00	0.00	0.00	1
2479.36	12.60	12.60	0.00	1
2479.39	25.20	25.20	0.00	1
2479.42	37.80	37.80	0.00	1
2479.45	50.40	50.40	0.00	1
2479.47	63.00	63.00	0.00	1
2479.50	75.60	75.60	0.00	1
2479.52	88.20	88.20	0.00	1
2479.54	100.80	100.80	0.00	1
2479.56	113.40	113.40	0.00	1
2479.58	126.00	126.00	0.00	1
2480.30	241.83	241.83	0.00	Overtopping

Table 48 - Culvert Summary Table: 3-49"x33" Steel Pipe Arch

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	2475.27	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
12.60	12.60	2479.36	4.088	0.0*	5-S2n	0.381	0.440	0.381	0.509	4.006	2.055
25.20	25.20	2479.39	4.124	0.0*	5-S2n	0.560	0.643	0.569	0.753	4.809	2.572
37.80	37.80	2479.42	4.154	0.178	5-S2n	0.698	0.807	0.698	0.942	5.587	2.915
50.40	50.40	2479.45	4.180	0.381	5-S2n	0.820	0.955	0.842	1.101	5.934	3.180
63.00	63.00	2479.47	4.205	0.585	5-S2n	0.933	1.089	0.933	1.240	6.561	3.396
75.60	75.60	2479.50	4.227	0.792	5-S2n	1.041	1.208	1.041	1.365	6.927	3.581
88.20	88.20	2479.52	4.249	1.002	5-S2n	1.143	1.316	1.148	1.480	7.220	3.743
100.80	100.80	2479.54	4.270	1.220	5-S2n	1.244	1.415	1.244	1.586	7.527	3.887
113.40	113.40	2479.56	4.289	1.453	5-S2n	1.344	1.512	1.344	1.686	7.780	4.018
126.00	126.00	2479.58	4.308	0.909	5-S2n	1.445	1.607	1.445	1.779	7.996	4.139

* Full Flow Headwater elevation is below inlet invert.

