# FINAL DRAINAGE REPORT

**FOR**

# MONTEZUMA CASTLE NATIONAL MONUMENT

**NPS Project No. NM-05-112018-16**

Located in
Yavapai County Parcel No. 800-09-001D
Northeast of the City of Camp Verde

*Prepared for*
National Park Services
Montezuma Castle RD
Camp Verde, AZ 86322

*Prepared by*
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April 27, 2018
Revised: March 16, 2018
Job #51118

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# APPENDICES

## INTRODUCTION

Montezuma Castle National Monument (MCNM) is a National Monument under National Park Service jurisdiction. The site is known for the cliff dwellings and is also known for the large amount of rooms within the dwelling. The site is used for educational and destination visits from local residents and tourists. The site is located 5 miles north from the City of Camp Verde and is located along Beaver Creek. The access to the site is on a single two lane road that comes from the east and south into the current parking lot. National Park Services is proposing a new parking lot to the south of the current drive and parking lot. Site improvements for this project will include a new parking lot, picnic area, sidewalks and water mitigation.

This site currently drains to the south and west and is channeled into Beaver Creek. The hydrology basins are smaller than 200 acres and the existing structures show no sign of lack of efficiency. The proposed drainage will follow the existing drainage patterns.

This project site is located within Zone X of FEMA FIRM Map #04025C2180H effective October 16, 2015. Zone X is described as areas determined to be outside the 0.2% annual chance floodplain. The FEMA map is provided in Appendix A.

## OBJECTIVE

The objective of this drainage report is to determine the impact the proposed parking lot will have on the runoff characteristics of the site. Mitigation measures will be provided for adverse impacts to the runoff conditions per the Federal Highway Administration Urban Design Manual (FHAUDM).

## PROCEDURE

The Rational Method was used to determine peak discharge rates for the pre and post-development conditions. Topographic and boundary information was provided by Yavapai County Geographic Information Systems, dated in 2014, were used for analysis. Rainfall data was taken from National Oceanic and Atmospheric Administration (NOAA) Atlas 14. Soil information was taken from the NRCS Web Soil Survey website and is provided in Appendix B. The site plan was prepared by Multicultural Technical Engineers (MTE) and was used to determine the additional impervious areas proposed with the development. Appendix C includes a drainage exhibit which illustrates the drainage patterns and proposed site improvements.

Pre-Development Conditions

The existing runoff is concentrated through two concentration points. Drainage Basin A (DB-A) is located north of the access road and is approximately 5 acres. Concentration Point A (CP-A) is concentrated through a 15 inch CSP culvert (N/S) that crosses the access road (E/W) and flows in an unimproved channel Beaver Creek to the southwest. This has provided a natural stream to form and deposit water in a low sloped ground where the channel disappears and allows the water to seep into the ground prior to reaching Beaver Creek. Drainage Basin B (DB-B) is located south of the access road and is approximately

8 acres and at (CP-B) sheet flows and natural channels to Beaver Creek to the southwest. There is no defined channel to Beaver Creek but the existing topography shows that the water flows to it. Both of these basins and points were used to determine the pre-development peak flow rates.

There is no evidence that runoff from the most upper part of the basin reaches Beaver Creek. This was determined by extensive topography review and a site walk. There was also no evidence that the existing infrastructure was underperforming or required maintenance.

Post-Development Conditions

The drainage will not change within the existing parking lot with the proposed picnic area because the addition of sidewalk is minimal considered the overall size of the drainage basin and will be mitigated through the addition of landscape and proper grading.

The proposed site grading in the post-development condition will not change the size of either drainage basins. DB-A will be unchanged in size and in surface types. DB-B will be unchanged in size but will have an increase in impervious area due to the addition of a parking lot with associated sidewalks. The overall post-development peak runoff will be increased due to the addition of impervious area with no change in the overall drainage base size.

DB-A is routed under the access road via CSP and will be routed through DB-B with an open channel to Beaver Creek. The open channel will include the runoff from DB-A and DB-B.

The FHWA Urban Design Manual does not specify when a detention basin is required. If Yavapai County Drainage requirements were to be followed, a detention basin would be required. At a minimum MTE recommends providing a Low Impact Detention Basin to treat the first flush in order to remove pollutants prior to the runoff entering Beaver Creek. A conceptual detention basin has been designed and is detailed on the construction plans. The detention basin analysis is included in the Appendix D.

As stated above a detention basin will be recommended for implementation. Computer software was used to analyze the pre- and post-condition runoff. A modified rational method was used with a user defined IDF Table provided by NOAA. The software takes the pre-development site and compares it the post-development site once asphalt was added and determines the total volume is needed to be stored.

## RESULTS

Multicultural Technical Engineers used the Rational Method provided from the design manual to calculate total runoff in DB-A and DB-B. The Rational Method was used because each Drainage Basin meets the requirements provided by the FHAUDM.

Pre-Development Conditions

DB-A has a net area of 5.51 acres. The Weighted C was calculated by taking the area (4.89 acres) of natural landscape (C = 0.3) and the area (0.62 acres) of impervious area (C = 0.95) and giving a weighted average of 0.373 because there is significantly more natural landscape than impervious area. The flow

from DB-A for the 100-year storm is 7.80 CFS. When analyzing CP-A the use of CulvertMaster was used. With a flow of 7.80 CFS through a 15 inch corrugated steel pipe (CSP) provides an exit velocity of 13.3 FPS. The velocity exiting the CSP is significant and is considered to be an extreme scour velocity that has the potential of destroying landscaping and property.

DB-B has a net area of 12.98 acres. The Weighted C was calculated by taking the area (12.73 acres) of natural landscape (C = 0.3) and the area (0.25 acres) of impervious area (C = 0.95) and giving a weighted average of 0.31 because there is significantly more natural landscape than impervious area. The flow from DB-B for the 100-year storm is 5.30 CFS.

Post-Development Conditions

DB-A did not change in size or in surface types. The amount of flow through CP-A is 7.80 CFS with a velocity of 13.3 FPS.

DB-B did not change in size but there was an increase of impervious area by 1.45 acres. Using the Rational Method again the net flow with additional impervious area is increased to 7.00 CFS.

DB-A and DB-B will be drained into a single open channel and discharged through CP-B at Beaver Creek. FlowMaster was used to determine the normal depth and velocity of the channel. In Appendix C includes the generated reports for each section of the channel including the culvert. The amount of freeboard through the channel is 1 to 3 feet. The depth is between 0.28 and .9 feet. The velocities are between 10.66 to 3.0 FPS. The channel flow was increased from 7.8 CFS to 10.8 CFS as the channel moves southeast to Beaver Creek to accommodate the additional drainage area DB-B provides.

