SURFACE WATER STATION DESCRIPTION
MONTEZUMA WELL OUTLET NEAR RIMROCK, AZ – 343853111450201
MONTEZUMA CASTLE NATIONAL MONUMENT

Updated by: Gwen Gerber Date: 3/22/2006

LOCATION

The National Park Service's Water Resource Division – Water Rights Branch (NPS-WRB) surface water gaging station (Station) on the Montezuma Well Outlet Ditch (Outlet Ditch) within Montezuma Castle National Monument (MOCA) is located at Latitude 34°38′53", Longitude 111°45′02" (NAD27[1]) just northeast of Lake Montezuma in Yavapai County, Arizona (NE ¼ NW ¼ SE ¼ Section 31, T15N, R6E, see **Figures 1 and 2)**. The Station is located on the eastern-most of two units (the Well Unit) of MOCA approximately 140 feet downstream of the Well Outlet. To access the Station from the parking lot of the Well Unit of MOCA, follow the paved foot path towards the Outlet Ditch. Where the path crosses the Outlet Ditch follow the ditch downstream approximately 80 feet to the Station.

ESTABLISHMENT

The Station was operated by the Arizona District of the USGS from April 1977 to October 1992 (Station # 09505260). The Station was re-established at the same location by the NPS-WRB on February 28, 2002, and began recording at one hour intervals starting on March 1, 2002.

ELEVATION

The elevation of the Station is approximately 3,560 feet above the National Geodetic Vertical Datum of 1929 as determined from the Lake Montezuma USGS 7.5 minute topographic map.

DRAINAGE AREA

Not applicable, the Outlet Ditch is spring/groundwater fed.

HYDROLOGIC CONDITIONS

The Well Unit lies in the Verde Valley of Central Arizona at the junction of the Colorado Plateau and Basin and Range physiographic provinces. The climate is arid with moderate temperatures and less than 12 inches of rainfall annually. Vegetation consists of desert species (including mesquite, catclaw and saltbush) with ribbons of lush riparian areas along the Outlet Ditch and Wet Beaver Creek (including willow, sycamore, and cottonwood trees). (http://www.nps.gov/moca/pphtml/nature.html).

The geology of the Well Unit consists of the Verde Formation, a sequence of lake bed deposits formed from the damming of Verde Valley by tectonic and volcanic activity in mid-Tertiary times. The deposits are primarily limestone, clay- and mudstone, sandstone, and interbedded volcanics (Twenter and Metzger, 1963).

The Station is located approximately 140 feet downstream of the Well Outlet in an ancient irrigation ditch (**Figures 3 and 4**). Flow originates from Montezuma Well, a 300 foot wide limnocrene (a pooled spring) fed by water rising from the confined aquifer (**Figure 5**). Water in Montezuma Well flows through a screen (also referred to as a grate) to catch leaves and debris to a small opening (also referred to as a swallet, **Figure 6**) in the rock wall on the south side of the Well. Water then travels about 180 feet horizontally and drops about 20 feet vertically before exiting from the Well Outlet (**Figure 3)** into the Outlet Ditch (Ward, 2005).

[1] 1927 North American datum

Precipitation data from the Prescott airport weather station (http://www.wunderground.com/history/airport/KPRC/2004/12/29/CustomHistory.html) was plotted with gage heights on graphs in *Section 4* of the Water Year folders for 2002 and 2003 to determine if precipitation/runoff affect gage heights. No conclusive correlations were found.

The Station, the entire Outlet Ditch upstream of the Station, approximately one mile of ditch downstream from the Station, and Montezuma Well all lie within park property. NPS staff maintains the portion of the Outlet Ditch within the NPS boundary.

