science for a changing world

Micrometeorological, Evapotranspiration, and Soil-Moisture Data at the Amargosa Desert Research Site in Nye County near Beatty, Nevada, 2006–11

Data Series 725

U.S. Department of the Interior
U.S. Geological Survey

Micrometeorological, Evapotranspiration, and Soil-Moisture Data at the Amargosa Desert Research Site in Nye County near Beatty, Nevada, 2006–11

By Jonathan M. Arthur, Michael J. Johnson, C. Justin Mayers, and Brian. J. Andraski

Data Series 725

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2012

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment, visit http://www.usgs.gov or call 1–888–ASK–USGS.

For an overview of USGS information products, including maps, imagery, and publications, visit http://www.usgs.gov/pubprod

To order this and other USGS information products, visit http://store.usgs.gov

Suggested citation:
Arthur, J.M., Johnson, M.J., Mayers, C.J., and Andraski, B.J., 2012, Micrometeorological, evapotranspiration, and soil-moisture data at the Amargosa Desert Research site in Nye County near Beatty, Nevada, 2006–11: U.S. Geological Survey Data Series 725, 12 p.

Contents

Figures

Conversion Factors and Datums

Conversion Factors

SI to Inch/Pound

Multiply	By	To obtain
becquerel per liter (Bq/L)	27.027	picocurie per liter
centimeters (cm)	0.3937	inch
cubic meter (m^3)	35.31	cubic foot
kilometer (km)	0.6214	mile
kilopascal (kPa)	0.1450	pound-force per square inch
liter (L)	0.2642	gallon
meter (m)	3.281	foot
meter per second (m/s)	3.281	foot per second
micrometer (µm)	0.000039	inch
millibar (mbar)	0.0145	pounds per square inch
millimeter (mm)	0.03937	inch
millimeter per day (mm/d)	0.0397	inch per day
millimeter per hour (mm/h)	0.03937	inch per hour
Watts per square meter (W/m^2)	0.005290	British Thermal Unit per square foot per minute

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8×°C)+32.$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C=(°F–32)/1.8.$$

Radiation: A unit of activity is a Curie (Ci), which is equivalent to 3.7×10^{10} disintegrations per second (dps); the standard disintegration rate of 1 gram of Radium. In International Units a Bequerel (Bq) is equivalent to 1 disintegration per second (dps). Thus, 1 Curie (Ci) equals 3.7×10^{10} Bequerels (Bq) or 37 gigaBecquerels (GBq).

Datums

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83) unless otherwise stated.

Altitude, as used in this report, refers to distance above the vertical datum.

Micrometeorological, Evapotranspiration, and Soil-Moisture Data at the Amargosa Desert Research Site in Nye County near Beatty, Nevada, 2006–11

By Jonathan M. Arthur, Michael J. Johnson, C. Justin Mayers, and Brian J. Andraski

Abstract

This report describes micrometeorological, evapotranspiration, and soil-moisture data collected since 2006 at the Amargosa Desert Research Site adjacent to a low-level radioactive waste and hazardous chemical waste facility near Beatty, Nevada. Micrometeorological data include precipitation, solar radiation, net radiation, air temperature, relative humidity, saturated and ambient vapor pressure, wind speed and direction, barometric pressure, near-surface soil temperature, soil-heat flux, and soil-water content. Evapotranspiration (ET) data include latent-heat flux, sensible-heat flux, net radiation, soil-heat flux, soil temperature, air temperature, vapor pressure, and other principal energy-budget data. Soil-moisture data include periodic measurements of volumetric water-content at experimental sites that represent vegetated native soil, devegetated native soil, and simulated waste disposal trenches—maximum measurement depths range from 5.25 to 29.25 meters. All data are compiled in electronic spreadsheets that are included with this report.

Introduction

Research at the U.S. Geological Survey (USGS) Amargosa Desert Research Site (ADRS) is intended to develop a fundamental understanding of hydrologic and contaminant-transport processes in arid environments. Research objectives are to advance the understanding of hydrologic science and to provide scientific information for those making decisions concerning waste isolation and water management in desert environments (U.S. Geological Survey, 2012). In support of ongoing research, micrometeorological, evapotranspiration, and soil-moisture data were collected at the ADRS, located adjacent to a low-level radioactive and hazardous-chemical waste facility near Beatty, Nevada (fig. 1). The waste facility has been used for the burial of low-level radioactive waste from 1962 through 1992 and hazardous-chemical waste from 1970 to present. Research at the ADRS began in 1983 and the site was incorporated into the USGS Toxic Substances Hydrology Program in 1997. The ADRS has produced long-term benchmark data on hydrologic characteristics and soil-water movement in undisturbed conditions and in simulated waste-disposal conditions in arid environments (Andraski and Stonestrom, 1999).

This report includes micrometeorological, evapotranspiration, and soil-moisture data collected from 2006 through 2011. Instrumentation used to collect the data is described herein. Complete micrometeorological, evapotranspiration, and soil-moisture data are available in the appendixes of this report.

This report is the ninth in a series of ADRS data reports (Wood and Fischer, 1991, 1992; Wood and others, 1992; Wood and Andraski, 1992, 1995; Wood, 1996; Johnson and others, 2002, 2007). These previous reports include weather data collected during a 7-year period (1986–92) and an 8-year period (1998–2005). Evapotranspiration data have been collected since 2002 (Johnson and others, 2007). Soil-moisture data have been collected continuously since 1997 (Johnson and others, 2002, 2007). Data were not collected between 1993 and 1997.