The proposed parking lot will be graded to drain to the open channel. There are locations where water will be graded to drain within proposed green spaces to help alleviate the amount of runoff to the channel but the channel will be designed to accommodate the entire design flow. The green spaces will include existing vegetation or vegetation the client believes will survive. Refer to the landscape plan, prepared by others, for plant specifications/ locations and types for the area of the green spaces.

A detention basin was determine to have a total storage of 0.184 acre-ft (~8000 ft^3). This storage is approximately 3 large swimming pools. The detention basin will take place to the south of the parking lot and be routed to the proposed channel.

## CONCLUSION

The peak discharge for the 100-year storm event were determined for the proposed parking lot site for both the pre- and post-development conditions. The proposed lot has been designed to discharge runoff into the proposed channel, into the proposed detention basin, and then into Beaver Creek. The design concepts in this report will ensure that the drainage integrity of the site is sustained with proper maintenance activity. The proposed drainage plan provides a low maintenance system but may require clearing large debris and any grass/ shrubs inside the channel and parking lot basins. Refer to the construction plans by MTE for grades, locations, and notes of design.

## REFERENCES

https://msc.fema.gov/portal/search?AddressQuery=montezuma%20castle%20national%20monument#searchresultsanchor

Soil Map:

https://www.nps.gov/im/sodn/images/soilmapMOCA_1.png?maxwidth=650&autorotate=false

Geology info:

https://www.nps.gov/im/sodn/moca.htm

# Appendix HA

FEMA Floodplain Map

# National Flood Hazard Layer FIRMette

FEMA


## Legend

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

**SPECIAL FLOOD HAZARD AREAS**
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth
- Regulatory Floodway *Zone AE, AO, AH, VE, AR*

**OTHER AREAS OF FLOOD HAZARD**
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

**OTHER AREAS**
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

**GENERAL STRUCTURES**
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

**OTHER FEATURES**
- 20.2 / 17.5 Cross Sections with 1% Annual Chance Water Surface Elevation
- Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

**MAP PANELS**
- Digital Data Available
- No Digital Data Available
- Unmapped

N

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

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 2/28/2018 at 11:51:19 AM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

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

# NOTES TO USERS

This map is for use in administering the National Flood Insurance Program. It does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size. The **community map repository** should be consulted for possible updated or additional flood hazard information.

To obtain more detailed information in areas where **Base Flood Elevations** (BFEs) and/or **floodways** have been determined, users are encouraged to consult the Flood Profiles and Floodway Data and/or Summary of Stillwater Elevations tables contained within the Flood Insurance Study (FIS) report that accompanies this FIRM. Users should be aware that BFEs shown on the FIRM represent rounded whole-foot elevations. These BFEs are intended for flood insurance rating purposes only and should not be used as the sole source of flood elevation information. Accordingly, flood elevation data presented in the FIS report should be utilized in conjunction with the FIRM for purposes of construction and/or floodplain management.

**Coastal Base Flood Elevations** shown on this map apply only landward of 0.0' North American Vertical Datum of 1988 (NAVD 88). Users of this FIRM should be aware that coastal flood elevations are also provided in the Summary of Stillwater Elevations table in the Flood Insurance Study report for this jurisdiction. Elevations shown in the Summary of Stillwater Elevations table should be used for construction and/or floodplain management purposes when they are higher than the elevations shown on this FIRM.

Boundaries of the **floodways** were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data are provided in the Flood Insurance Study report for this jurisdiction.

Certain areas not in Special Flood Hazard Areas may be protected by **flood control structures.** Refer to Section 2.4 "Flood Protection Measures" of the Flood Insurance Study report for information on flood control structures for this jurisdiction.

The **projection** used in the preparation of this map was Universal Transverse Mercator (UTM) zone 12. The **horizontal datum** was NAD83, GRS1980 spheroid. Differences in datum, spheroid, projection or UTM zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this FIRM.

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

NGS Information Services
NOAA, N/NGS12
National Geodetic Survey
SSMC–3, #9202
1315 East–West Highway
Silver Spring, MD 20910–3282

To obtain current elevation, description, and/or location information for **bench marks** shown on this map, please contact the Information Services Branch of the National Geodetic Survey at **(301) 713–3242**, or visit its website at http://www.ngs.noaa.gov/.

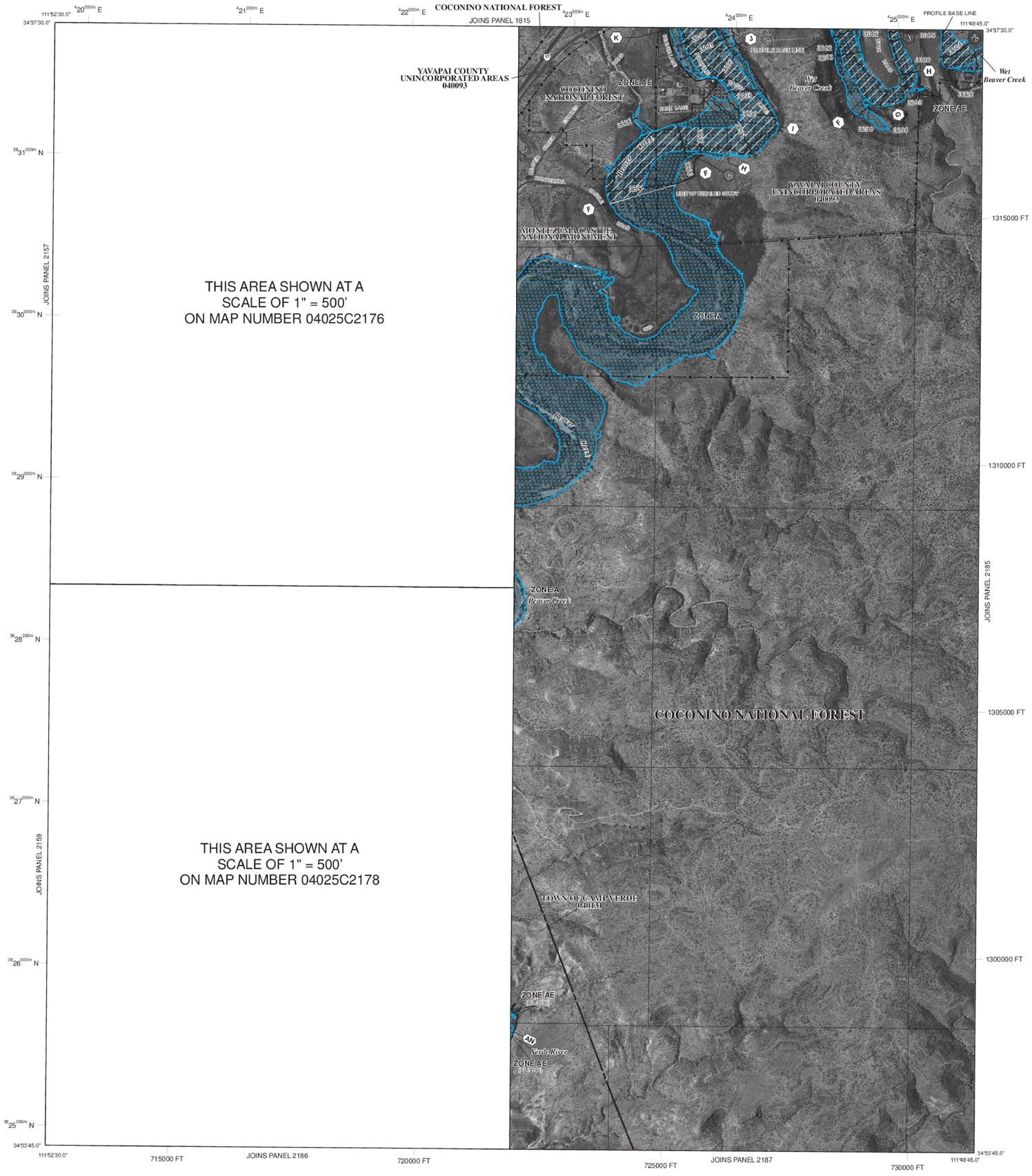
**Base map** information shown on this FIRM was derived from Arizona Digital Orthophoto Quadrangles (DOQs) with a resolution of 1 ft. per pixel from the USDA Aerial Photography Field Office dated 2010.