CHANNEL AND CONTROL

The Outlet Ditch is a man-made earthen canal composed of silt and clay with cobbles and bedrock forming the outside edges of the canal. The channel itself is smooth and lined by travertine leached from the mineralized waters of Montezuma Well. The Outlet Ditch is straight for about 50 feet upstream of the Station, where it makes a moderate bend to the west around a large rock outcrop. The control is located approximately 10 feet below the stilling well, and is a non-standard steel plate Cippolletti weir with a crest length of 1.5 feet. Since discharge within the Outlet Ditch varies little, no shifting, bank overflow, and scour and fill occur. Banks are stable but are sometimes subject to leaks both above and below the Station. All flow can be diverted into the adjacent Wet Beaver Creek above and below the Station for ditch repair.

According to previous USGS notes, park staff, and observed conditions, the channel (and thus recorded gage heights) can be affected by aquatic growth. The warm mineral rich waters of Montezuma Well support algae growth year round. Heavy vegetatation and roots adjacent to the Outlet Ditch also may impede the canal.

GAGE

A Sutron 8400 was installed in the original USGS stilling well and enclosure on February 28, 2002. NPS data collection officially began on March 1, 2002. The stilling well is a 12-inch diameter corrugated metal pipe with a plywood instrument shelf (**Figure 7**). The Sutron 8400 is an electronic datalogger combined with a float/weight system with an encoder in a single unit (**Figure 8**). This unit is connected to a 12-volt voltage regulator (replaced in Water Year 2005 due to battery problems) and charged by an attached 10-watt solar panel. A new float and float-tape were installed with the logger. There is no backup recorder. Gage height data is logged at one-hour intervals. Data are stored by the Sutron 8400 and downloaded to a data card for retrieval. MOCA staff mails the data card to the WRD for data processing and storage.

The base gage is an enamelled outside vertical staff plate (OVS) mounted on a 2 x 6 inch board embedded in concrete immediately upstream of the control. The OVS reads from 0.00 to 3.35 feet. The OVS currently in use is the original USGS gage.

The NPS-WRB has a cooperative agreement with the Cheyenne, Wyoming district of the USGS to use their database for processing stream flow records (Automated Data Processing System, ADAPS, version 4.5). Streamflow records for the Station are processed on a water year basis in ADAPS.

HISTORY

The USGS completed three or less discharge measurements each year at the Station (USGS Station# 09505260) from 1948-59, 1961, and 1976 and operated it as a continuous record station from April 1977 to October 1992. The NPS-WRB began continuous operation in March 2002.

REFERENCE AND BENCHMARKS

Levels were not previously run by the USGS, however a USGS brass cap (referred to as the benchmark[2], BM) was installed on a large boulder on the left bank approximately 11 feet upstream from the gage in Water Year 1990 (Brewsaugh, 1989).

[2] A benchmark or reference mark is a permanent marker installed in the vicinity of the gage. Its elevation above the gage datum is determined via levels survey.

The OVS, the BM, three reference marks[3] (RM-1, RM-2, and RM-3), and the point of zero flow (PZF) were surveyed by the NPS-WRB on February 28, 2002 for elevation control. See **Table 1** for elevations. The top of the OVS (reading 3.35 feet) was used as the base[4] to determine the elevation of other survey points in reference to the OVS, or gage datum.

On August 20, 2004 the NPS-WRB completed a second survey using the BM as the base. The BM was used as the base so that any changes in elevation of the OVS would be noted. Due to inadequate descriptions only one survey point (RM-1) from the February 28, 2002 survey could be duplicated exactly. During this survey RM-2 and RM-3 were re-established, the surveyed points on the OVS and PZF were better defined, and the wier plate (WP) was surveyed. See *Section 3* of the Water Year folder for a sketch map, photos, and description's of survey points. All survey points shown in **bold** in **Table 1** will be duplicated in future surveys.

Table 1: Survey Elevations.