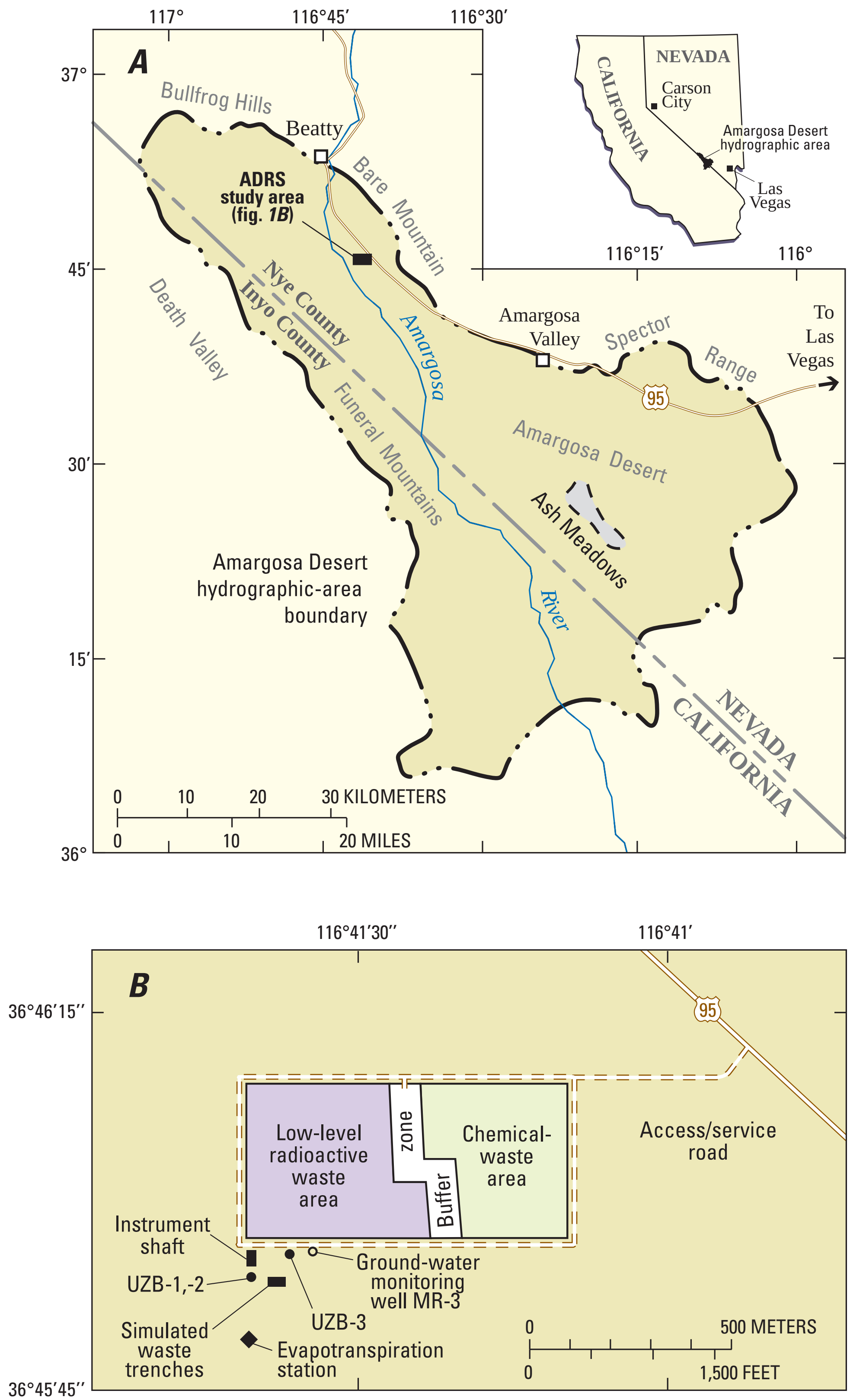

Figure 1. Location of (*A*) Amargosa Desert Research Site (ADRS) near Beatty, Nevada, and (*B*) instrument shaft and simulated waste trenches adjacent to waste-disposal facility.

Site Description

The ADRS is adjacent to a waste-burial facility, which is located about 17 km south of Beatty, Nev., and 20 km east of Death Valley, Calif. (fig. 1*A*). The ADRS is in the Mojave Desert—one of the most arid regions in the United States. Vegetation in the area is sparse, covering about 6–8 percent of the land surface, and dominated by creosote bush (*Larrea tridentata*) (Andraski and others, 2005). Sediments in the area primarily are basin fill consisting of unconsolidated alluvial fan, fluvial, and marsh deposits (Clebsch, 1968). The basin fill is estimated to be more than 170-m thick (Nichols, 1987, p. 8). Depth to the water table ranges from 85 to 115 m below land surface (Fischer, 1992, p. 12).

The research site has two fenced areas—one encloses an instrument shaft (figs. 1*B* and 2; Fischer, 1992), and the other encloses simulated waste trenches (figs. 1*B* and 3; Andraski, 1990). A weather station, two precipitation gages, and three neutron-probe access tubes are within the instrument-shaft area (fig. 2). The neutron-probe access tubes in the instrument-shaft area are used for monitoring soil-water content in a vegetated, native-soil profile. Six neutron-probe access tubes and a single precipitation gage are within the simulated waste-trench area (fig. 3). These six tubes are used to measure soil-water content under nonvegetated, simulated waste-trench conditions and under devegetated, undisturbed native-soil conditions. An evapotranspiration station (fig. 1*B*) is located approximately 200 m south of the instrument shaft area.