This map may reflect more detailed or up to date stream channel configurations than those shown on the previous FIRM. The floodplains and floodways that were transferred from the previous FIRM may have been adjusted to conform to these new stream channel configurations and improved topographic data. The profile baselines depicted on this map represent the hydraulic modeling baselines that match the flood profiles and Floodway Data Tables if applicable, in the FIS report. As a result, the profile baselines may deviate significantly from the new base map channel representation and may appear outside of the floodplain.

**Corporate limits** shown on this map are based on the best data available at the time of publication. Because changes due to annexations or de–annexations may have occurred after this map was published, map users should contact appropriate community officials to verify current corporate limit locations.

Please refer to the separately printed **Map Index** for an overview map of the county showing the layout of map panels; community map repository addresses; and a Listing of Communities table containing National Flood Insurance Program dates for each community as well as a listing of the panels on which each community is located.

For information and questions about this map, available products associated with this FIRM including historic versions of this FIRM, how to order products or the National Flood Insurance Program in general, please call the FEMA Map Information eXchange at 1-877-FEMA-MAP (1–877–336–2627) or visit the **FEMA Map Service Center** website at http://msc.fema.gov. Available products may include previously issued Letters ofMap Change, a Flood Insurance Study Report, and/or digital versions of this map. Many of these products can be ordered or obtained directly from the website. Users may determine the current map date for each FIRM panel by visiting the **FEMA Map Service Center** website or by calling the FEMA Map Information eXchange.




# LEGEND

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

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

**ZONE A** No Base Flood Elevations determined.

**ZONE AE** Base Flood Elevations determined.

**ZONE AH** Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.

**ZONE AO** Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.

**ZONE AR** Special Flood Hazard Area formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.

**ZONE A99** Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.

**ZONE V** Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.

**ZONE VE** Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

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

OTHER FLOOD AREAS

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

OTHER AREAS

**ZONE X** Areas determined to be outside the 0.2% annual chance floodplain.

**ZONE D** Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

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

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

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

- A — A — Cross section line
- 23 — 23 — Transect line
- 97°07'30", 32°22'30" — Geographic coordinates referenced to the North American Datum of 1983 (NAD 83)
- 4275000mN — 1000-meter Universal Transverse Mercator grid ticks, zone 12
- 6000000 FT — 5000-foot grid ticks: Arizona State Plane coordinate system, central zone (FIPSZONE 0202), Transverse Mercator
- DX5510 — Bench mark (see explanation in Notes to Users section of this FIRM panel)
- M1.5 — River Mile

MAP REPOSITORIES
Refer to Map Repositories list on Map Index

EFFECTIVE DATE OF COUNTYWIDE FLOOD INSURANCE RATE MAP
June 6, 2001
EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL
September 3, 2010
October 16, 2015 –to change Special Flood Hazard Areas, to change Base Flood Elevations, and to reflect updated topographic information.

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

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

MAP SCALE 1" = 1000'
500 0 1000 2000 FEET
300 0 300 600 METERS

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 2180H

# FIRM
## FLOOD INSURANCE RATE MAP

## YAVAPAI COUNTY, ARIZONA

AND INCORPORATED AREAS

**PANEL 2180 OF 3900**
(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

| COMMUNITY | NUMBER | PANEL | SUFFIX |
|---|---|---|---|
| YAVAPAI COUNTY | 040093 | 2180 | H |
| CAMP VERDE, TOWN OF | 040131 | 2180 | H |

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

**MAP NUMBER**
**04025C2180H**

**MAP REVISED**
**OCTOBER 16, 2015**

Federal Emergency Management Agency

# Appendix HB

NRCS Soil Map

# Soil Map—Beaver Creek Area, Arizona
(Montezuma Castle National Monument)

111° 50' 15" W — 111° 50' 8" W
34° 36' 42" N — 34° 36' 32" N
423200 — 423230 — 423260 — 423290 — 423320 — 423350 — 423380
3830310 — 3830280 — 3830250 — 3830220 — 3830190 — 3830160 — 3830130 — 3830100 — 3830070 — 3830040 — 3830010

Re

Gu

Soil Map may not be valid at this scale.

Map Scale: 1:862 if printed on B portrait (11" x 17") sheet.