Date	**OVS (top of metal)**	**OVS (top of wood)**	**BM**	**RM-1**	RM-2 (old)	**RM-2 (new)**	RM-3 (old)	**RM-3 (new)**	PZF	**PZF-1**	**PZF-2**	**WP-1**	**WP-2**	Remarks
02/28/02	**3.35**		**2.01**	**2.30**	4.46		4.47		0.29					first survey (top of staff plate, 3.350 feet entered as base)
08/20/04		**3.36**	**2.01**	**2.30**		**4.45**		**4.48**		**0.29**	**0.30**	**1.28**	**1.30**	BM entered as base

DISCHARGE MEASUREMENTS

All wading discharge measurements are taken at a cross-section just downstream of the Station's staff gage (**Figure 9**). The cross-section has uniformly distributed flow, a smooth channel bottom, and concrete banks. A pygmy meter is used to measure discharge with section widths of 0.20 feet. Only 15 verticals are measured because the channel width is fixed at 3.1 feet. Since the channel is rectangular, bank coefficients are used when calculating total discharge (Rantz, 1982). Algae growth within the channel and vegetation growth both in and adjacent to the channel likely explains measurement variation from the rating curve. Measurement accuracy is good.

Ratings 1.0 - 4.0 were created by the USGS prior to Water Year 2002. The last rating in use by the USGS, rating 4.0, poorly correlated with NPS-WRB's discharge measurements, therefore, Rating 5.0 was created by the NPS-WRB in Water Year 2002 (see *Section 2* of the Water Year 2002 folder for a comparison plot of Ratings 4.0 and 5.0). Rating 5.0 was created from 32 discharge measurements (numbers 135-167) performed by NPS-WRB from February 28, 2002 through September 30, 2004 ranging from 1.85 to 2.84 cfs. Rating 5.0 was developed using discharge measurements rather than the standard formula for a Cippoletti weir because of its non-standard design.

HIGH FLOWS

The maximum daily discharge recorded was 3.3 cfs on July 7, 2004 (see Summary Statistics on manuscript page in *Section 6* of the Water Year Folder).

POINT OF ZERO FLOW

The PZF (bottom of the weir plate, **Figure 7**) was surveyed by the NPS on February 28, 2002 and determined to be 0.285 feet. Although there was no record of a survey performed by the USGS they reported a PZF of 0.28 feet in their Station Description (Brewsaugh, 1989).

[3] A benchmark or reference mark is a permanent marker installed in the vicinity of the gage. Its elevation above the gage datum is determined via levels survey.

[4] The base is the reference mark on which all reference mark elevations are based. It is considered the most stable.

WINTER FLOW

The Station is not affected by ice due to moderate winter temperatures and the warm mineralized spring water from Montezuma Well.

REGULATION AND DIVERSION

The Outlet Ditch is occasionally diverted upstream of the Station when ditch maintenance occurs.

ACCURACY

Station accuracy is considered good because the Outlet Ditch is a stable channel with a fixed control and little variation in flow. Accuracy is not considered excellent because of the effects of algae and vegetation growth both in and near the Outlet Ditch. Discharge measurement accuracy is good (< 5 percent error) and is not considered excellent (< 2 percent error) because of the narrow width of the Outlet Ditch and the inability to measure 25 verticals. Station instrumentation accuracy is considered to be +/- 0.01 feet.

LOCAL PARK PARTNER / COOPERATION

The following Park employee performs discharge measurements, downloads the data logger, obtains regular staff plate readings, and performs Station maintenance and repair:

Virginia Bartling (Seasonal Park Employee)

Address:
Montezuma Castle National Monument
P.O. Box 219
Camp Verde, AZ 86322

Phone Numbers:
(928)-567-5648 (Home)
(928)-567-5276 (MOCA headquarters)
(928)-567-3322 (Castle Unit)
(928)-567-4521 (Well Unit)
(928)-634-5564 (Tuzigoot)

REFERENCES

Brewsaugh, F. C., 1989. *Station Description for Station #09505260, Montezuma Well Outlet near Rimrock, AZ*. U.S. Geological Survey (copy located in Station's History Folder).