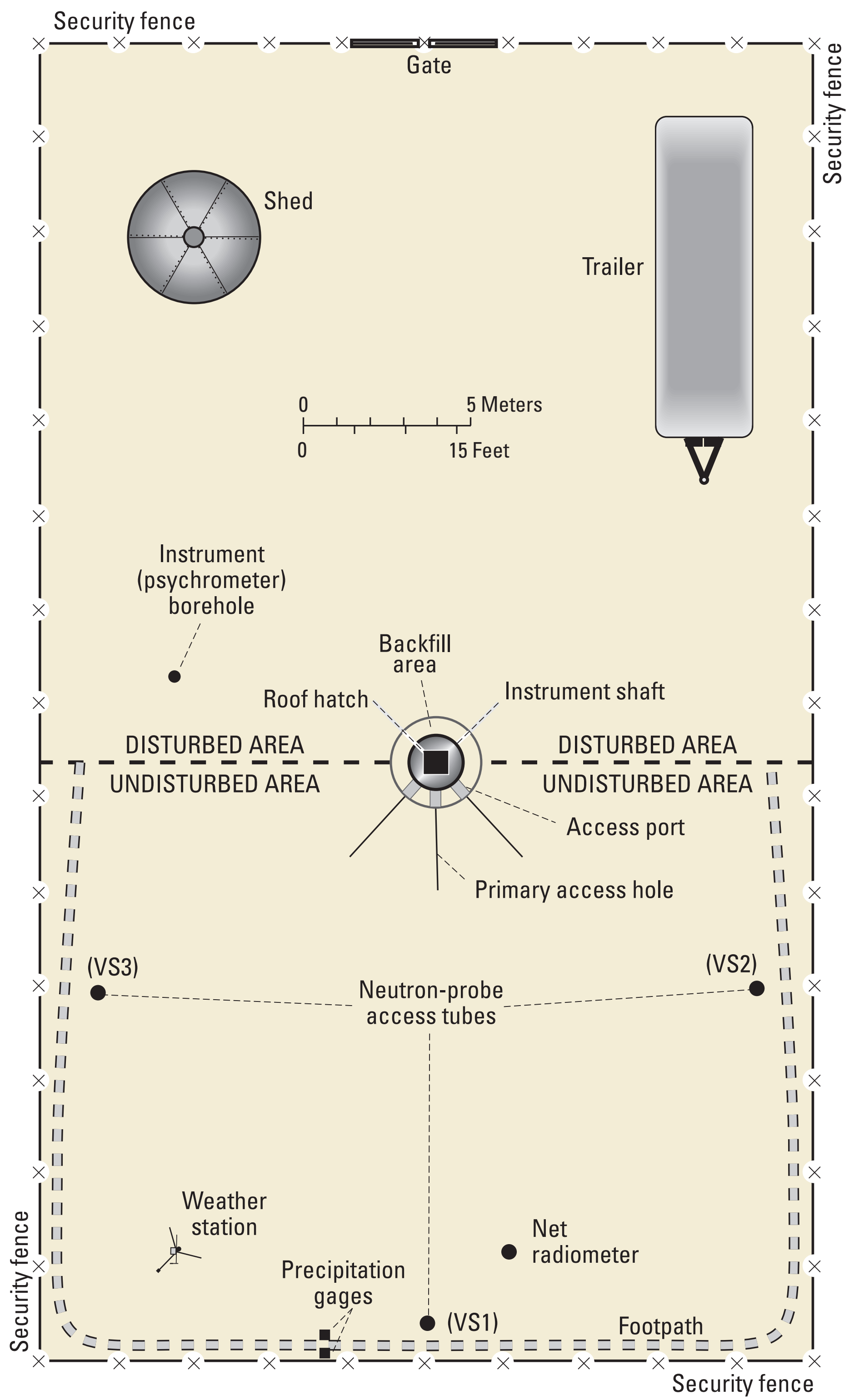

Figure 2. Fenced area containing instrument shaft, weather station, neutron-probe access tubes VS1, VS2, and VS3 in vegetated native soil, and precipitation gages at Amargosa Desert Research Site near Beatty, Nevada.