N

Meters: 0 10 20 40 60

Feet: 0 40 80 160 240

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 12N WGS84

## MAP LEGEND

**Area of Interest (AOI)**
- Area of Interest (AOI)

**Soils**
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

**Special Point Features**
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

**Water Features**
- Streams and Canals

**Transportation**
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

**Background**
- Aerial Photography

## MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:31,700.

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

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

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

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

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

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

Soil Survey Area: Beaver Creek Area, Arizona
Survey Area Data: Version 7, Sep 11, 2017

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

Date(s) aerial images were photographed: Aug 28, 2014—Feb 13, 2017

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

# Map Unit Legend

| Map Unit Symbol | Map Unit Name | Acres in AOI | Percent of AOI |
|---|---|---|---|
| Gu | Guest clay | 5.7 | 90.1% |
| Re | Retriever loam | 0.6 | 9.9% |
| **Totals for Area of Interest** | | **6.3** | **100.0%** |

# Appendix HC

FlowMaster Channel Analysis

# Worksheet for 00+00.00 to 00+10.00

## Project Description

| | |
|---|---|
| Friction Method | Manning Formula |
| Solve For | Normal Depth |

## Input Data

| | | |
|---|---|---|
| Roughness Coefficient | 0.035 | |
| Channel Slope | 46.5000 | % |
| Left Side Slope | 2.00 | ft/ft (H:V) |
| Right Side Slope | 2.00 | ft/ft (H:V) |
| Bottom Width | 2.00 | ft |
| Discharge | 7.80 | ft³/s |

## Results

| | | |
|---|---|---|
| Normal Depth | 0.28 | ft |
| Flow Area | 0.73 | ft² |
| Wetted Perimeter | 3.27 | ft |
| Hydraulic Radius | 0.22 | ft |
| Top Width | 3.14 | ft |
| Critical Depth | 0.63 | ft |
| Critical Slope | 0.02530 | ft/ft |
| Velocity | 10.66 | ft/s |
| Velocity Head | 1.77 | ft |
| Specific Energy | 2.05 | ft |
| Froude Number | 3.89 | |
| Flow Type | Supercritical | |

## GVF Input Data

| | | |
|---|---|---|
| Downstream Depth | 0.00 | ft |
| Length | 0.00 | ft |
| Number Of Steps | 0 | |

## GVF Output Data

| | | |
|---|---|---|
| Upstream Depth | 0.00 | ft |
| Profile Description | | |
| Profile Headloss | 0.00 | ft |
| Downstream Velocity | Infinity | ft/s |
| Upstream Velocity | Infinity | ft/s |
| Normal Depth | 0.28 | ft |
| Critical Depth | 0.63 | ft |
| Channel Slope | 46.5000 | % |

# Worksheet for 00+00.00 to 00+10.00

## GVF Output Data

| | | |
|---|---|---|
| Critical Slope | 0.02530 | ft/ft |

# Worksheet for 00+10.00 to 00+51.85

## Project Description

| | |
|---|---|
| Friction Method | Manning Formula |
| Solve For | Normal Depth |

## Input Data

| | | |
|---|---|---|
| Roughness Coefficient | 0.035 | |
| Channel Slope | 13.2600 | % |
| Left Side Slope | 2.00 | ft/ft (H:V) |
| Right Side Slope | 2.00 | ft/ft (H:V) |
| Bottom Width | 2.00 | ft |
| Discharge | 7.80 | ft³/s |

## Results

| | | |
|---|---|---|
| Normal Depth | 0.40 | ft |
| Flow Area | 1.13 | ft² |
| Wetted Perimeter | 3.80 | ft |
| Hydraulic Radius | 0.30 | ft |
| Top Width | 3.61 | ft |
| Critical Depth | 0.63 | ft |
| Critical Slope | 0.02530 | ft/ft |
| Velocity | 6.89 | ft/s |
| Velocity Head | 0.74 | ft |
| Specific Energy | 1.14 | ft |
| Froude Number | 2.17 | |
| Flow Type | Supercritical | |

## GVF Input Data

| | | |
|---|---|---|
| Downstream Depth | 0.00 | ft |
| Length | 0.00 | ft |
| Number Of Steps | 0 | |

## GVF Output Data

| | | |
|---|---|---|
| Upstream Depth | 0.00 | ft |
| Profile Description | | |
| Profile Headloss | 0.00 | ft |
| Downstream Velocity | Infinity | ft/s |
| Upstream Velocity | Infinity | ft/s |
| Normal Depth | 0.40 | ft |
| Critical Depth | 0.63 | ft |
| Channel Slope | 13.2600 | % |

# Worksheet for 00+10.00 to 00+51.85

## GVF Output Data

| | | |
|---|---|---|
| Critical Slope | 0.02530 | ft/ft |

# Worksheet for 00+51.85 to 02+46.70

## Project Description

| | |
|---|---|
| Friction Method | Manning Formula |
| Solve For | Normal Depth |

## Input Data

| | | |
|---|---|---|
| Roughness Coefficient | 0.035 | |
| Channel Slope | 6.1900 | % |
| Left Side Slope | 2.00 | ft/ft (H:V) |
| Right Side Slope | 2.00 | ft/ft (H:V) |
| Bottom Width | 2.00 | ft |
| Discharge | 10.80 | ft³/s |

## Results

| | | |
|---|---|---|
| Normal Depth | 0.59 | ft |
| Flow Area | 1.87 | ft² |
| Wetted Perimeter | 4.63 | ft |
| Hydraulic Radius | 0.40 | ft |
| Top Width | 4.36 | ft |
| Critical Depth | 0.75 | ft |
| Critical Slope | 0.02424 | ft/ft |
| Velocity | 5.77 | ft/s |
| Velocity Head | 0.52 | ft |
| Specific Energy | 1.11 | ft |
| Froude Number | 1.55 | |
| Flow Type | Supercritical | |

## GVF Input Data

| | | |
|---|---|---|
| Downstream Depth | 0.00 | ft |
| Length | 0.00 | ft |
| Number Of Steps | 0 | |

## GVF Output Data

| | | |
|---|---|---|
| Upstream Depth | 0.00 | ft |
| Profile Description | | |
| Profile Headloss | 0.00 | ft |
| Downstream Velocity | Infinity | ft/s |
| Upstream Velocity | Infinity | ft/s |
| Normal Depth | 0.59 | ft |
| Critical Depth | 0.75 | ft |
| Channel Slope | 6.1900 | % |

# Worksheet for 00+51.85 to 02+46.70

## GVF Output Data

| | | |
|---|---|---|
| Critical Slope | 0.02424 | ft/ft |

# Worksheet for 02+46.70 to 05+19.98

## Project Description

| | |
|---|---|
| Friction Method | Manning Formula |
| Solve For | Normal Depth |

## Input Data

| | | |
|---|---|---|
| Roughness Coefficient | 0.035 | |
| Channel Slope | 2.7100 | % |
| Left Side Slope | 2.00 | ft/ft (H:V) |
| Right Side Slope | 2.00 | ft/ft (H:V) |
| Bottom Width | 2.00 | ft |
| Discharge | 10.80 | ft³/s |