Dai, Mike, 1992. *Station Analysis 1992 Water Year for Station #09505260, Montezuma Well Outlet near Rimrock, AZ*. U.S. Geological Survey (copy located in Station's History Folder).

Rantz, R E., 1982. *Measurement and Computation of Stream flow*, Volume 1: U.S. Geological Survey Water-Supply Paper 2175, page 82.

Twenter, F.R. and D.G. Metzger, 1963, *Geology and Ground Water in Verde Valley-the Mogollon Rim Region, Arizona*. U.S. Geological Survey Bulletin 1177.

Ward, J. J., 2005. *Revised Draft – Hydrogeologic Investigation of Montezuma Castle National Monument, Arizona*, Task 1 Report Gila River Adjudication, Docket 23214 DOJ File 90-6-2-47C

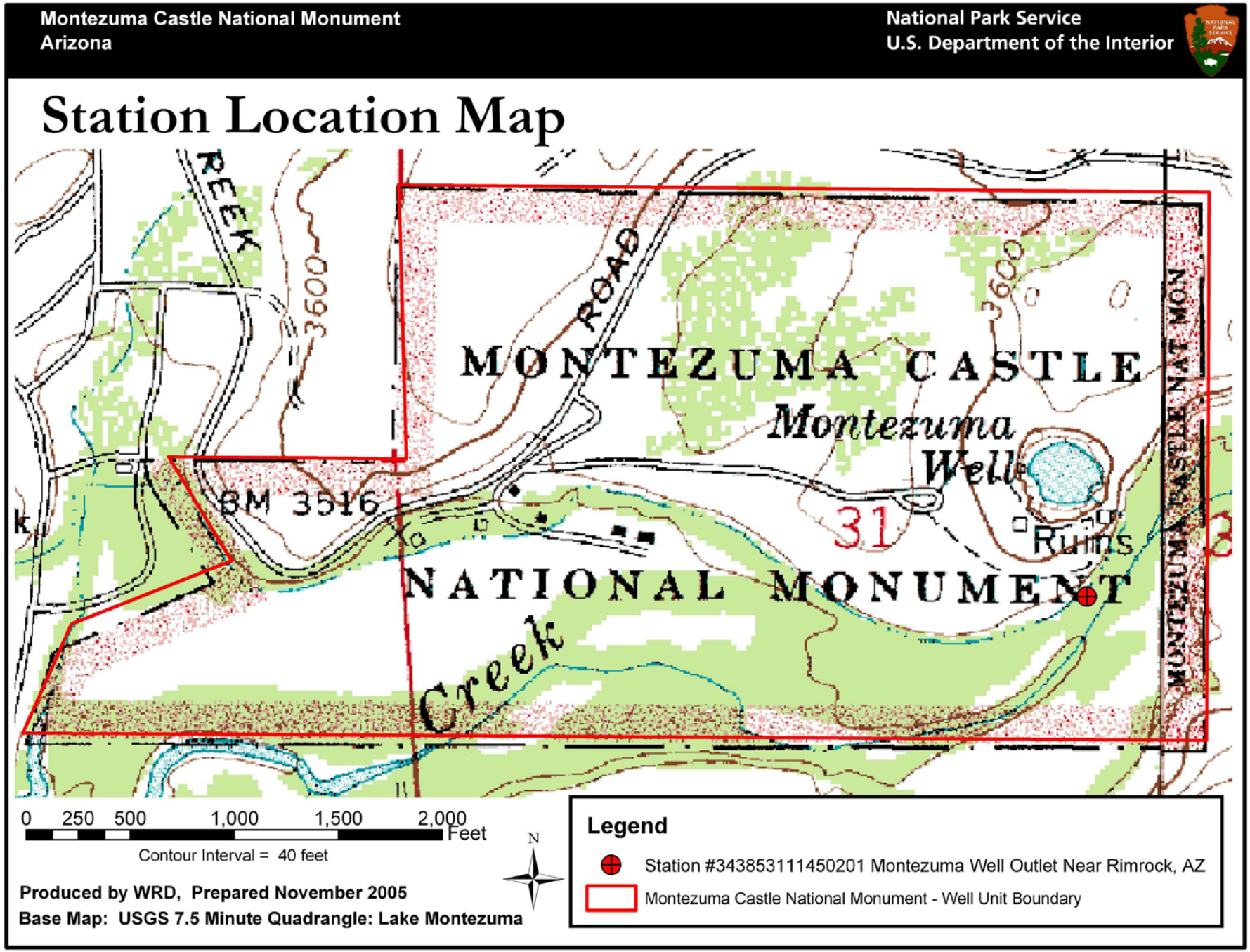

Figure 1: Station Location Map (using USGS 7.5 minute quadrangle)