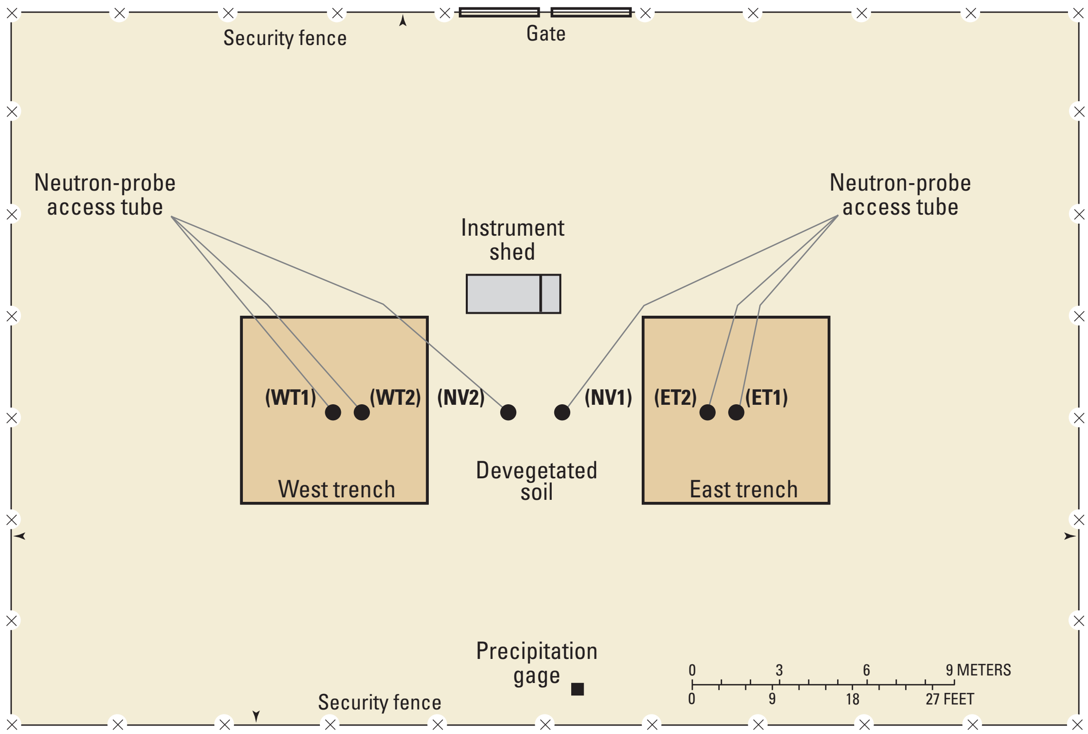

Figure 3. Fenced area containing simulated waste trenches and location of neutron-probe access tubes NV1 and NV2 in devegetated native soil; neutron-probe access tubes ET1, ET2, WT1, and WT2 in simulated waste trenches; and precipitation gage at Amargosa Desert Research Site near Beatty, Nevada.

Micrometeorological measurements include precipitation, solar radiation, net radiation, air temperature, relative humidity, saturated and ambient vapor pressure, wind speed and direction, barometric pressure, near-surface soil temperature, soil-heat-flux, and soil-water content. Evapotranspiration measurements include daily totals and 15-minute energy fluxes of net radiation, soil-heat flux, latent-heat flux, and sensible-heat flux along with other soil and air parameters collected and used in equations to derive evapotranspiration. Soil-moisture profiles collected periodically consist of volumetric soil-water content measurements made using a neutron probe. Micrometeorological, evapotranspiration, and soil-moisture profile datasets summarized in this report are provided in appendixes A-G in Microsoft© Excel spreadsheets.

Methods and Instrumentation

Micrometeorological Sensors

Micrometeorological sensors consisting of a tipping-bucket precipitation gage, an air-temperature and relative-humidity probe, a barometric-pressure sensor, a pyranometer, and an anemometer with wind vane were installed in December 1997. A net radiometer was installed at the site in July 1998. Soil-temperature probes and two soil-heat-flux plates were installed in September 1999. A soil-moisture probe was installed in January 2002.

Data from all sensors were recorded using a Campbell© Scientific, Inc. (CSI), 23X datalogger using a 10-second interval. The logger was programmed to output data in three formats: daily mean values (except for precipitation where only daily totals are output), hourly mean values (except for precipitation where only hourly totals are output), and 5-minute totals for precipitation (to determine storm event timing information not included in this report). The data logger reference is Pacific Standard Time (PST) throughout the year.

The air temperature and relative-humidity sensor, pyranometer, and anemometer with wind vane are mounted on a CM10 tripod at heights of 1.5, 3, and 3 m, respectively, above the ground surface. The barometric-pressure sensor is mounted 1 m above the ground and housed with the data logger in a shed approximately 30 m north of the tripod (fig. 2). The net radiometer is mounted 1.5 m above the ground and approximately 10 m from the tripod. The net radiometer monitors principally bare soil radiation within the undisturbed vegetated area. The tipping-bucket precipitation gage is mounted approximately 5 m from the tripod with an orifice height of 1 m. Two soil-heat-flux plates are buried in the near-surface soil at a depth of about 0.08 m approximately 2 m from the tripod. Between the flux plates and the soil surface, the averaging soil-temperature probes are buried at depths of 0.02 and 0.06 m. The soil-moisture probe is buried to measure average soil moisture in the depth interval between the flux plate depth of 0.08 m and the soil surface. The probe has two 0.3 m rods spaced approximately 0.03 m apart. The rods are inserted into the ground at a slight angle to integrate the water content of the soil over the depth interval.

The accuracy of the data is dependent on the sensors being used. Instrumentation manuals from the manufacturers (vendors) contained the following sensor specifications. The tipping-bucket precipitation gage is a WeatherMeasure model P-501 with a resolution of 0.25 mm representing one tip of the bucket. The air temperature and relative humidity probe is a Vaisala HMP35C from Campbell© Scientific, Inc. with a temperature accuracy of ±0.4°C over a range of -24–48°C, and a relative humidity accuracy of ±2 percent within the range from 0 to 90 percent and ±3 percent within the range from 90 to 100 percent. The Vaisala temperature and humidity probe is mounted inside a 12-plate gill radiation shield. Solar radiation is measured with a LI-COR LI200X silicon pyranometer with a maximum error of ±5 percent. The net radiometer is a Radiation and Energy Balance Systems (REBS) Q7.1 net radiometer, which has a spectral response from 0.25 to 60 µm, with a nominal resistance of 4 ohms. Wind speed and direction are measured by a Met One 034A-L Windset with a wind speed accuracy of ±0.12 m/s and a threshold of 0.28 m/s, and with a wind direction accuracy of ±4 degrees. Winds of less than the anemometer threshold are set to zero by the data logger to indicate they are not measurable. The barometric-pressure sensor is a CSI SBP270 with a pressure range from 800 to 1,100 mbar and an accuracy of ±0.2 mbar. Soil temperature is measured with a TCAV-L averaging soil temperature probe manufactured by Campbell© Scientific, Inc. with two junctions at two depths and constructed using a Type-E thermocouple (chromel-constantan) wire. The four thermocouples and associated reference temperature define an averaged soil temperature with a typical uncertainty of 0.5°C, but the uncertainty can be as high as 1.6°C. The soil-heat flux is measured with two REBS HFT3.1 heat-flow transducer plates with a nominal resistance of 2 ohms and a thermal conductivity of 1.00 (W/m)/°K. The soil-heat-flux plates have an error of about ±5 percent. The near-surface soil moisture is measured using a CS615 water content reflectometer designed to measure volumetric water content derived from the probe sensitivity to the unique dielectric content of the soil, which changes with changing moisture conditions. The soil-moisture probe has an accuracy of ±2 percent when calibrated for a specific soil. The soil moisture values have been calibrated to the specific soil at the site by periodic field sampling of soil between the 0.08 m flux-plate depth and the soil surface. Samples were analyzed to determine gravimetric water, bulk density, and volumetric water content.