## Results

| | | |
|---|---|---|
| Normal Depth | 0.73 | ft |
| Flow Area | 2.52 | ft² |
| Wetted Perimeter | 5.26 | ft |
| Hydraulic Radius | 0.48 | ft |
| Top Width | 4.92 | ft |
| Critical Depth | 0.75 | ft |
| Critical Slope | 0.02424 | ft/ft |
| Velocity | 4.28 | ft/s |
| Velocity Head | 0.28 | ft |
| Specific Energy | 1.01 | ft |
| Froude Number | 1.05 | |
| Flow Type | Supercritical | |

## GVF Input Data

| | | |
|---|---|---|
| Downstream Depth | 0.00 | ft |
| Length | 0.00 | ft |
| Number Of Steps | 0 | |

## GVF Output Data

| | | |
|---|---|---|
| Upstream Depth | 0.00 | ft |
| Profile Description | | |
| Profile Headloss | 0.00 | ft |
| Downstream Velocity | Infinity | ft/s |
| Upstream Velocity | Infinity | ft/s |
| Normal Depth | 0.73 | ft |
| Critical Depth | 0.75 | ft |
| Channel Slope | 2.7100 | % |

# Worksheet for 02+46.70 to 05+19.98

## GVF Output Data

| | | |
|---|---|---|
| Critical Slope | 0.02424 | ft/ft |

# Culvert Designer/Analyzer Report
## Under Maintenance Road
05+19.98 to 05+49.98

| Analysis Component | | | |
|---|---|---|---|
| Storm Event | Design | Discharge | 10.80 cfs |

| Peak Discharge Method: User-Specified | | | |
|---|---|---|---|
| Design Discharge | 10.80 cfs | Check Discharge | 7.80 cfs |

Tailwater properties: Trapezoidal Channel

| Tailwater conditions for Design Storm. | | | |
|---|---|---|---|
| Discharge | 10.80 cfs | Bottom Elevation | 0.00 ft |
| Depth | 0.66 ft | Velocity | 3.09 ft/s |

| Name | Description | Discharge | HW Elev. | Velocity |
|---|---|---|---|---|
| Culvert-1 | 2-18 inch Circular | 10.80 cfs | 1.34 ft | 3.06 ft/s |
| Weir | Not Considered | N/A | N/A | N/A |

# Culvert Designer/Analyzer Report
## Under Maintenance Road
05+19.98 to 05+49.98

Component:Culvert-1

| Culvert Summary | | | | | |
|---|---|---|---|---|---|
| Computed Headwater Elev | 1.34 | ft | Discharge | 10.80 | cfs |
| Inlet Control HW Elev. | 1.27 | ft | Tailwater Elevation | 0.66 | ft |
| Outlet Control HW Elev. | 1.34 | ft | Control Type | Entrance Control | |
| Headwater Depth/Height | 0.90 | | | | |

| Grades | | | | | |
|---|---|---|---|---|---|
| Upstream Invert | 0.00 | ft | Downstream Invert | -1.50 | ft |
| Length | 30.00 | ft | Constructed Slope | 5.0000 | % |

| Hydraulic Profile | | | | | |
|---|---|---|---|---|---|
| Profile | CompositePressureProfileS1S2 | | Depth, Downstream | 2.16 | ft |
| Slope Type | N/A | | Normal Depth | 0.47 | ft |
| Flow Regime | N/A | | Critical Depth | 0.90 | ft |
| Velocity Downstream | 3.06 | ft/s | Critical Slope | 0.5064 | % |

| Section | | | | | |
|---|---|---|---|---|---|
| Section Shape | Circular | | Mannings Coefficient | 0.012 | |
| Section Material | Corrugated HDPE (Smooth Interior) | | Span | 1.50 | ft |
| Section Size | 18 inch | | Rise | 1.50 | ft |
| Number Sections | 2 | | | | |

| Outlet Control Properties | | | | | |
|---|---|---|---|---|---|
| Outlet Control HW Elev. | 1.34 | ft | Upstream Velocity Head | 0.37 | ft |
| Ke | 0.20 | | Entrance Loss | 0.07 | ft |

| Inlet Control Properties | | | | | |
|---|---|---|---|---|---|
| Inlet Control HW Elev. | 1.27 | ft | Flow Control | N/A | |
| Inlet Type | Groove end projecting | | Area Full | 3.5 | ft² |
| K | 0.00450 | | HDS 5 Chart | 1 | |
| M | 2.00000 | | HDS 5 Scale | 3 | |
| C | 0.03170 | | Equation Form | 1 | |
| Y | 0.69000 | | | | |

# Worksheet for 05+49.98 to 07+05.00

## Project Description

| | |
|---|---|
| Friction Method | Manning Formula |
| Solve For | Normal Depth |

## Input Data

| | | |
|---|---|---|
| Roughness Coefficient | 0.035 | |
| Channel Slope | 3.3800 | % |
| Left Side Slope | 2.00 | ft/ft (H:V) |
| Right Side Slope | 2.00 | ft/ft (H:V) |
| Bottom Width | 2.00 | ft |
| Discharge | 10.80 | ft³/s |

## Results

| | | |
|---|---|---|
| Normal Depth | 0.69 | ft |
| Flow Area | 2.33 | ft² |
| Wetted Perimeter | 5.08 | ft |
| Hydraulic Radius | 0.46 | ft |
| Top Width | 4.76 | ft |
| Critical Depth | 0.75 | ft |
| Critical Slope | 0.02424 | ft/ft |
| Velocity | 4.64 | ft/s |
| Velocity Head | 0.33 | ft |
| Specific Energy | 1.02 | ft |
| Froude Number | 1.17 | |
| Flow Type | Supercritical | |

## GVF Input Data

| | | |
|---|---|---|
| Downstream Depth | 0.00 | ft |
| Length | 0.00 | ft |
| Number Of Steps | 0 | |

## GVF Output Data

| | | |
|---|---|---|
| Upstream Depth | 0.00 | ft |
| Profile Description | | |
| Profile Headloss | 0.00 | ft |
| Downstream Velocity | Infinity | ft/s |
| Upstream Velocity | Infinity | ft/s |
| Normal Depth | 0.69 | ft |
| Critical Depth | 0.75 | ft |
| Channel Slope | 3.3800 | % |