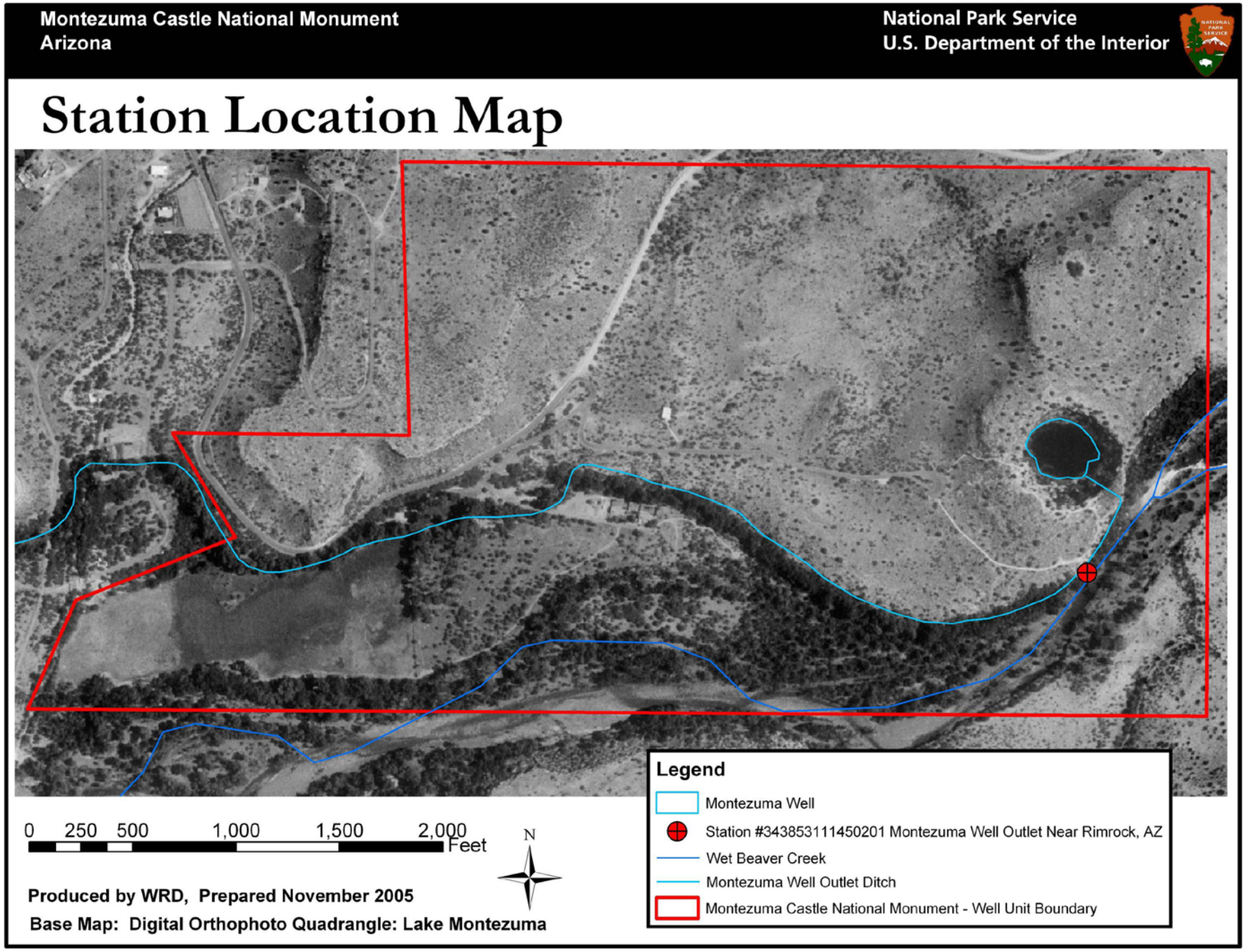

Figure 2: Station Location Map (using Digital Orthophoto Quadrangle)

