

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
NEW MEXICO WATER SCIENCE CENTER

Rito de los Frijoles in Bandelier National Monument, NM 08313350
4-Section Slope Area Computation
Flood of July 26, 2013

TYPE OF MEASUREMENT – Slope Area computation.

LOCATION OF SITE: The survey site is approximately one mile downstream of the gage and down slope from the National Park Service horse stables. At the gage location, a quality reach could not be defined because the flood flow was complicated by overflow into the complex and inconsistent floodplain terrains of the front and back parking lots, parking-lot island, entrance road, and sewer lift station. The downstream survey site was chosen because although the reach was short, the channel was relatively straight, consistent, and well constrained by the narrow, steeply-sloping canyon walls.

LOCATION OF GAGE: The gage is on the right bank just upstream of the Falls Trail trailhead, at a concrete weir. The gage was installed in October 2011 after a flood event on August 21, 2011 destroyed the previous gage. The gage is a non-submersible pressure transducer with satellite telemetry. During the event on July 26, 2013 the continuous gage did not capture the full extent of the hydrograph peak due to a faulty valve in the bubbler system. A 7 foot long, steel-pipe crest-stage gage (CSG) was attached to a tree on the right bank just down stream of the weir. A second, ancillary 2 foot CSG pipe is installed on a tree on the left bank across from the original gage. This ancillary gage is equipped with a pressure transducer which captured the upper ½ of the hydrograph of the July 26 flood.

SURVEY OF SITE:

- Site selected and flagged by A. Tillery and S. Chavarria on August 7, 2013.
- Site surveyed by A. Tillery (rod), J. Cederberg (instrument), and S. Chavarria (rod) on August 8, 2013.
- Datum: Arbitrary datum, referenced to RM-1 (elevation 100.00 ft). Gage datum was not used due to location of survey downstream from gage.
- Instrument: Topcon, ES-103 (S/N BR-0303), two-peg test was not performed.

The total station used for surveying the site utilized a data logging card to record data. In conjunction, survey data were manually recorded in a field book. Standard fiberglass

survey rods in tenths of foot and prisms were used. Back sights were established as local reference marks and were repeated to check the vertical and horizontal accuracy of the total station.

The survey set up was completed according to USGS standards. An arbitrary survey grid was established with its origin set to X=1,000; Y=1,000; Z= 100 at the location of Hub1. Hub 1 was located on an outcrop to the right of the channel with all shots visible from the hub. Horizontal accuracy was roughly within 1-2 cm in most cases. An additional hub, Hub 2, was located and oriented but not needed or used during the survey. The total distance of the reach modeled for the slope-area computation is 325 ft. A longer reach was not possible because the channel curved sharply just beyond the ends of this reach.

The total station survey was reported in a local arbitrary coordinate system and adjusted to UTM WGS84 UTM zone 13S coordinates using control points established with a handheld GPS unit. The total station data were transformed and rotated using two GPS control points with the CHaMP Transformation Tool which is an ArcGIS add-in developed for this purpose out of the Utah State University Columbia Habitat Monitoring Protocol (ctt.joewheaton.org). The transformation is used for display purposes only.

DISCHARGE AND GAGE HEIGHT: Discharge: 4,900 cfs, Gage height: 10.38 ft (gage datum).

Gage height was determined from cork line in 7-foot CSG on right bank. This gage height is 0.4 feet higher than the gage height of 9.98 as determined from the pressure transducer. The pressure transducer was set to record on one minute increments and this event was extremely flashy so it follows that the pressure transducer might have missed the top of the hydrograph Peak.

DRAINAGE AREA: 17.5 square miles at gage (from adapts).

UNIT DISCHARGE: 280 cfs/m²

NATURE OF FLOOD: The flood triggered the Upper Crossing early warning system stream gage at 11:52PM on July 25th. The water surface elevation at the Upper Crossing stream gage triggered all 7 early warning system alarms (1-, 2-, 3-, 4-, and 5-ft, low float, and high float) simultaneously. The final gage height at upper crossing as recorded by the pressure transducer and verified by field reconnaissance was 17.78 ft. The flood peak reached the continuous gage near the Visitor Center at 1:50 AM. Stage at the continuous gage was 10.384' based on a cork line from the crest-stage gage. This is in fairly close agreement with the peak of 9.98' determined from a pressure transducer that recorded once every minute throughout the flood. This is 1 foot below the stage of the August 2011 flood which was 11.44 ft at the gage site.