# Worksheet for 05+49.98 to 07+05.00

## GVF Output Data

| | | |
|---|---|---|
| Critical Slope | 0.02424 | ft/ft |

# Appendix HD

Bentley PondPack – Detention Basin Analysis

# Scenario Calculation Summary
## Licensed for Academic Use Only

| Scenario Summary | |
|---|---|
| ID | 1 |
| Label | Pre-Development 100 Year |
| Notes | |
| Active Topology | Pre-Development Active Topology |
| Hydrology | Pre-Development Hydrology |
| Rainfall Runoff | 100 Year |
| Physical | Pre-Development Physical |
| Initial Condition | Pre-Development Initial Condition |
| Boundary Condition | Pre-Development Boundary Condition |
| Infiltration and Inflow | Pre-Development Infiltration and Inflow |
| Output | Pre-Development Output |
| User Data Extensions | Pre-Development User Data Extensions |
| PondPack Engine Calculation Options | Base Calculation Options |

| Output Summary | | | |
|---|---|---|---|
| Output Increment | 0.050 hours | Duration | 24.000 hours |

| Rainfall Summary | | | |
|---|---|---|---|
| Return Event Tag | 100 | Rainfall Type | I-D-F Storm |
| Total Depth | (N/A) in | Storm Event | User Defined IDF Table - 1 - 100 Year |

### Modified Rational Method Grand Summary

| Frequency (years) | Area (acres) | Adjusted C Coefficient | Duration (hours) | Intensity (in/h) | Flow (Peak) (ft³/s) | Flow (Allowable) (ft³/s) | Volume (inflow) (ac-ft) | Volume (Storage) (ac-ft) |
|---|---|---|---|---|---|---|---|---|
| 100 | 2.000 | 0.870 | 0.317 | 5.159 | 9.05 | 5.27 | 0.237 | 0.104 |

### Executive Summary (Nodes)

| Label | Scenario | Return Event (years) | Truncation | Hydrograph Volume (ac-ft) | Time to Peak (hours) | Peak Flow (ft³/s) | Maximum Water Surface Elevation (ft) | Maximum Pond Storage (ac-ft) |
|---|---|---|---|---|---|---|---|---|
| DB-B | Pre-Development 100 Year | 100 | None | 0.232 | 0.100 | 9.05 | (N/A) | (N/A) |
| O-1 | Pre-Development 100 Year | 100 | None | 0.232 | 0.100 | 9.05 | (N/A) | (N/A) |

### Executive Summary (Links)

| Label | Type | Location | Hydrograph Volume (ac-ft) | Peak Time (hours) | Peak Flow (ft³/s) | End Point | Node Flow Direction |
|---|---|---|---|---|---|---|---|

# Appendix HE

Modified Rational Method

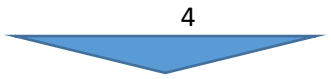
# North Watershed into Proposed Lot

| Flow Segment | Length (ft) | Beginning Elevation (ft) | End Elevation (ft) | Slope (ft/ft) | Manning's Coefficient (n) |
|---|---|---|---|---|---|
| Sheet Flow | 145 | 3320.43 | 3300.00 | 0.14089655 | 0.2 |
| Shallow | None - Straight into Roadside Channel | | | | |
| Channel | 876 | 3300.00 | 3228.50 | 0.081621 | |

Channel Analysis

$V = (K_u/n)\, R^{2/3}\, S^{1/2}$

| | | Units/ Location Found |
|---|---|---|
| V | 13.501 | Ft/s |
| K_u | 1.49 | Known |
| n | 0.02 | Table 3-4 |
| R | 0.45 | ---> |
| S | 0.0952 | From Topo |



in Feet

$T_{t3} = L/(60\,V)$

| | | |
|---|---|---|
| T_t3 | 0.6 | Minute(s) |
| L | 450 | From Topo |

Shallow Flow Analysis

$V = K_u\, k\, S_p^{0.5}$

| | | |
|---|---|---|
| V | 0.2258 | ft/s |
| K_u | 3.28 | Given |
| k | 0.46 | Table 3-3 |
| S_p | 15% | %, Topo |

$T_{t2} = L/(60\,V)$

| | | |
|---|---|---|
| T_t2 | 6.6425 | Minutes |
| L | 90 | |

Sheet Flow $T_{ti} = \frac{K_u}{I^{0.4}} \left( \frac{n\,L}{\sqrt{S}} \right)^{0.6}$ 3.2.2.3 FHA Code Book Equ 3-3

| | | |
|---|---|---|
| Tsf | 11.119 | Minutes |
| K_u | 0.933 | Given |
| I | 2.03 | in/hr (NOAA) 50Y1HR |
| n | 0.2 | Table 3-2 |
| L | 215 | ft,Topo |
| S | 0.186 | ft/ft, Topo |

| | | |
|---|---|---|
| Total, Tc | 18.3 | Minutes |

# North Watershed into Proposed Lot

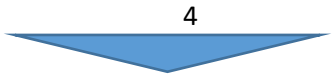
| $Q = (CIA)/K_u$ | | Weighted C | 0.373 | / |
|---|---|---|---|---|
| | | I_10Y30M | 2.21 | in/hr |
| | | I_25Y30M | 2.78 | |
| | | I_50Y30M | 3.26 | |
| | | I_100Y30M | 3.78 | |
| | | Area | 5.51 | acres |
| | | K_u | 1 | Unit adjustment |
| Q_10Y30M | 4.5438 | CFS | | |
| Q_25Y30M | 5.7157 | CFS | | |
| Q_50Y30M | 6.7026 | CFS | | |
| Q_100Y30M | 7.7717 | CFS | | |

# South Watershed Pre-Development

Channel Analysis

$V = (K_u/n)\, R^{2/3}\, S^{1/2}$

| | | Units/ Location Found |
|---|---|---|
| V | 13.501 | Ft/s |
| K_u | 1.49 | Known |
| n | 0.02 | Table 3-4 |
| R | 0.45 | ---> |
| S | 0.0952 | From Topo |



in Feet

$T_{t3} = L/(60\ V)$

| | | |
|---|---|---|
| T_t3 | 0.0 | Minute(s) |
| L | 0 | From Topo |

Reason to believe there is no dedicated or topographic channel displayed for water to run through.

