Ground-Water Quality and Levels, and Surface-Water, Meteorological and Other Environmental Data Collected at Two Storm-Water Retention Basins Near DuPont, Washington, Water Years 1998-2000

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WASHINGTON STATE DEPARTMENT OF TRANSPORTATION
TECHNICAL REPORT

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CONVERSION FACTORS, VERTICAL DATUM, AND BRAND NAME DISCLAIMER

CONVERSION FACTORS

Multiply	By	To obtain
acre	4,047	square meter
foot (ft)	0.3048	meter
kilopascal (kPa)	0.01	bar
	0.1450	pound per square inch
inch (in.)	25.4	millimeter
joule (J)	0.2388	calorie
miles per hour (mi/h)	0.4470	meter per second
micrometer (µm)	3.937×10^{-5}	inch
mile (mi)	1.609	kilometer
milligram (g)	3.527×10^{-5}	ounce, avoirdupois
square meter (m^2)	10.76	square foot
watt (W)	0.2388	calorie per second

Temperature in degrees Celsius (^oC) may be converted to degrees Fahrenheit (^oF) as follows:

$$^oF=1.8\ ^oC+32.$$

Temperature in degrees Fahrenheit (^oF) may be converted to degrees Celsius (^oC) as follows:

$$^oC=(^oF-32)/1.8.$$

Chemical concentrations in water are given in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter is a unit expressing the solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter. For concentrations less than 7,000 mg/L, milligrams per liter is equivalent to "parts per million" and micrograms per liter is equivalent to "parts per billion."

Specific conductance is given microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25^{o}C).

VERTICAL DATUM

Sea level: In this report "sea level" refers to the North American Vertical Datum of 1988.

Altitude, as used in this report, refers to distance above or below sea level.

BRAND NAME DISCLAIMER

Any use of brand, firm, or trade names and the use and distribution of specific products in this report are for identification purposes only, and do not imply endorsement by the U.S. Government. No warranty is made for use of the products.

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ABSTRACT

Hydrologic, meteorological, and other environmental data were collected from water years 1998 to 2000 near two recently constructed storm-water retention basins near DuPont, Washington. A mixture of gypsum, grass seeds, and mulch was added to soils of one of the basins to slow infiltration by water. Six monitoring wells were installed in May 1997 near the two retention basins: one upgradient of the basins, four adjacent to the basin without gypsum, and one near the basin with the gypsum soil amendment. Water-quality samples were collected to monitor possible changes in ground-water chemistry. Ground-water levels in selected wells were measured both manually with a steel tape and with automatic monitoring systems. Water level of an intermittent pond in the gypsum-treated basin was monitored, as were selected meteorological and other environmental variables. The hydrologic, meteorological, and other environmental data are presented in this report.

INTRODUCTION

Storm-water runoff from highways and urban areas can be a source of contamination to ground water (Hoos, 1990; Granato, 1996). Retention ponds for storm-water runoff from highways commonly are constructed to minimize runoff, erosion, and flooding, and potentially, to reduce amounts of contaminants in water recharging underlying ground-water systems. Possible mechanisms of contaminant reduction in water flowing through retention basins include volatilization and physical and biological breakdown of some contaminant organic compounds, and sorption of some contaminants, particularly trace metals, to sediments that then remain in the basin.

To better understand effects of storm-water retention basins on ground-water quality, the U.S. Geological Survey (USGS), in cooperation with the Washington State Department of Transportation, began an investigation of two storm-water runoff retention basins along Interstate 5 at DuPont, Washington (fig. 1). The study, which began in 1997, included laboratory-based assessments of effects of selected infiltration media on infiltration rate and water quality, and field-based investigation of effects of the two retention basins on infiltration rates and ground-water quality. Results of the laboratory-based assessments have been published (Ames and others, 2001). The field-based investigation was terminated due to the poor hydrologic performance of the retention basins. This report describes the methods of data collection for the field-based investigation and it presents data for ground-water quality and levels, and surface-water, meteorological, and other environmental data collected at the retention basins during water years 1998 to 2000. The water year ends on September 30 and is named for the calendar year in which it ends.

Voluminous ground-water-level, surface-water, meteorological, and other environmental data that were collected using automatic data-collection systems are summarized in this report using tables and graphs, and the detailed data records are stored in Microsoft Excel 2000 files that are recorded on the CD ROM that accompanies this report. Data in each Microsoft Excel 2000 files are duplicated on the CD ROM in corresponding ASCII (American Standard Code for Information Interchange) text files that can be accessed using a text editor.