****

Straight Culvert

Inlet Elevation (invert): 2475.27 ft, Outlet Elevation (invert): 2474.57 ft

Culvert Length: 140.00 ft, Culvert Slope: 0.0050

Inlet Throat Elevation: 2475.27 ft, Inlet Crest Elevation: 2479.30 ft

****

Site Data - 3-49"x33" Steel Pipe Arch

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 2479.00 ft

Outlet Station: 140.00 ft

Outlet Elevation: 2474.57 ft

Number of Barrels: 3

Culvert Data Summary - 3-49"x33" Steel Pipe Arch

Barrel Shape: Pipe Arch

Barrel Span: 49.00 in

Barrel Rise: 33.00 in

Barrel Material: Steel or Aluminum

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Headwall

Inlet Depression: Yes

APPENDIX D

PROPOSED CHANNEL HYDRAULIC COMPUTATIONS

Valencia Rd - Wade to Ajo: Roadside Channel Summary Table

7/25/2016

Approx. Roadway Station		Water-shed (CP)	Est. Q100 (cfs)	Channel Stationing		Roadside Channels												
						Channel Dsgn Type - C=collector ND=normal depth	Channel Lining Type	Channel Segment Flowline Elevs.		Trapezoidal Channel Bottom Width (ft)	Channel Longitudal Slope (ft/ft)	Channel Slope Same As Rdwy Slope (yes/no)	Side Slope (_H:1V)		Min Required Depth (ft)	Normal Flow Depth (ft)	Channel Flow Velocity (fps)	Min Normal Depth Freeboard per COT Eq (ft)
From Downstream (DS)	To Upstream (US)			From (DS)	To (US)			DS	US				Fore	Back				
Valencia Rd																		
CP 1A Channel																		
90+70	94+35	1A	47			ND	Veg Earth	2433.00	2434.80	10	0.005		4	4	1.2	1.0	3.7	0.2
CP 1B Channel																		
95+75	99+95	1B	48			C	1	2433.60	2435.70	6	0.005		4	1	2.3	1.3	4.0	0.3
CP 2 Channel																		
100+90	107+15	2	142			C	1	2434.80	2438.00	10	0.005		4	1	2.3	1.3	4.1	0.3
107+15	113+50	2E	68			C	2	2438.00	2441.2	10	0.005		4	1	3.2	2.2	4.0	0.4
CP 3A Channel																		
114+50	117+50	3A	64			C	1	2440.50	2442.00	10	0.005		4	1	2.2	1.2	4	0.2
CP 3B Channel																		
117+95	122+45	3B	125			C	2	2441.20	2443.50	10	0.005		4	1	3.1	2.1	3.9	0.4
CP 3C Channel																		
122+70	126+00	3C	203			C	1	2442.20	2442.90	25	0.002		4	1	2.9	1.9	3.6	0.4
126+00	131+40	3CE	126			C	1	2442.90	2445.10	20	0.004		4	1	2.3	1.3	4.0	0.3
CP 4 Channel																		
131+85	133+45	4	122			C	1	2444.5	2445.1	20	0.004		4	1	2.3	1.3	4.0	0.3
CP 5 Channel																		
134+00	137+00	5	192			C	2	2445.50	2447.00	20	0.005		4	1	2.9	1.9	4	0.4
137+00	139+00	5Cntr	141			C	2	2447.00	2448.00	20	0.005		4	1	2.6	1.6	3.6	0.3
139+00	142+50	5E	104			C	1	2448.00	2449.75	20	0.005		4	1	2.1	1.1	4.1	0.2
CP 6 Channel																		
143+50	147+00	6	173			C	2	2450.50	2452.25	20	0.005		4	1	2.8	1.8	3.9	0.3
147+00	149+00	6E	105			C	1	2452.25	2453.25	20	0.005		4	1	2.2	1.1	4.1	0.2
CP 11B W Channel																		
177+00	175+00	11BW	65			C	1	2461.30	2462.10	6	-0.004		3	1	2.7	1.7	4.1	0.3
CP 11B E Channel																		
178+15	180+00	11B E	61			C	1	2461.30	2462.00	6	0.004		3	1	2.6	1.6	4.1	0.3
CP 12 Channel																		
181+00	184+50	12	125			C	2	2462.00	2463.80	12	0.005		2	1	3.0	2	4.0	0.4
CP 13 W Channel																		
187+00	184+50	13W	135			C	2	2462.10	2463.40	12	-0.005		2	1	3.1	2.1	4.2	0.4
CP 13 E Channel																		
189+70	192+65	13E	153			C	2	2462.10	2464.00	12	0.006		2	1	3.2	2.2	4.6	0.4
CP 14A W Channel																		
194+70	192+70	14A W	67			C	1	2465.10	2465.90	10	-0.004		2	1	2.4	1.4	4.0	0.3
CP 14A E Channel																		
195+15	196+00	14A E	45			C	1	2466.10	2466.40	6	0.005		3	1	2.3	1.3	4.0	0.3

Open Channel Hydraulic Analysis Report
Valencia Rd – Wade Rd to Ajo Way
7-25-16

Project Data

Project Title: Valencia Rd-Wade to Ajo

Date: 7-25-16

CMG Project No: 15-043

Channel Analysis: CP1A Collector chnl [7-17-16]

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 4.0000 ft/ft

Side Slope 2 (Z2): 1.0000 ft/ft

Channel Width: 10.0000 ft

Longitudinal Slope: 0.0050 ft/ft

Manning's n: 0.0250

Flow: 47.0000 cfs

Result Parameters

Depth: 1.0194 ft

Area of Flow: 12.7917 ft^2

Wetted Perimeter: 15.6446 ft

Hydraulic Radius: 0.8176 ft

Average Velocity: 3.6743 ft/s

Top Width: 15.0969 ft

Froude Number: 0.7034

Critical Depth: 0.8208 ft

Critical Velocity: 4.7511 ft/s

Critical Slope: 0.0107 ft/ft

Critical Top Width: 14.10 ft

Calculated Max Shear Stress: 0.3180 lb/ft^2

Calculated Avg Shear Stress: 0.2551 lb/ft^2

Channel Analysis: CP1B Collector chnl [7-25-16]