Evapotranspiration Instrumentation

Evapotranspiration (ET) instrumentation consists of a Campbell© Scientific, Inc. eddy covariance system and additional sensors used to measure principle energy-budget components. The eddy covariance system includes a CSAT3 three-dimensional sonic anemometer, a KH20 krypton hygrometer, and a FW05 fine-wire thermocouple (type E, 0.0005-inch diameter). These instruments measure two of the main energy-budget components: the transfer of water vapor (latent-heat flux) and the transfer of heat (sensible-heat flux) through the atmosphere, using the eddy covariance technique (Swinbank, 1951). The eddy covariance system also uses a HMP45C Vaisala temperature and relative humidity probe to derive other necessary variables for the eddy covariance technique. Additional sensors were added to this instrumentation to document the two other principal energy-budget components of net radiation and soil-heat flux. Net radiation is measured by a REBS Q7.1 net radiometer. Soil-heat flux is calculated using measurements obtained from ground sensors consisting of two REBS HFT3.1 heat-flow transducer plates, a TCAV-L (Campbell© Scientific, Inc.) averaging soil-temperature probe, and a CS616 water content reflectometer.

The anemometer, hygrometer, and fine-wire thermocouple were mounted on a separate tripod with cables running to a second tripod used to mount the net radiometer, Vaisala temperature and relative humidity probe, cellular-phone antenna, and enclosure box containing a CSI 23X data logger, storage module, cellular phone, and other terminals and controls. The installation geometry of the soil sensors is the same as at the weather station. The net radiometer was mounted 3 m above the ground and 3 m out from the tripod; this sensor placement was selected to provide a representative measurement of the land surface consisting of sparse plant canopy and bare soil. The temperature and humidity probe along with the anemometer, hygrometer, and fine-wire thermocouple were mounted 2 m above the ground surface.

The ET station was operated using a field program (flx232_3.csi, version 2.3, 22 March 2001) obtained from Campbell© Scientific, Inc. (Ed Swiatek, Campbell© Scientific, Inc., written commun., 2002). The field program was modified to the specific sensors used at the ADRS. The eddy covariance fluxes are computed for a 15-minute covariance period based on a 0.1-second execution or sampling interval. Other sensors generally sample data at a 1-second sampling interval and output data every 15 minutes.

Soil-Moisture Profile Instrumentation

Measurements of soil-water content were collected at depth from neutron-probe access tubes using a CPN 503 Hydroprobe manufactured by Campbell© Pacific Nuclear International, Inc. The probe uses a 50 mCi Americium-241: Beryllium neutron source, or in System International units, a 1.85-GBq source. This source emits fast neutrons that are not detected by the neutron detectors in the probe. The fast neutrons propagate through the soil, collide with hydrogen atoms in soil water, become thermalized or slowed, and are then reflected back as slow neutrons. The reflected slow neutrons are detected in the tube of the probe and the surface electronic sensor counts each slow neutron event. Counts are accumulated for a specified time interval and recorded. Soil-water content is proportional to the number of slow neutron reflections counted. Because the neutron source and its detector tube can vary in radiation-flux emissions and detections with time, count ratios are used to normalize the field counts for a given set of measurements. Count ratios are calculated by dividing the field counts by standard counts obtained while the neutron probe is within its shield above the ground.

At depth, soil-water content under natural-site and simulated waste-site conditions was monitored at four experimental sites: one vegetated native-soil profile, one devegetated native-soil profile, and two non-vegetated, simulated waste trenches with disturbed soil used as backfill (figs. 2 and 3). Access tubes at both the vegetated-soil profile (VS1, VS2, and VS3; fig. 2) and the devegetated-soil profile (NV1 and NV2; fig. 3) are large-steel tubes with a 140-mm outside diameter and a 6.4-mm wall thickness. These access tubes were installed at the vegetated-soil site (July 1984) and the devegetated-soil site (September 1988) using a pneumatically driven downhole-hammer system (Tyler, 1988). Access tubes at the two simulated waste trenches (ET1, ET2, WT1, and WT2; fig. 3) are small-steel tubes measuring 51-mm outside diameter and 3.0-mm wall thickness. These access tubes were installed during trench construction (September 1987) with tubes placed in holes that were hand-augered beneath the trench floor prior to backfilling (Andraski, 1996). The simulated waste trenches have 208-L soil-filled drums buried at depths from 1.5 to 2.5 m and 3.5 to 4.5 m; soil-water content is not determined for these depths because of the influence of simulated waste drums on neutron-probe readings. Three access tubes (VS1, VS2, and VS3; fig. 2) were used at the vegetated-soil profile with the neutron probe reaching a maximum recording depth of 13.75, 29.75, and 13.75 m, respectively. Two access tubes were used at each of the other sites (fig. 3) with a maximum neutron probe depth of about 5.25 m.