Shallow Flow Analysis

$V = K_u\, k\, S_p^{0.5}$

| | | |
|---|---|---|
| V | 0.0813 | ft/s |
| K_u | 3.28 | Given |
| k | 0.46 | Table 3-3 |
| S_p | 5.4% | %, Topo |

$T_{t2} = L/(60\ V)$

| | | |
|---|---|---|
| T_t2 | 95.349 | Minutes |
| L | 465 | |

Sheet Flow $T_{ti} = \frac{K_u}{I^{0.4}} \left( \frac{n\ L}{\sqrt{S}} \right)^{0.6}$ 3.2.2.3 FHA Code Book Equ 3-3

| | | |
|---|---|---|
| Tsf | 20.756 | Minutes |
| K_u | 0.933 | Given |
| I | 2.03 | in/hr (NOAA) 50Y1HR |
| n | 0.2 | Table 3-2 |
| L | 475 | ft,Topo |
| S | 0.1134 | ft/ft, Topo |

| | | |
|---|---|---|
| Total, Tc | 116.1 | Minutes |

# South Watershed Pre-Development

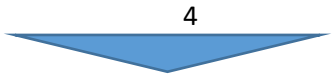
| | | | | |
|---|---|---|---|---|
| $Q = (CIA)/K_u$ | | Weighted C | 0.31 | / |
| | | I_10Y120M | 0.777 | in/hr |
| | | I_25Y120M | 0.972 | |
| | | I_50Y120M | 1.13 | |
| | | I_100Y120M | 1.31 | |
| | | Area | 12.98 | acres |
| | | K_u | 1 | Unit adjustment |
| Q_10Y120M | 3.157 | CFS | | |
| Q_25Y120M | 3.949 | CFS | | |
| Q_50Y120M | 4.591 | CFS | | |
| Q_100Y120M | 5.322 | CFS | | |

# South Watershed Post-Development

Channel Analysis

$V = (K_u/n)\, R^{2/3}\, S^{1/2}$

| | | Units/ Location Found |
|---|---|---|
| V | 13.501 | Ft/s |
| K_u | 1.49 | Known |
| n | 0.02 | Table 3-4 |
| R | 0.45 | ---> |
| S | 0.0952 | From Topo |



in Feet

$T_{t3} = L/(60\,V)$

| | | |
|---|---|---|
| T_t3 | 0.0 | Minute(s) |
| L | 0 | From Topo |

Reason to believe there is no dedicated or topographic channel displayed for water to run through.

Shallow Flow Analysis

$V = K_u\, k\, S_p^{0.5}$

| | | |
|---|---|---|
| V | 0.0813 | ft/s |
| K_u | 3.28 | Given |
| k | 0.46 | Table 3-3 |
| S_p | 5.4% | %, Topo |

$T_{t2} = L/(60\,V)$

| | | |
|---|---|---|
| T_t2 | 95.349 | Minutes |
| L | 465 | |

Sheet Flow $T_{ti} = \frac{K_u}{I^{0.4}} \left( \frac{n\,L}{\sqrt{S}} \right)^{0.6}$ 3.2.2.3 FHA Code Book Equ 3-3

| | | |
|---|---|---|
| Tsf | 20.756 | Minutes |
| K_u | 0.933 | Given |
| I | 2.03 | in/hr (NOAA) 50Y1HR |
| n | 0.2 | Table 3-2 |
| L | 475 | ft,Topo |
| S | 0.1134 | ft/ft, Topo |

| | | |
|---|---|---|
| Total, Tc | 116.1 | Minutes |

# South Watershed Post-Development

| | | | | |
|---|---|---|---|---|
| $Q = (CIA)/K_u$ | | Weighted C | 0.39 | / |
| | | I_10Y120M | 0.777 | in/hr |
| | | I_25Y120M | 0.972 | |
| | | I_50Y120M | 1.13 | |
| | | I_100Y120M | 1.31 | |
| | | Area | 12.98 | acres |
| | | K_u | 1 | Unit adjustment |
| Q_10Y120M | 3.889 | CFS | | |
| Q_25Y120M | 4.865 | CFS | | |
| Q_50Y120M | 5.656 | CFS | | |
| Q_100Y120M | 6.557 | CFS | | |

# Parking Lot Influence

| | | | | |
|---|---|---|---|---|
| $Q = (CIA)/K_u$ | | Weighted C | 0.95 | / |
| | | I_10Y120M | 5.26 | in/hr |
| | | I_25Y120M | 6.62 | |
| | | I_50Y120M | 7.75 | |
| | | I_100Y120M | 8.99 | |
| | | Area | 1.45 | acres |
| | | K_u | 1 | Unit adjustment |
| Q_10Y120M | 7.241 | CFS | | |
| Q_25Y120M | 9.113 | CFS | | |
| Q_50Y120M | 10.668 | CFS | | |
| Q_100Y120M | 12.375 | CFS | | |

# Channel Characteristics

| | | | | Upstream | Downstream | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Station | Length (ft) | Elevation (ft) | | Slope (%) | Flows (CFS) | Flow (FT/s) | Normal Depth (ft) |
| Surface Elevations | 1 | 00+00.00 | 10.00 | 3216.52 | | 33.40 | 7.8 | 9.51 | 0.31 |
| | | 00+10.00 | | | 3213.18 | | | | |
| | 2 | 00+10.00 | 41.85 | 3213.18 | | 13.02 | 7.8 | 6.84 | 0.41 |
| | | 00+51.85 | | | 3207.73 | | | | |
| | 3 | 00+51.85 | 194.85 | 3207.73 | | 6.10 | 10.8 | 5.74 | 0.59 |
| | | 02+46.70 | | | 3195.84 | | | | |
| | 4 | 02+46.70 | 258.64 | 3195.84 | | 2.26 | 10.8 | 4.01 | 0.76 |
| | | 05+19.98 | | | 3190 | | | | |
| | 5 | 05+19.98 | 30.00 | 3190 | | 0.00 | 10.8 | 3.06 | 0.9 |
| | | 05+49.98 | | | 3190 | | | | |
| | 6 | 05+49.98 | 155.02 | 3190 | | 5.16 | 10.8 | 5.40 | 0.62 |
| | | 07+05.00 | | | 3182 | | | | |

| | | | | Upstream | Downstream | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Station | Length (ft) | Elevation (ft) | | Slope (%) | Flows (CFS) | Flow (FT/s) | Normal Depth (ft) | Freeboard (FT) |
| Channel Elevations | 1 | 00+00.00 | 10.00 | 3216.52 | | 46.50 | 7.8 | 10.66 | 0.28 | 1.03 |
| | | 00+10.00 | | | 3211.87 | | | | | |
| | 2 | 00+10.00 | 41.85 | 3211.87 | | 13.26 | 7.8 | 6.89 | 0.4 | 1.01 |
| | | 00+51.85 | | | 3206.32 | | | | | |
| | 3 | 00+51.85 | 194.85 | 3206.32 | | 6.19 | 10.8 | 5.77 | 0.59 | 1 |
| | | 02+46.70 | | | 3194.25 | | | | | |
| | 4 | 02+46.70 | 258.64 | 3194.25 | | 2.71 | 10.8 | 4.28 | 0.73 | 2.03 |
| | | 05+19.98 | | | 3187.24 | | | | | |
| | 5 | 05+19.98 | 30.00 | 3187.24 | | 5.00 | 10.8 | 3.06 | 0.9 | 3.36 |
| | | 05+49.98 | | | 3185.74 | | | | | |
| | 6 | 05+49.98 | 155.02 | 3185.74 | | 3.38 | 10.8 | 4.64 | 0.69 | 0.81 |
| | | 07+05.00 | | | 3180.5 | | | | | |