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 4.0000 ft/ft

Side Slope 2 (Z2): 1.0000 ft/ft

Channel Width: 6.0000 ft

Longitudinal Slope: 0.0050 ft/ft

Manning's n: 0.0250

Flow: 48.0000 cfs

Result Parameters

Depth: 1.3074 ft

Area of Flow: 12.1177 ft^2

Wetted Perimeter: 13.2395 ft

Hydraulic Radius: 0.9153 ft

Average Velocity: 3.9611 ft/s

Top Width: 12.5370 ft

Froude Number: 0.7100

Critical Depth: 1.0751 ft

Critical Velocity: 5.1389 ft/s

Critical Slope: 0.0104 ft/ft

Critical Top Width: 11.38 ft

Calculated Max Shear Stress: 0.4079 lb/ft^2

Calculated Avg Shear Stress: 0.2856 lb/ft^2

Channel Analysis: CP2 E Collector chnl [7-17-16]

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 4.0000 ft/ft

Side Slope 2 (Z2): 1.0000 ft/ft

Channel Width: 10.0000 ft

Longitudinal Slope: 0.0050 ft/ft

Manning's n: 0.0250

Flow: 68.0000 cfs

Result Parameters

Depth: 1.2547 ft

Area of Flow: 16.4824 ft^2

Wetted Perimeter: 16.9476 ft

Hydraulic Radius: 0.9726 ft

Average Velocity: 4.1256 ft/s

Top Width: 16.2734 ft

Froude Number: 0.7224

Critical Depth: 1.0306 ft

Critical Velocity: 5.2462 ft/s

Critical Slope: 0.0101 ft/ft

Critical Top Width: 15.15 ft

Calculated Max Shear Stress: 0.3915 lb/ft^2

Calculated Avg Shear Stress: 0.3034 lb/ft^2

Channel Analysis: CP2 W Collector chnl [7-17-16]

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 4.0000 ft/ft

Side Slope 2 (Z2): 1.0000 ft/ft

Channel Width: 10.0000 ft

Longitudinal Slope: 0.0050 ft/ft

Manning's n: 0.0350

Flow: 142.0000 cfs

Result Parameters

Depth: 2.2479 ft

Area of Flow: 35.1110 ft^2

Wetted Perimeter: 22.4472 ft

Hydraulic Radius: 1.5642 ft

Average Velocity: 4.0443 ft/s

Top Width: 21.2393 ft

Froude Number: 0.5543

Critical Depth: 1.6015 ft

Critical Velocity: 6.3315 ft/s

Critical Slope: 0.0177 ft/ft

Critical Top Width: 18.01 ft

Calculated Max Shear Stress: 0.7013 lb/ft^2

Calculated Avg Shear Stress: 0.4880 lb/ft^2

Channel Analysis: CP3A Collector chnl [7-17-16]

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 4.0000 ft/ft

Side Slope 2 (Z2): 1.0000 ft/ft

Channel Width: 10.0000 ft

Longitudinal Slope: 0.0050 ft/ft

Manning's n: 0.0250

Flow: 64.0000 cfs

Result Parameters

Depth: 1.2128 ft

Area of Flow: 15.8057 ft^2

Wetted Perimeter: 16.7158 ft

Hydraulic Radius: 0.9456 ft

Average Velocity: 4.0492 ft/s

Top Width: 16.0641 ft

Froude Number: 0.7194

Critical Depth: 0.9931 ft

Critical Velocity: 5.1627 ft/s

Critical Slope: 0.0102 ft/ft

Critical Top Width: 14.97 ft

Calculated Max Shear Stress: 0.3784 lb/ft^2

Calculated Avg Shear Stress: 0.2950 lb/ft^2

Channel Analysis: CP3B Collector chnl [7-17-16]