Neutron counts were accumulated for 30-second time intervals at each depth selected within the individual access tubes. Within the vegetated-soil profile (within the instrument shaft area; fig. 2), single readings were obtained at each depth, and readings were obtained at intervals of 0.25 m to a depth of 10.75 m and then at an interval of 0.5 m for depths greater than 10.75 m. Within the devegetated-soil profile and the two trenches (within the simulated trench area; fig. 3), two readings were obtained at each depth, and readings typically were obtained at intervals of 0.25 m.

Using count ratios, calibration equations were developed that had coefficients of determination greater than 0.96 (Andraski, 1997, p. 1904). The standard error of estimate for small-diameter tubes ranged from 0.017 m^3/m^3 for measurements at the 0.15 m depth to 0.012 m^3/m^3 for measurements at depths greater than 0.15 m. For large-diameter tubes, the standard error of estimate was less than 0.009 m^3/m^3 at all depths.

Micrometeorological Data

Long-term (1981–2011) annual average and daily total precipitation are summarized in appendix A. Complete daily and hourly micrometeorological data files are available in appendixes B–C. Tipping-bucket precipitation gages have characteristics that can cause underestimation of precipitation. In cases where the tipping-bucket malfunctioned, precipitation volumes from the waste-facility standard precipitation gage were used. Precipitation data were not adjusted for potential wind effects. Micrometeorological data were graphically checked and reviewed for data gaps and to ensure data quality. Gaps in micrometeorological data are filled with estimated values that are interpolated from values adjacent to the missing values. Long periods of 4 or more consecutive hours of missing data are not estimated.

Winter frontal systems typically account for most of ADRS precipitation (Johnson and others, 2007). In the Amargosa Desert, the predominant winter precipitation comes from regional winter frontal systems moving in from the west coast. However, the amount of precipitation is unpredictable and influenced by the rain shadow effect of the Sierra Nevada Mountains, which similarly shadow Death Valley to the west of the Amargosa Desert. Summer precipitation, primarily from localized convective storms, is even more uncertain within different locations of the Amargosa Desert. Summer storms are dependent on water vapor transported into the area by southwesterly winds, which bring water vapor principally from subtropical low-pressure systems from off the west coast of either Mexico or Baja, California.

Solar radiation is the amount of incident radiation from the sun that reaches the surface of the Earth at the point of detection. The maximum radiation for the year generally occurs during summer clear sky days. Conversely, during winter clear sky days solar radiation is reduced.

Net radiation is the difference between incoming and outgoing radiation fluxes of both short- and long-wave radiation. Net radiation is a measure of the energy available at the surface of the Earth that can be partitioned into such energy-consuming processes as heating the soil and air, evapotranspiration, and plant growth. Net radiation typically is positive after sunrise and before sunset as positive shortwave components exceed negative longwave components.

Variations in measured net radiation values can occur over time as the transparent polyethylene shields on the net radiometer age and become less translucent from the ultraviolet radiation component of solar radiation or from the scouring from wind driven particles. Cracking of the shield will cause abrupt changes in net radiation values. UV radiation can dry the polyethylene shield to the point where the shield is shattered from heavy rains during summer thunderstorms or from wind driven particles such as sand. Radiation values can increase or decrease when the radiometer is not level, such as when birds damage the shields or tilt the sensor head. Most sensor problems can be easily fixed by replacing shields and leveling the sensors.

Daily and seasonal temperature fluctuations are large at the study site. Differences between daily maximum and minimum temperatures commonly exceed 20°C. Differences between winter minimum and summer maximum temperatures exceed more than 40°C, and sometimes more than 50°C. The desert environment, with its high percentage of clear skies has a large heating capacity from incoming solar (short-wave) radiation during the day, and a proportionally large heat discharge by terrestrial (long-wave) radiation during the night. The large gains and losses in energy on a daily basis and their relative variation on a seasonal basis are what regulate the temperatures that occur in this environment.

Relative humidity is the ratio of the amount of water vapor in the air at a specific temperature (vapor pressure) to the maximum amount of water vapor that the air can hold at that temperature (saturated vapor pressure), expressed as a percent. During mid-day hours in the summer, relative-humidity values of less than 10 percent are common in the Amargosa Desert where prevailing high summer temperatures lower the relative humidity of available vapor content of the air.

Saturated vapor pressure is the highest concentration of water vapor that can exist in equilibrium over a free-water surface at that temperature. The data logger calculates the saturated vapor pressure in kilopascals from measured air temperature using an algorithm from Lowe (1977). Ambient vapor pressure is the partial pressure exerted by water vapor present in the air and indicates the water-vapor content of the air under prevailing atmospheric conditions. The ambient vapor pressure is the product of the saturated vapor pressure and the relative humidity.

Daily mean saturated vapor pressures are higher during the summer months and lower during winter months because warm air can potentially hold considerably more water vapor than cold air. For this reason, summer precipitation events generally cause somewhat higher ambient vapor pressure than winter precipitation events. In contrast, the difference between the daily mean ambient vapor pressures measured during the summer and the winter is much less.

Mean horizontal wind-vector direction was calculated by vectorially summing the individual wind vectors consisting of wind magnitude and direction using available data logger commands. Daily wind directions indicate seasonal variability and annual recurrent patterns. Wind at the ADRS predominantly was from the northwest from September through February, and generally associated with regional frontal systems moving in from the west coast during the autumn and winter seasons. Winds from March to September are more evenly distributed from the northwest, southwest, and southeast.

Barometric pressures at the ADRS facility are corrected to sea level using an altitude of 847.2 m. Higher pressures generally occurred during clear winter days and lower pressures occurred during storm periods and summer.