The National Weather Service radar data showed an elongated east-west trending bull's-eye-pattern storm that traversed the entire canyon from north to south in less than an hour. Because of the shape and aspect of the storm, rainfall occurred over the majority of the watershed simultaneously. Rainfall intensity approached 3 inches/hour. A park service rain gage located on the north rim of the canyon just above the canyon narrows at Ponderosa Campground documented 0.5 inches of rainfall within 11 minutes. Other rain gages in the area reported between 0.66 and 1.45 inches over the course of the storm. The peak of the hydrograph was extremely brief.

FIELD CONDITIONS: The reach was selected because it is relatively straight and unobstructed and because of how the flood was contained within the canyon walls. The channel has a narrow trapezoidal geometry and is inset 4 to 6 feet below the steeply sloping walls of the canyon. Channel substrate is sand and silt with occasional bedrock and loose boulders. Canyon slopes are vegetated with ponderosa pine woodlands and some riparian vegetation, (Cottonwood, Box Elder and various shrubs and grasses). The high water marks and debris lines were clear and easy to locate in the soil surfaces but difficult along the vertical bedrock surfaces.

Flagging of high water marks was complicated by clear evidence of the August 21, 2011 flood of similar magnitude to this flood. The flood of August 21, started smaller than the current flood in the upper portions of the watershed. However, because the 2011 storm traveled relatively slowly down the east-west axis of the canyon, that flood grew as it travelled downstream. Contrarily, this flood was already a very large flood by the time it reached the Upper Crossing Early Warning System gage (6 miles upstream from the continuous gage) as evidenced by the 17.78 foot peak reported by that gage and by subsequent reconnaissance by park service employees. The storm for this flood traversed the east-west trending canyon from north to south essentially raining on the entire watershed at the same time. As the 2013 flood traveled downstream, it decreased somewhat in magnitude as compared to the 2011 flood. The high water marks from the recent flood therefore obliterated the high water marks from the 2011 flood in the upper reaches of the canyon but are as much as 3 feet lower than the 2011 flood in the lower reaches of the canyon as evidenced by mud lines on a bedrock wall along the Falls Trail approximately one mile downstream of the survey site.

In the survey reach, the high water marks for the 2011 flood were generally easily identifiable in the soil and pine-needle strewn surfaces and were generally approximately 1-2 feet higher than the 2013 flood. Confusion between the floods was an issue in places where only one set of high water marks was evident as was often the case on the bare bed-rock surfaces where high water marks are not well preserved.

- Profiles: Surveyed HWMs were used throughout the survey reach to create water profiles for both the right and left banks. In general, a constant slope is observed by a best fit line to the high-water marks. Profiles were weighted to areas with more HWMs even if they were rated lower than points that appear to be outliers. An average of the left and right profiles was used to determine the water surface at each cross section.
- Cross Sections: Cross-sections for the survey were selected by looking at surveyed high-water marks, upper and lower reach conditions, distance between sections, and significant changes in channel morphology. Four cross sections were selected and numbered from 1 (downstream) to 4 (upstream). Cross sections were not subdivided into multiple subareas for differences in roughness. Main channel and stream bank cross-section bed material was primarily composed of sand, gravel, cobble, boulder and bedrock with lightly vegetated stream banks and moderately vegetated overbanks.
- Roughness Values: The roughness coefficient was selected based on, channel morphology, channel substrate, and overbank vegetation for a net value of 0.070. The main channel is angular blocks of bedrock with sand, gravel, cobble and boulders throughout the reach. It is mostly free of vegetation and trees and likely has a lower n-value (0.065) (Chow, 1959). The overbank has much more vegetation (Ponderosa and Juniper) and has a soil horizon dispersed throughout the bedrock substrate. The overbank was assigned a much higher n-value (0.080). Flow in the canyon was very turbulent and likely carried a lot of debris.
- Photographs: Relatively few digital photographs were taken during the flagging and surveying site visits. Photos of each cross section and of the overbank vegetation are included in the “Photos” folder contained within the “final package” folder.