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 4.0000 ft/ft

Side Slope 2 (Z2): 1.0000 ft/ft

Channel Width: 10.0000 ft

Longitudinal Slope: 0.0050 ft/ft

Manning's n: 0.0350

Flow: 125.0000 cfs

Result Parameters

Depth: 2.1011 ft

Area of Flow: 32.0471 ft^2

Wetted Perimeter: 21.6343 ft

Hydraulic Radius: 1.4813 ft

Average Velocity: 3.9005 ft/s

Top Width: 20.5054 ft

Froude Number: 0.5498

Critical Depth: 1.4858 ft

Critical Velocity: 6.1344 ft/s

Critical Slope: 0.0180 ft/ft

Critical Top Width: 17.43 ft

Calculated Max Shear Stress: 0.6555 lb/ft^2

Calculated Avg Shear Stress: 0.4622 lb/ft^2

Channel Analysis: CP3CE Collector chnl [7-17-16]

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 4.0000 ft/ft

Side Slope 2 (Z2): 1.0000 ft/ft

Channel Width: 20.0000 ft

Longitudinal Slope: 0.0040 ft/ft

Manning's n: 0.0250

Flow: 126.0000 cfs

Result Parameters

Depth: 1.3250 ft

Area of Flow: 30.8885 ft^2

Wetted Perimeter: 27.3368 ft

Hydraulic Radius: 1.1299 ft

Average Velocity: 4.0792 ft/s

Top Width: 26.6249 ft

Froude Number: 0.6674

Critical Depth: 1.0257 ft

Critical Velocity: 5.4438 ft/s

Critical Slope: 0.0096 ft/ft

Critical Top Width: 25.13 ft

Calculated Max Shear Stress: 0.3307 lb/ft^2

Calculated Avg Shear Stress: 0.2820 lb/ft^2

Channel Analysis: CP3CW Collector chnl [7-17-16]

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 4.0000 ft/ft

Side Slope 2 (Z2): 1.0000 ft/ft

Channel Width: 25.0000 ft

Longitudinal Slope: 0.0020 ft/ft

Manning's n: 0.0250

Flow: 203.0000 cfs

Result Parameters

Depth: 1.8900 ft

Area of Flow: 56.1788 ft^2

Wetted Perimeter: 35.4653 ft

Hydraulic Radius: 1.5841 ft

Average Velocity: 3.6135 ft/s

Top Width: 34.4498 ft

Froude Number: 0.4987

Critical Depth: 1.2175 ft

Critical Velocity: 5.9454 ft/s

Critical Slope: 0.0091 ft/ft

Critical Top Width: 31.09 ft

Calculated Max Shear Stress: 0.2359 lb/ft^2

Calculated Avg Shear Stress: 0.1977 lb/ft^2

Channel Analysis: CP4 Collector chnl [7-17-16]

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 4.0000 ft/ft

Side Slope 2 (Z2): 1.0000 ft/ft

Channel Width: 20.0000 ft

Longitudinal Slope: 0.0040 ft/ft

Manning's n: 0.0250

Flow: 122.0000 cfs

Result Parameters

Depth: 1.3007 ft

Area of Flow: 30.2442 ft^2

Wetted Perimeter: 27.2025 ft

Hydraulic Radius: 1.1118 ft

Average Velocity: 4.0338 ft/s

Top Width: 26.5036 ft

Froude Number: 0.6655

Critical Depth: 1.0049 ft

Critical Velocity: 5.3931 ft/s

Critical Slope: 0.0097 ft/ft

Critical Top Width: 25.02 ft

Calculated Max Shear Stress: 0.3247 lb/ft^2

Calculated Avg Shear Stress: 0.2775 lb/ft^2

Channel Analysis: CP5E Collector chnl [7-18-16]