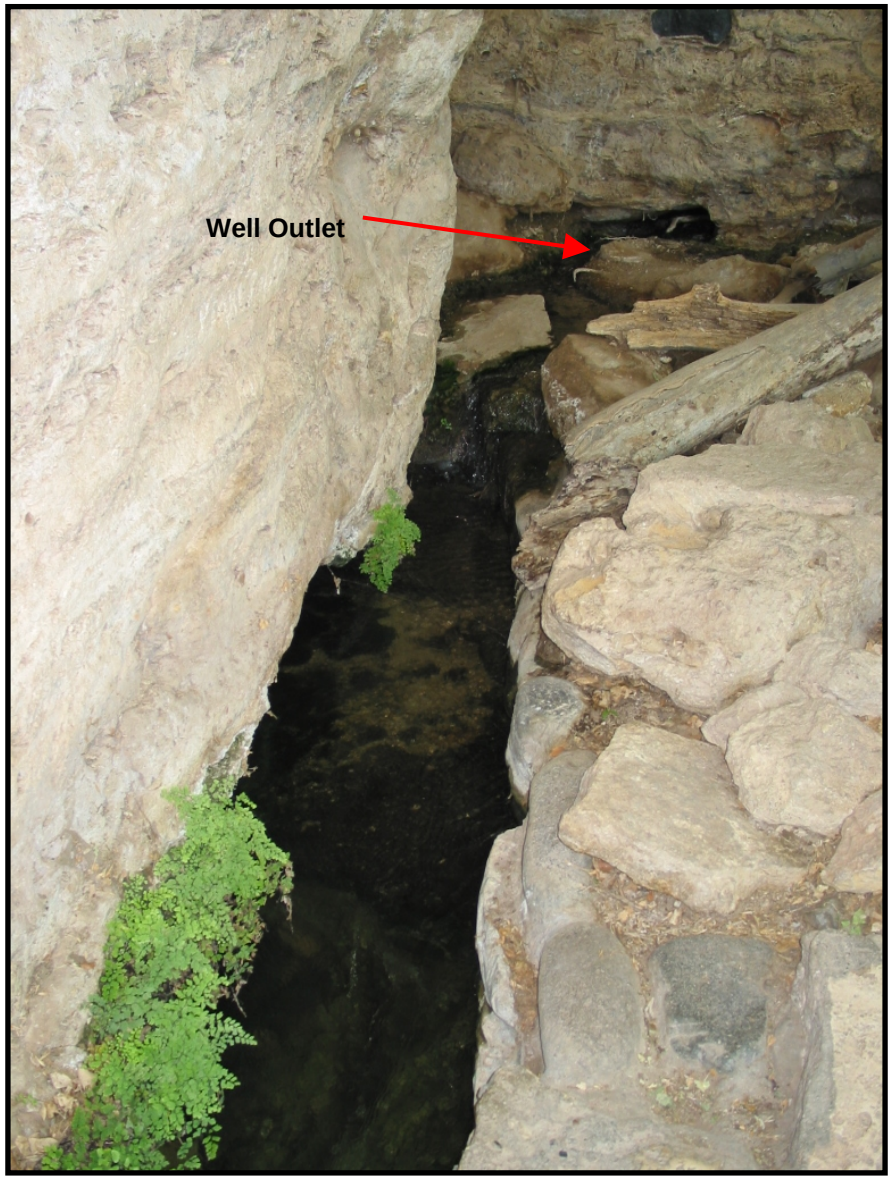

Figure 3: Photo of Well Outlet (taken by Gwen Gerber in 8/2004)