COMPUTATIONS: The USGS Slope Area Computation program (version 2.0), in conjunction with the graphical user interface (version 1.0), is used to compute flow consistent with the water-surface elevations. Computational water surface is derived by averaging the left and right water-surface profiles at each cross section. Final discharge obtained by using the 4 section formula. Computed discharge is 4,871 cfs (4,900 cfs rounded).

Table 1: Cross section summary

Cross Section (downstream order)	Area (sq. ft)	Width (ft)	Hydraulic radius (ft)	Convey- ance (cfs)	Alpha	Velocity head (ft)	Froude number
1	386	52	5.89	26,827	1.0	2.47	0.82
2	407	65	5.44	26,840	1.0	2.22	0.84
3	383	63	5.30	24,791	1.0	2.51	0.91
4	389	65	5.41	25,495	1.0	2.44	0.91

Table 2: Computational summary

Reach (downstream order)	Discharge (cfs)	Percent diff.	Expansion / Contraction	Spread (%)	Length (ft)	Fall (ft)	Velocity head change (ft)	Friction head (ft)
XS1 – XS2	4,791	1.6	Contracting	0	115	3.92	0.25	3.679
XS2 – XS3	5,554	14.0	Expanding	4	107	4.77	-0.29	4.960
XS3 – XS4	4,223	-13.3	Contracting	0	102	2.94	0.07	2.884
XS1 – XS3	5,168	6.1	Contracting	1	222	8.69	-0.04	8.575
XS2 – XS4	4,912	0.8	contracting	1	209	7.71	-0.22	7.783
XS1 – XS4	4,871	--	Contracting	1	325	11.63	0.03	11.453

EVALUATION OF RESULTS: Percent differences between reach computations and summary computation ranges from -13.3 percent to 14.0 percent. Length of entire reach is 325 ft, which is less than the recommended distance of 413 ft as calculated by the equation $75 * \text{average depth}$. Total fall is 11.63 feet which exceeds the velocity head for each reach. Calculated fall between each two section reach exceeds the recommended fall of 0.5 ft. The reach between cross-section 1 and cross-section 4 has a calculated spread of 1%, indicating this is a contracting reach. The highest percent difference between two section discharges and the total discharge was 14% for a poor rating but because of the short reach length the measurement should be rated as poor.

Discharge calculations were completed in SAC using the lower (0.065) and upper (0.080) estimated Manning's "n" roughness coefficients at the site. Calculated discharge ranged from 5,239 cfs using a 0.065 n-value to 4,270 cfs using a 0.080 n-value or 7.5 percent to -12.3 percent, respectively.

Measurement 122 (measurement defined here) and measurement 121 (an indirect measurement completed for the event on August 21, 2011) were used to define the upper end of rating 4.0 for the Rito de Frijoles streamgage (see attached). Measurement 122 has a percent difference of -9.1% from rating 4.0. The measurement plots more negative relative to measurement 121 but still within the accuracy of the measurement. It is suspected that this measurement is more negative because the event was very flashy with rainfall originating high in the upper part of the basin, allowing for quick attenuation of the flood peak over a short distance. Because the indirect measurement was completed about 0.5 miles downstream of the gage it is possible the peak had attenuated and would account for this difference in calculated discharges. High flow marks at the streamgage

from both events were evident and noted at similar elevations, whereas at the downstream site the more recent flood marks were noticeably lower than the high water marks from the 2011 event. Though this section was a better measuring section, the calculated discharge may be less than the actual discharge at the gage but still within the accuracy of the measurement method. Because of the conditions listed above this measurement is rated poor.

PREVIOUS COMPUTATIONS

<i>Date</i>	<i>Measurement type</i>	<i>Gage height</i>	<i>Discharge</i>
07/05/1977	Slope Area	5.02	654
07/27/1977	Slope Area	3.88	397
08/29/2007	Slope-Conveyance	4.62	623
08/21/2011	Slope Area	11.44	7,000

REMARKS: None.

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