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 4.0000 ft/ft

Side Slope 2 (Z2): 1.0000 ft/ft

Channel Width: 20.0000 ft

Longitudinal Slope: 0.0050 ft/ft

Manning's n: 0.0250

Flow: 104.0000 cfs

Result Parameters

Depth: 1.1103 ft

Area of Flow: 25.2878 ft^2

Wetted Perimeter: 26.1481 ft

Hydraulic Radius: 0.9671 ft

Average Velocity: 4.1127 ft/s

Top Width: 25.5515 ft

Froude Number: 0.7285

Critical Depth: 0.9073 ft

Critical Velocity: 5.1477 ft/s

Critical Slope: 0.0100 ft/ft

Critical Top Width: 24.54 ft

Calculated Max Shear Stress: 0.3464 lb/ft^2

Calculated Avg Shear Stress: 0.3017 lb/ft^2

Channel Analysis: CP5Cntr Collector chnl [7-18-16]

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 4.0000 ft/ft

Side Slope 2 (Z2): 1.0000 ft/ft

Channel Width: 20.0000 ft

Longitudinal Slope: 0.0050 ft/ft

Manning's n: 0.0350

Flow: 141.0000 cfs

Result Parameters

Depth: 1.6100 ft

Area of Flow: 38.6802 ft^2

Wetted Perimeter: 28.9151 ft

Hydraulic Radius: 1.3377 ft

Average Velocity: 3.6453 ft/s

Top Width: 28.0500 ft

Froude Number: 0.5470

Critical Depth: 1.1022 ft

Critical Velocity: 5.6217 ft/s

Critical Slope: 0.0185 ft/ft

Critical Top Width: 25.51 ft

Calculated Max Shear Stress: 0.5023 lb/ft^2

Calculated Avg Shear Stress: 0.4174 lb/ft^2

Channel Analysis: CP5W Collector chnl [7-18-16]

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 4.0000 ft/ft

Side Slope 2 (Z2): 1.0000 ft/ft

Channel Width: 20.0000 ft

Longitudinal Slope: 0.0050 ft/ft

Manning's n: 0.0350

Flow: 192.0000 cfs

Result Parameters

Depth: 1.9205 ft

Area of Flow: 47.6319 ft^2

Wetted Perimeter: 30.6346 ft

Hydraulic Radius: 1.5548 ft

Average Velocity: 4.0309 ft/s

Top Width: 29.6027 ft

Froude Number: 0.5600

Critical Depth: 1.3399 ft

Critical Velocity: 6.1367 ft/s

Critical Slope: 0.0175 ft/ft

Critical Top Width: 26.70 ft

Calculated Max Shear Stress: 0.5992 lb/ft^2

Calculated Avg Shear Stress: 0.4851 lb/ft^2

Channel Analysis: CP6E Collector chnl [7-18-16]

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 4.0000 ft/ft

Side Slope 2 (Z2): 1.0000 ft/ft

Channel Width: 20.0000 ft

Longitudinal Slope: 0.0050 ft/ft

Manning's n: 0.0250

Flow: 105.0000 cfs

Result Parameters

Depth: 1.1166 ft

Area of Flow: 25.4485 ft^2

Wetted Perimeter: 26.1829 ft

Hydraulic Radius: 0.9720 ft

Average Velocity: 4.1260 ft/s

Top Width: 25.5829 ft

Froude Number: 0.7290

Critical Depth: 0.9129 ft

Critical Velocity: 5.1622 ft/s

Critical Slope: 0.0100 ft/ft

Critical Top Width: 24.56 ft

Calculated Max Shear Stress: 0.3484 lb/ft^2

Calculated Avg Shear Stress: 0.3032 lb/ft^2

Channel Analysis: CP6W Collector chnl [7-18-16]

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 4.0000 ft/ft

Side Slope 2 (Z2): 1.0000 ft/ft

Channel Width: 20.0000 ft

Longitudinal Slope: 0.0050 ft/ft

Manning's n: 0.0350

Flow: 173.0000 cfs

Result Parameters

Depth: 1.8106 ft

Area of Flow: 44.4064 ft^2

Wetted Perimeter: 30.0256 ft

Hydraulic Radius: 1.4789 ft

Average Velocity: 3.8958 ft/s

Top Width: 29.0528 ft

Froude Number: 0.5553

Critical Depth: 1.2547 ft

Critical Velocity: 5.9592 ft/s

Critical Slope: 0.0178 ft/ft

Critical Top Width: 26.27 ft

Calculated Max Shear Stress: 0.5649 lb/ft^2

Calculated Avg Shear Stress: 0.4614 lb/ft^2

Channel Analysis: CP11B W Collector chnl [7-20-16]