Figure 4: Photo of Outlet Ditch (unknown photographer)

Figure 5: Photo of Montezuma Well from above (Photo taken 5/2004 by Paul Christensen)

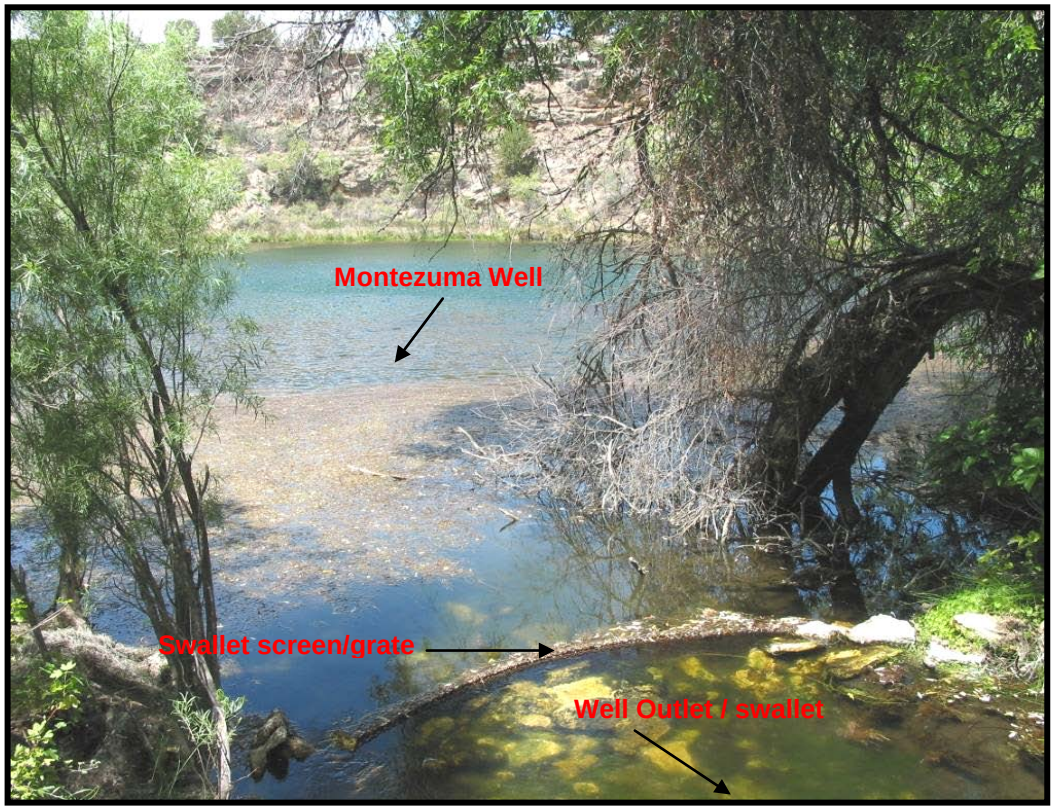

Figure 6: Photo of swallet screen (or grate, taken by Gwen Gerber in 8/2004)

Figure 7: Photo of Station (taken by Gwen Gerber in 8/2004)

Figure 8: Photo of instrument shelf and Sutron 8400 (taken by Gwen Gerber in 8/2004)

Figure 9: Photo of OVS and discharge measurement location (taken by Gwen Gerber in 8/2004)