Description of Study Area

The study area is part of an overpass and interchange that was completed in 1997 and was intended to accommodate projected increases in traffic in the DuPont area (fig. 1). The two retention basins, constructed to the northwest and southwest of the interchange, were designed to hold runoff from the pavement of the interchange. Each basin was roughly three-sided, with highway embankments on two sides and a levee on the third side parallel to Interstate 5. Because the water table in the area around the retention basins is fairly shallow, the rapidly infiltrating water could readily transport storm-water contaminants to the ground water beneath the basins. During construction of the basins, a thin layer of gypsum mixed with grass seeds and mulch was sprayed on the surface of one of the basins to help retard infiltration. Gypsum, grass seeds, and mulch were not applied in the second basin.

The study site is underlain by Steilacoom Gravel, which is a glacial recessional outwash deposit (Jones, 1999). The unit averages about 40 feet in thickness but can be as much as 150 feet thick (Jones, 1999). Vashon till underlies the outwash deposits, generally is about 20 to 30 feet thick, and acts as a regional confining unit (Walters and Kimmel, 1968). The soil in this area is Spanaway gravelly sandy loam, which is described as having excessive drainage (Zulauf, 1979). The water table in this area generally is about 25 to 40 feet below land surface, with direction of regional ground-water flow toward the west. Annual precipitation ranges from 35 to 45 inches and the mean annual air temperature is 51 degrees Fahrenheit (^{o}F) (Zulauf, 1979).

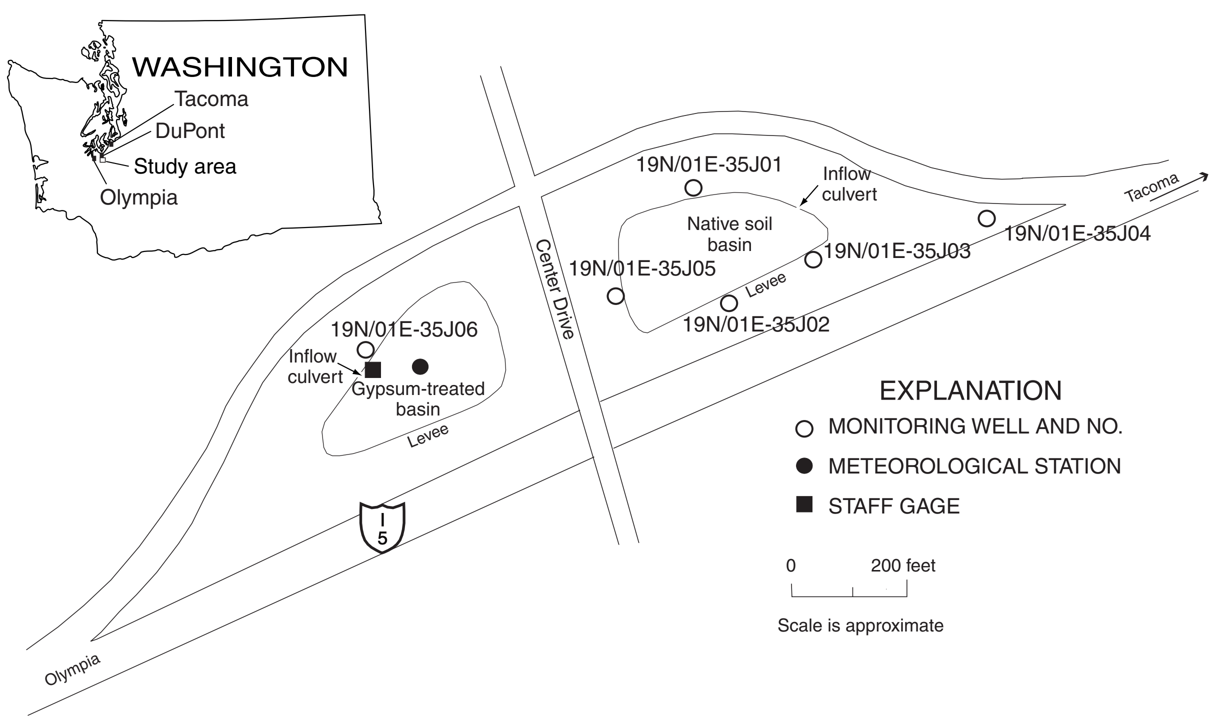


Figure 1. Location of two storm-water retention basins and data-collection sites near DuPont, Washington.

Well-Numbering System

The well-numbering system used by the USGS in the State of Washington is based on the rectangular subdivision of public land, and indicates township, range, section, and 40-acre tract within the section (fig. 2). For example, in well number 19N/01E-35J01 (fig. 1), the part preceding the hyphen indicates the township and range (Township 19 North, Range 1 East). The first number following the hyphen (35) indicates the section number, and the letter (J) gives the 40-acre tract within that section. The last number (01) is the sequence number of the well in that 40-acre tract.