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 3.0000 ft/ft

Side Slope 2 (Z2): 1.0000 ft/ft

Channel Width: 6.0000 ft

Longitudinal Slope: 0.0040 ft/ft

Manning's n: 0.0250

Flow: 65.0000 cfs

Result Parameters

Depth: 1.6819 ft

Area of Flow: 15.7485 ft^2

Wetted Perimeter: 13.6970 ft

Hydraulic Radius: 1.1498 ft

Average Velocity: 4.1274 ft/s

Top Width: 12.7275 ft

Froude Number: 0.6539

Critical Depth: 1.3193 ft

Critical Velocity: 5.7035 ft/s

Critical Slope: 0.0099 ft/ft

Critical Top Width: 11.28 ft

Calculated Max Shear Stress: 0.4198 lb/ft^2

Calculated Avg Shear Stress: 0.2870 lb/ft^2

Channel Analysis: CP11B E Collector chnl [7-22-16]

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 3.0000 ft/ft

Side Slope 2 (Z2): 1.0000 ft/ft

Channel Width: 6.0000 ft

Longitudinal Slope: 0.0040 ft/ft

Manning's n: 0.0250

Flow: 61.0000 cfs

Result Parameters

Depth: 1.6264 ft

Area of Flow: 15.0485 ft^2

Wetted Perimeter: 13.4431 ft

Hydraulic Radius: 1.1194 ft

Average Velocity: 4.0536 ft/s

Top Width: 12.5055 ft

Froude Number: 0.6512

Critical Depth: 1.2715 ft

Critical Velocity: 5.6160 ft/s

Critical Slope: 0.0100 ft/ft

Critical Top Width: 11.09 ft

Calculated Max Shear Stress: 0.4059 lb/ft^2

Calculated Avg Shear Stress: 0.2794 lb/ft^2

Channel Analysis: CP12 Collector chnl [7-22-16]

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 2.0000 ft/ft

Side Slope 2 (Z2): 1.0000 ft/ft

Channel Width: 12.0000 ft

Longitudinal Slope: 0.0050 ft/ft

Manning's n: 0.0350

Flow: 125.0000 cfs

Result Parameters

Depth: 2.0393 ft

Area of Flow: 30.7089 ft^2

Wetted Perimeter: 19.4439 ft

Hydraulic Radius: 1.5794 ft

Average Velocity: 4.0705 ft/s

Top Width: 18.1178 ft

Froude Number: 0.5510

Critical Depth: 1.4101 ft

Critical Velocity: 6.2803 ft/s

Critical Slope: 0.0179 ft/ft

Critical Top Width: 16.23 ft

Calculated Max Shear Stress: 0.6362 lb/ft^2

Calculated Avg Shear Stress: 0.4928 lb/ft^2

Channel Analysis: CP13W Collector chnl [7-22-16]

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 2.0000 ft/ft

Side Slope 2 (Z2): 1.0000 ft/ft

Channel Width: 12.0000 ft

Longitudinal Slope: 0.0050 ft/ft

Manning's n: 0.0350

Flow: 135.0000 cfs

Result Parameters

Depth: 2.1308 ft

Area of Flow: 32.3809 ft^2

Wetted Perimeter: 19.7782 ft

Hydraulic Radius: 1.6372 ft

Average Velocity: 4.1691 ft/s

Top Width: 18.3925 ft

Froude Number: 0.5537

Critical Depth: 1.4797 ft

Critical Velocity: 6.4160 ft/s

Critical Slope: 0.0177 ft/ft

Critical Top Width: 16.44 ft

Calculated Max Shear Stress: 0.6648 lb/ft^2

Calculated Avg Shear Stress: 0.5108 lb/ft^2

Channel Analysis: CP13E Collector chnl [7-22-16]