The averaging soil-thermocouple probe measures the temperature in the soil between the soil surface and the 8-cm depth. The soil-heat-flux plates measure thermal energy that enters or leaves the soil. As the thermal energy enters the soil and moves downward, the soil-heat flux is defined as positive, and as the thermal energy leaves the soil, the soil-heat flux is defined as negative. Spikes in the soil-water content are indications of rain events occurring at the research site.

Evapotranspiration Data

Complete daily and 15-minute evapotranspiration rates are given in appendixes D–E. The 15-minute data include the four principal energy budget components of latent-heat flux, sensible-heat flux, soil-heat flux, and net radiation. Other parameters that were measured and used to derive variable coefficients used in calculations included in this report are air temperature, air-vapor pressure, soil-heat flux at the individual flux plates, soil-temperature, soil-water content above the flux plates, and soil-temperature change above the flux plates. Evapotranspiration terms, equations, and corrections used in calculating ET are provided in appendixes D–E.

Evapotranspiration at the ADRS is highly variable and dependent on available moisture principally from precipitation and precipitation-derived water stored in the upper soil profile (Johnson and others, 2007). A much smaller component of the evapotranspiration is supplied by water moving upward through the deep unsaturated zone to the root zone (Scanlon and others, 2003; Walvoord and others, 2004).

Evapotranspiration is limited throughout the year by precipitation. Daily evapotranspiration spikes after a rainstorm and gradually decreases until the next rain event. High evapotranspiration right after a storm is derived from evaporation of surface and near-surface soil moisture and increased plant transpiration supplemented by increased soil moisture. This high rate of evaporation can last for one to several days depending on the amount of precipitation. Depending on the duration and intensity of the rain event, deeper soil-moisture percolation may occur and maintain the decreasing daily evapotranspiration curve for longer periods. This more sustained daily evapotranspiration is attributed primarily to loss of root-zone soil-moisture by plant transpiration.

The energy used to drive the evapotranspiration process is latent-heat flux, while sensible-heat flux is the energy used to heat the air. Both latent-heat flux and sensible-heat flux partition the total available energy. With little soil moisture for plant transpiration or soil evaporation, the energy used for sensible-heat flux would nearly equal the available energy. Conversely, with sufficient moisture the energy used for latent-heat flux would dominate.

Soil-Moisture Data

Complete soil-water content profile data and the associated calibration equations are given in appendixes F–G. Soil-water content is reported in units of cubic meter per cubic meter (volumetric water content).

Factors controlling the vertical and temporal changes in soil water content at the four experimental sites are discussed in detail by Andraski (1997) and Johnson and others (2007). These factors include presence or absence of vegetation and differences in soil properties that affect moisture movement and retention within the profiles.

References Cited

Andraski, B.J., 1990, Water movement and trench stability at a simulated arid burial site for low-level radioactive waste near Beatty, Nevada: La Grange Park, Ill., American Nuclear Society, Nuclear Waste Isolation in the Unsaturated Zone, Las Vegas, Nev., September 1989, Proceedings, p. 166–173.

Andraski, B.J., 1996, Properties and variability of soil and trench fill at an arid waste-burial site: Soil Science Society of America Journal, v. 60, p. 54–66.

Andraski, B.J., 1997, Soil-water movement under natural-site and waste-site conditions—A multiple-year field study in the Mojave Desert, Nevada: Water Resources Research, v. 33, no. 9, p. 1901–1916.

Andraski, B.J., and Stonestrom, D.A., 1999, Overview of research on water, gas, and radionuclide transport at the Amargosa Desert Research Site, Nevada, *in* Morganwalp, D.W., and Buxton, H.T., eds., U.S. Geological Survey Toxic Substances Hydrology Program—Proceedings of the Technical Meeting, Charleston, South Carolina, March 8–12, 1999—Volume 3 of 3—Subsurface Contamination from Point Sources: U.S. Geological Survey Water-Resources Investigations Report 99–4018–C, p. 459–466. (Also available at http://pubs.er.usgs.gov/publication/wri994018C.)

Andraski, B.J., Stonestrom, D.A., Michel, R.L., Halford, K.J., and Radyk, J.C., 2005, Plant-based plume-scale mapping of tritium contamination in desert soils: Vadose Zone, v. 4, p. 819–827.

Clebsch, Alfred, Jr., 1968, Geology and hydrogeology of a proposed site for burial of solid radioactive waste southeast of Beatty, Nye County, Nevada, *in* Morton, R.J., Land burial of solid radioactive wastes—Study of commercial operations and facilities: Atomic Energy Commission, NTIS Report WASH-1143, p. 70–100.

Fischer, J.M., 1992, Sediment properties and water movement through shallow unsaturated alluvium at an arid site for disposal of low-level radioactive waste near Beatty, Nye County, Nevada: U.S. Geological Survey Water-Resources Investigations Report 92–4032, 48 p. (Also available at http://pubs.er.usgs.gov/publication/wri924032.)

Johnson, M.J., Mayers, C.J., and Andraski, B.J., 2002, Selected micrometeorological and soil-moisture data at Amargosa Desert Research Site in Nye County near Beatty, Nevada, 1998–2000: U.S. Geological Survey Open-File Report 02–348, 14 p. (Also available at http://pubs.er.usgs.gov/publication/ofr2002348.)

Johnson, M.J., Mayers, C.J., Garcia, C.A., and Andraski, B.J., 2007, Selected micrometeorological, soil-moisture, and evapotranspiration data at Amargosa Desert Research Site in Nye County near Beatty, Nevada, 2001–05: U.S. Geological Survey Data Series 284, 29 p. (Also available at http://pubs.er.usgs.gov/publication/ds284.)