# Appendix HF

CulvertMaster Analysis

# Culvert Analysis Report
## Culvert under Montezuma Castle Road (Into Proposed Parking Lot)

| Analysis Component | | | |
|---|---|---|---|
| Storm Event | Design | Discharge | 7.80 cfs |

| Peak Discharge Method: User-Specified | | | |
|---|---|---|---|
| Design Discharge | 7.80 cfs | Check Discharge | 6.70 cfs |

| Tailwater Conditions: Constant Tailwater | |
|---|---|
| Tailwater Elevation | N/A ft |

| Name | Description | Discharge | HW Elev. | Velocity |
|---|---|---|---|---|
| Culvert-1 | 1-15 inch Circular | 7.80 cfs | 3,223.44 ft | 13.31 ft/s |
| Weir | Not Considered | N/A | N/A | N/A |

# Culvert Analysis Report
## Culvert under Montezuma Castle Road (Into Proposed Parking Lot)

Component:Culvert-1

| Culvert Summary | | | | | |
|---|---|---|---|---|---|
| Computed Headwater Elevation | 3,223.44 | ft | Discharge | 7.80 | cfs |
| Inlet Control HW Elev. | 3,223.44 | ft | Tailwater Elevation | N/A | ft |
| Outlet Control HW Elev. | 3,223.37 | ft | Control Type | Inlet Control | |
| Headwater Depth/Height | 1.80 | | | | |

| Grades | | | | | |
|---|---|---|---|---|---|
| Upstream Invert | 3,221.19 | ft | Downstream Invert | 3,208.61 | ft |
| Length | 56.00 | ft | Constructed Slope | 22.4643 | % |

| Hydraulic Profile | | | | | |
|---|---|---|---|---|---|
| Profile | S2 | | Depth, Downstream | 0.60 | ft |
| Slope Type | Steep | | Normal Depth | 0.60 | ft |
| Flow Regime | Supercritical | | Critical Depth | 1.11 | ft |
| Velocity Downstream | 13.31 | ft/s | Critical Slope | 4.4482 | % |

| Section | | | | | |
|---|---|---|---|---|---|
| Section Shape | Circular | | Mannings Coefficient | 0.024 | |
| Section Material | CMP | | Span | 1.25 | ft |
| Section Size | 15 inch | | Rise | 1.25 | ft |
| Number Sections | 1 | | | | |

| Outlet Control Properties | | | | | |
|---|---|---|---|---|---|
| Outlet Control HW Elev. | 3,223.37 | ft | Upstream Velocity Head | 0.72 | ft |
| Ke | 0.50 | | Entrance Loss | 0.36 | ft |

| Inlet Control Properties | | | | | |
|---|---|---|---|---|---|
| Inlet Control HW Elev. | 3,223.44 | ft | Flow Control | N/A | |
| Inlet Type | Headwall | | Area Full | 1.2 | ft² |
| K | 0.00780 | | HDS 5 Chart | 2 | |
| M | 2.00000 | | HDS 5 Scale | 1 | |
| C | 0.03790 | | Equation Form | 1 | |
| Y | 0.69000 | | | | |

# Culvert Analysis Report
# Under Maintenance Road

| Analysis Component | | | |
|---|---|---|---|
| Storm Event | Design | Discharge | 10.80 cfs |

| Peak Discharge Method: User-Specified | | | |
|---|---|---|---|
| Design Discharge | 10.80 cfs | Check Discharge | 7.80 cfs |

Tailwater properties: Trapezoidal Channel

| Tailwater conditions for Design Storm. | | | |
|---|---|---|---|
| Discharge | 10.80 cfs | Bottom Elevation | 0.00 ft |
| Depth | 0.66 ft | Velocity | 3.09 ft/s |

| Name | Description | Discharge | HW Elev. | Velocity |
|---|---|---|---|---|
| Culvert-1 | 2-18 inch Circular | 10.80 cfs | 1.34 ft | 3.06 ft/s |
| Weir | Not Considered | N/A | N/A | N/A |

# Culvert Analysis Report
# Under Maintenance Road

Component:Culvert-1

| Culvert Summary | | | | | |
|---|---|---|---|---|---|
| Computed Headwater Elevation | 1.34 | ft | Discharge | 10.80 | cfs |
| Inlet Control HW Elev. | 1.27 | ft | Tailwater Elevation | 0.66 | ft |
| Outlet Control HW Elev. | 1.34 | ft | Control Type | Entrance Control | |
| Headwater Depth/Height | 0.90 | | | | |

| Grades | | | | | |
|---|---|---|---|---|---|
| Upstream Invert | 0.00 | ft | Downstream Invert | -1.50 | ft |
| Length | 30.00 | ft | Constructed Slope | 5.0000 | % |

| Hydraulic Profile | | | | | |
|---|---|---|---|---|---|
| Profile | CompositePressureProfileS1S2 | | Depth, Downstream | 2.16 | ft |
| Slope Type | N/A | | Normal Depth | 0.47 | ft |
| Flow Regime | N/A | | Critical Depth | 0.90 | ft |
| Velocity Downstream | 3.06 | ft/s | Critical Slope | 0.5064 | % |

| Section | | | | | |
|---|---|---|---|---|---|
| Section Shape | Circular | | Mannings Coefficient | 0.012 | |
| Section Material | Corrugated HDPE (Smooth Interior) | | Span | 1.50 | ft |
| Section Size | 18 inch | | Rise | 1.50 | ft |
| Number Sections | 2 | | | | |

| Outlet Control Properties | | | | | |
|---|---|---|---|---|---|
| Outlet Control HW Elev. | 1.34 | ft | Upstream Velocity Head | 0.37 | ft |
| Ke | 0.20 | | Entrance Loss | 0.07 | ft |

| Inlet Control Properties | | | | | |
|---|---|---|---|---|---|
| Inlet Control HW Elev. | 1.27 | ft | Flow Control | N/A | |
| Inlet Type | Groove end projecting | | Area Full | 3.5 | ft² |
| K | 0.00450 | | HDS 5 Chart | 1 | |
| M | 2.00000 | | HDS 5 Scale | 3 | |
| C | 0.03170 | | Equation Form | 1 | |
| Y | 0.69000 | | | | |