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 2.0000 ft/ft

Side Slope 2 (Z2): 1.0000 ft/ft

Channel Width: 12.0000 ft

Longitudinal Slope: 0.0060 ft/ft

Manning's n: 0.0350

Flow: 153.0000 cfs

Result Parameters

Depth: 2.1721 ft

Area of Flow: 33.1415 ft^2

Wetted Perimeter: 19.9286 ft

Hydraulic Radius: 1.6630 ft

Average Velocity: 4.6166 ft/s

Top Width: 18.5162 ft

Froude Number: 0.6081

Critical Depth: 1.5998 ft

Critical Velocity: 6.6414 ft/s

Critical Slope: 0.0174 ft/ft

Critical Top Width: 16.80 ft

Calculated Max Shear Stress: 0.8132 lb/ft^2

Calculated Avg Shear Stress: 0.6226 lb/ft^2

Channel Analysis: CP14A W Collector chnl [7-22-16]

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 2.0000 ft/ft

Side Slope 2 (Z2): 1.0000 ft/ft

Channel Width: 10.0000 ft

Longitudinal Slope: 0.0040 ft/ft

Manning's n: 0.0250

Flow: 67.0000 cfs

Result Parameters

Depth: 1.3800 ft

Area of Flow: 16.6565 ft^2

Wetted Perimeter: 15.0374 ft

Hydraulic Radius: 1.1077 ft

Average Velocity: 4.0225 ft/s

Top Width: 14.1400 ft

Froude Number: 0.6531

Critical Depth: 1.0574 ft

Critical Velocity: 5.4688 ft/s

Critical Slope: 0.0100 ft/ft

Critical Top Width: 13.17 ft

Calculated Max Shear Stress: 0.3444 lb/ft^2

Calculated Avg Shear Stress: 0.2765 lb/ft^2

Channel Analysis: CP14A E Collector chnl [7-22-16]

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 3.0000 ft/ft

Side Slope 2 (Z2): 1.0000 ft/ft

Channel Width: 6.0000 ft

Longitudinal Slope: 0.0050 ft/ft

Manning's n: 0.0250

Flow: 45.0000 cfs

Result Parameters

Depth: 1.3008 ft

Area of Flow: 11.1884 ft^2

Wetted Perimeter: 11.9529 ft

Hydraulic Radius: 0.9360 ft

Average Velocity: 4.0220 ft/s

Top Width: 11.2030 ft

Froude Number: 0.7092

Critical Depth: 1.0636 ft

Critical Velocity: 5.2062 ft/s

Critical Slope: 0.0104 ft/ft

Critical Top Width: 10.25 ft

Calculated Max Shear Stress: 0.4058 lb/ft^2

Calculated Avg Shear Stress: 0.2920 lb/ft^2

APPENDIX E

CROSS CULVERT OUTLET TREATMENT COMPUTATIONS

CMG DRAINAGE ENGINEERING, INC.
3555 N. Mountain Ave. Tucson, Arizona 85719
Phone (520) 882-4244 Fax (520) 888-1421

Hec-14 Riprap Apron for Culverts

Valencia Rd: SR 86 to Wade Rd

Client: Pima Co/KHA **Date** 7/21/2016
Project #: 15-043 **By:** jlc

U.S. Department of Transportation
Federal Highway Administration
Hydraulic Engineering Circular No. 14
Equation 10.4 Riprap Apron for Culverts
Length and Depth factors from table 10.1

$$D_{50} = 0.2D\left(\frac{Q}{\sqrt{g}D^{2.5}}\right)^{4/3}\left(\frac{D}{TW}\right)$$

D_{50} = riprap size (ft)
Q = design discharge (cfs)
D = culvert diameter (ft)
TW = tailwater depth (ft) (0.4D < TW < D)
$L_A = X_L * D$
L_A = Apron Length (ft); X_L = Length Coefficient
$D_A = X_D * D_{50}$
D_A = Apron Depth (ft); X_D = Depth Coefficient