STUDY DESIGN AND METHODS OF DATA COLLECTION

Six monitoring wells (table 1) were augered in May 1997 near the two retention basins: one upgradient of the basins, four immediately adjacent to the basin without gypsum, and one near the basin with the gypsum soil amendment (fig. 1). All wells were screened within the sand and gravel of the recessional outwash deposits. Ground-water levels were measured one or more times in each of the six monitoring wells, and ground-water levels were automatically monitored in two selected wells. The water level of an intermittent pond in the gypsum-treated basin was monitored, as were selected meteorological and environmental variables.

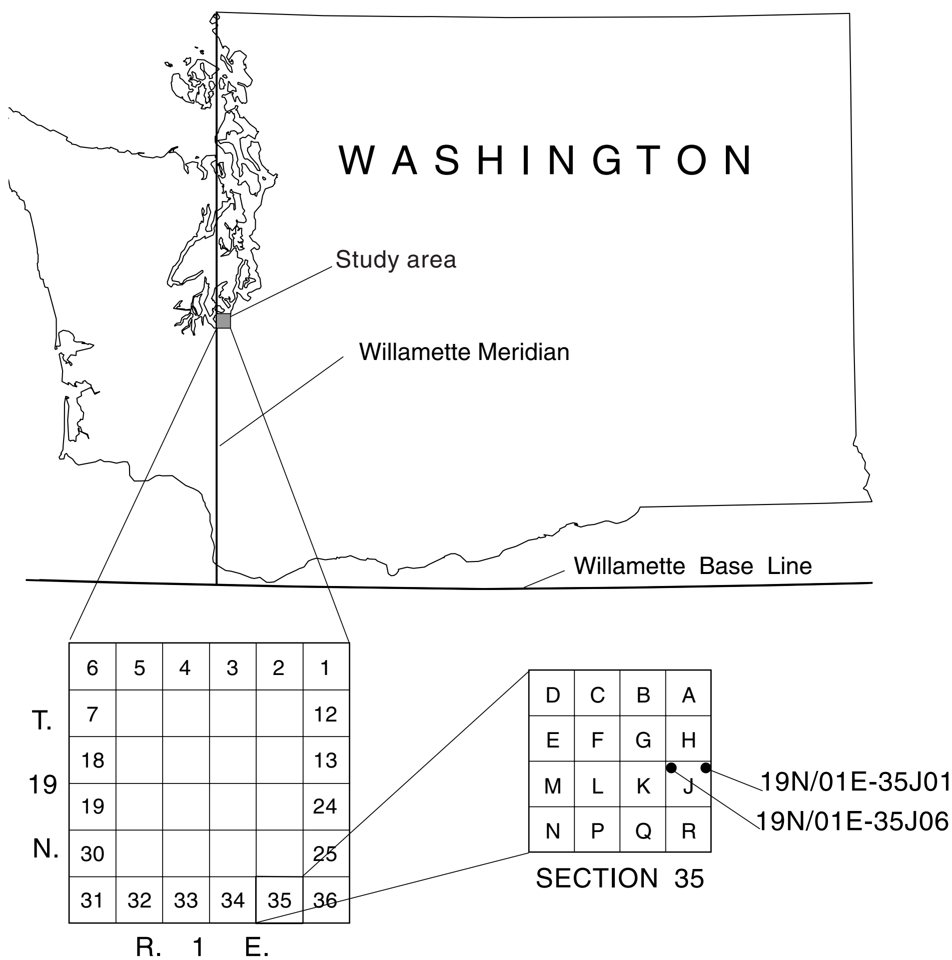


Figure 2. Well-numbering system used in Washington.

Table 1. Construction data for monitoring wells installed near retention basins near DuPont, Washington, May 1997

[**Well No**.: See figure 2 for explanation of well-numbering system. **Station identification No**: Unique number based on the latitude and longitude of the site. First six digits are latitude, next eight digits are longitude, and final two digits are a sequence number to uniquely identify a site. **Altitude of land surface:** References to "sea level" in this report are based on the North American Vertical Dautm of 1988. Depths are in feet below land surface. All wells have a screen slot size of 0.02 inch and a bentonite and concrete surface seal]

Well No.	Station identification No.	Altitude of land surface (feet above mean sea level)	Depth of well (feet)	Casing diameter (inches)	Depth to top of screened interval (feet)	Depth to bottom of screened interval (feet)
19N/01E-35J01	470522122383501	254.20	61	2	29	49
					59	61
19N/01E-35J02	470521122383501	256.15	37	2	5	25
					35	37
19N/01E-35J03	470521122383201	256.02	37	2	5	25
					35	37
19N/01E-35J04	470522122382801	256.22	37	2	5	25
					35	37
19N/01E-35J05	470521122383701	254.65	49	2	19	39
					47	49
19N/01E-35J06	470519122384301	254.42	51	2	19	39
					47	51

Data collection was terminated prematurely because of poor hydrologic performance of the retention basins. The untreated basin floor was very permeable and the basin appeared to have never held any water. Surface water in the gypsum-treated basin infiltrated very slowly and was present for months at a time. Because the gypsum effectively sealed the bottom of the treated basin, that basin overflowed during extended periods of rainy weather, therefore, the basin was not a practical model for storm-water management.