Lowe, P.R., 1977, An approximating polynomial for computation of saturation vapor pressure: Journal of Applied Meteorology, v. 16, p. 100–103.

Nichols, W.D., 1987, Geohydrology of the unsaturated zone at the burial site for low-level radioactive waste near Beatty, Nye County, Nevada: U.S. Geological Survey Water-Supply Paper 2312, 57 p. (Also available at http://pubs.er.usgs.gov/publication/wsp2312.)

Scanlon, B.R., Keese, Kelley, Reedy, R.C., Simunek, Jirka, and Andraski, B.J., 2003, Variations in flow and transport in thick desert vadose zones in response to paleoclimatic forcing (0–90 kyr): Field measurements, modeling, and uncertainties: Water Resources Research, v. 39, no. 7, p. 1179, doi:10.1029/2002WR001604.

Tyler, S.W., 1988, Neutron moisture meter calibration in large diameter boreholes: Soil Science Society of America Journal, v. 52, p. 890–893.

Swinbank, W.C., 1951, The measurement of vertical transfer of heat and water vapor by eddies in the lower atmosphere: Journal of Meteorology, v. 8, p.135–145.

U.S. Geological Survey, 2005 [2009], Collection, quality assurance, and presentation of precipitation data: U.S. Geological Survey Office of Surface Water Technical Memorandum No. 2006.01, 29 p., accessed August, 31, 2012, at http://water.usgs.gov/admin/memo/SW/OSW_2006-01_Revised_02122010.pdf.

U.S. Geological Survey, 2012, Amargosa Desert Research Site: Website, accessed August 31, 2012, at http://nevada.usgs.gov/adrs/.

Walvoord, M.A., Stonestrom, D.A., Andraski, B.J., and Striegl, R.G., 2004, Constraining the inferred paleohydrologic evolution of a deep unsaturated zone in the Amargosa Desert: Vadose Zone Journal, v. 3, p. 502–512.

Wood, J.L., 1996, Selected meteorological and micrometeorological data for an arid site near Beatty, Nye County, Nevada, calendar year 1992: U.S. Geological Survey Open-File Report 96–434, 33 p. (Also available at http://pubs.er.usgs.gov/publication/ofr96434.)

Wood, J.L., and Andraski, B.J., 1992, Selected meteorological data for an arid site near Beatty, Nye County, Nevada, calendar year 1989: U.S. Geological Survey Open-File Report 92–484, 27 p. (Also available at http://pubs.er.usgs.gov/publication/ofr92484.)

Wood, J.L., and Andraski, B.J., 1995, Selected meteorological data for an arid site near Beatty, Nye County, Nevada, calendar years 1990-91: U.S. Geological Survey Open-File Report 94–489, 49 p. (Also available at http://pubs.er.usgs.gov/publication/ofr94489.)

Wood, J.L., and Fischer, J.M., 1991, Selected meteorological data for an arid site near Beatty, Nye County, Nevada, calendar year 1986: U.S. Geological Survey Open-File Report 91–189, 27 p. (Also available at http://pubs.er.usgs.gov/publication/ofr91189.)

Wood, J.L., and Fischer, J.M., 1992, Selected meteorological data for an arid site near Beatty, Nye County, Nevada, calendar year 1987: U.S. Geological Survey Open-File Report 92–59, 27 p. (Also available at http://pubs.er.usgs.gov/publication/ofr9259.)

Wood, J.L., Hill, K.J., and Andraski, B.J., 1992, Selected meteorological data for an arid site near Beatty, Nye County, Nevada, calendar year 1988: U.S. Geological Survey Open-File Report 92–61, 27 p.(Also available at http://pubs.er.usgs.gov/publication/ofr9261.)

This page intentionally blank

Appendixes

Data files that contain long-term annual average precipitation and daily total precipitation (appendix A), and complete micrometeorological (appendixes B–C), evapotranspiration (appendixes D–E), and soil-moisture (appendixes F–G) datasets are included in seven Microsoft© Excel files. The appendixes can be accessed and downloaded at URL http://pubs.water.usgs.gov/ds/725/.

Appendix A. Summary of long-term (1981–2011) annual average precipitation and daily total precipitation at Amargosa Desert Research Site near Beatty, Nevada, 2006–11.

Appendix B. Daily mean micrometeorological data collected at Amargosa Desert Research Site near Beatty, Nevada, 2006–11.

Appendix C. Hourly mean micrometeorological data collected at Amargosa Desert Research Site near Beatty, Nevada, 2006–11.

Appendix D. Daily evapotranspiration data—evapotranspiration rates at Amargosa Desert Research Site near Beatty, Nevada, 2006–09.

Appendix E. 15-minute evapotranspiration data—energy flux rates and other field data parameters at Amargosa Desert Research Site near Beatty, Nevada, 2006–09.

Appendix F. Summary of volumetric water-content data at depth for each experimental site at Amargosa Desert Research Site near Beatty, Nevada, 2006–11.

Appendix G. Volumetric water-content at depth for each neutron-probe access tube at each experimental site at Amargosa Desert Research Site near Beatty, Nevada, 2006–11.

This page intentionally blank

Publishing support provided by the U.S. Geological Survey
Publishing Network, Tacoma Publishing Service Center

For more information concerning the research in this report, contact the
Director, Nevada Water Science Center
U.S. Geological Survey
2730 N. Deer Run Road
Carson City, Nevada 89701
http://nevada.usgs.gov

Arthur and others— **Micrometeoroglical, Evapotranspiration, and Soil-Moisture Data at the Amargosa Desert Research Site in Nye County near Beatty, Nevada, 2006–11**—Data Series 725