*Q is discharge rate per pipe

Sta. / CP	Q* (cfs)	D (ft)	TW (ft)	D_{50} (ft)	X_L	X_D	L_A (ft)	D_A (ft)
91+05 / CP-1A	16	2	1.42	0.5	4	3.3	8	1.7
94+34 / CP-1B	58	2.42	2.1	0.7	5	2.4	12.1	1.6
100+77 / CP-2	69	3.27	3.5	0.5	4	3.3	13.08	1.7
114+48 / CP-3A	56	3.66	3.77	0.5	4	3.3	14.64	1.7
117+95 / CP-3B	60	2.75	4.9	0.5	4	3.3	11	1.7
122+70 / CP-3C	37.5	2.75	2.51	0.5	4	3.3	11	1.7
131+84 / CP-4	61	2.1	1.88	0.9	6	2.2	12.6	2.1
134+20 / CP-5	83	3.7	3.82	0.5	4	3.3	14.8	1.7
142+85 / CP-6	56	2.53	2.66	0.5	4	3.3	10.12	1.7
178+13 / CP-11B	76	3.17	1.85	0.7	5	2.4	15.85	1.8
180+28 / CP-12	50	2.75	1.5	0.6	5	2.4	13.75	1.5
188+26 / CP-13	83	4	4.64	0.5	4	3.3	16	1.7
194+85 / CP-14A	45	3	1.7	0.5	4	3.3	12	1.7
198+40 / CP-14B	39	3	1.2	0.5	4	3.3	12	1.7
200+70 / CP-15	49	2.42	1.4	0.8	5	2.4	12.1	1.9
219+96 / CP-17	13	2	0.8	0.5	4	3.3	8	1.7
226+38 / CP-18	42	2.75	1.8	0.5	4	3.3	11	1.7
219+21 85' lt / CP-17A	42	2.75	1.6	0.5	4	3.3	11	1.7

CMG DRAINAGE ENGINEERING, INC.

3555 N. Mountain Ave. Tucson, Arizona 85719
Phone (520) 882-4244 Fax (520) 888-1421

HEC 14 RipRap Basin

Valencia Rd: SR 86 to Wade Rd

Client: Pima Co/KHA **Date** 7/15/2016
Project #: 15-043 **By:** jlc

HEC-14 Equation 10.1

$$\frac{h_s}{y_e} = 0.86\left(\frac{D_{50}}{y_e}\right)^{-0.55}\left(\frac{V_0}{\sqrt{g y_e}}\right) - C_0$$

h_s = dissipator pool depth (ft)
y_e = equivalent brink (outlet) depth (ft) = for circular culverts $(A/2)^{0.5}$
D_{50} = median rock size (ft)
W_0 = Culvert/Channel outlet width (ft)
C_0 = tailwater parameter

$TW/y_e < 0.75$	$C_0 = 1.4$
$0.75 < TW/y_e < 1.0$	$C_0 = 4.01(TW/y_e) - 1.6$
$1.0 < TW/y_e$	$C_0 = 2.4$

Error Note (1): If $(D_{50}/y_e) < 0.1$ then Change D_{50}, if not, then n/a.
Error Note (2): If $(h_s/D_{50}) < 2.0$ then Change D_{50}, if not, then n/a.
L_s (Pool length) = $10*h_s$; L_s minimum = $3*W_0$
L_A (Apron Length) = $5*h_s$; L_A minimum = W_0

For Min LB

Station	CP	W_0	V_0	A	D_{50}	T_w	y_e	C_0	h_s	L_s	L_A	L_B	Error Note (1):	Error Note (2):
208+80	16	10.0	12.4	n/a	0.5	3.4	2.13	2.4	1.0	30.0	10.0	40.0	n/a	n/a
				n/a				#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

APPENDIX F

ELECTRONIC FLO-2D MODEL FILES & REPORT PDF ON COMPACT DISK