Ground-Water Quality

Ground-water samples were collected for chemical analysis at all six wells once in the spring of 1998 and once in the spring of 1999. Additional quarterly or monthly ground-water samples were collected for chemical analyses from wells 19N/01E-35J01, 19N/01E-35J05, and 19N/01E-35J06. Field properties (dissolved oxygen, pH, and specific conductance) were measured, and samples for the analysis of major ions (calcium, magnesium, potassium, sodium, chloride, fluoride, and sulfate), nitrite plus nitrate as N, and trace metals (cadmium, copper, lead, and zinc) were collected. Samples for the analysis of oil and grease were collected only in 1998.

A submersible pump made of acrylonitrile butadiene styrene (ABS) plastic and stainless steel was used to purge the wells of at least three casing volumes and until the field parameters were stable. The pump generally was placed midway between the well screen and the water surface, but pump placement varied depending on the water level in each well. A hose for sampling was dedicated to each well to limit potential for cross contamination between well samples. The dedicated hoses were cleaned between individual sampling events. Water samples collected for analysis of major ions, nitrite plus nitrate as N, and trace metals were pumped through a polypropylene encapsulated filter with a pore size of 0.45 micrometer (µm). Samples for analysis of oil and grease were not filtered and were collected in organic-free glass bottles. After each sampling, all equipment was cleaned using a 0.2 percent mixture of phosphate-free detergent, followed by a tap-water rinse and a de-ionized water rinse.

Analytical Methods

The samples were packed in ice and shipped to the USGS National Water Quality Laboratory (NWQL) in Lakewood, Colo., where they were analyzed for major ions, nitrite plus nitrate as N, dissolved trace metals, and oil and grease. Major ions were analyzed using inductively coupled plasma (ICP) spectrometry, atomic absorption spectrometry, ion-exchange chromatography, or ion-selective electrode (Fishman and Friedman, 1989; Fishman, 1993) and nitrite plus nitrate as N was analyzed by cadmium reduction. Trace metals generally were analyzed by ICP spectrometry with the exception of one sample, which was analyzed by graphite furnace atomic absorption spectrophotometry (Fishman, 1993). Oil and grease samples were analyzed by a liquid-liquid extraction and gravimetric procedure that uses *n*-hexane as the extraction solvent, similar to the U.S. Environmental Protection Agency method 1664 (U.S. Geological Survey, 1996).

Results of Quality-Control Samples

Three field blank samples were collected to determine whether sampling procedures introduced bias or contamination to the samples during collection and processing. Blank samples generally were collected in the field prior to sampling the monitoring wells using the same field procedures followed in collecting environmental samples, and using water with no detectable amounts of the analyte of interest. Additionally, four replicate samples were collected at the same time as the environmental samples to measure analytical variability.

Although calcium, magnesium, sodium, chloride, zinc, suspended solids, and nitrite plus nitrate as N were detected in some blank samples, concentrations generally were much less than concentrations detected in environmental samples, indicating that sampling methods did not substantially contaminate the samples (table 2). However, there possibly may be positive bias for chloride, suspended solids, and zinc. One detection of suspended solids [52 milligrams per liter (mg/L)] and one detection of zinc [26.09 micrograms per liter (µg/L)] in a blank sample were similar in concentration to the environmental samples, and a detection of chloride (0.461 mg/L) was about 15 percent of the smallest environmental concentration (3 mg/L). Zinc concentrations in the environmental samples ranged from 13 to 37 mg/L with a median of 14 mg/L. Therefore, all low level detections of zinc possibly are the result of contamination. Suspended-solids concentrations in the environmental samples ranged from 6 to 4,550 mg/L with a median of 57 mg/L. Therefore, almost one-half of the suspended solids samples possibly are affected by contamination. However, the high detection of suspended solids in the field blank is believed to be caused by inadequate field cleaning of the equipment and does not affect the environmental samples because all equipment for the environmental samples was laboratory cleaned. Dissolved solids, potassium, fluoride, sulfate, cadmium, copper, and lead were not detected in any blanks.

Table 2. Concentrations of constituents and properties measured in blank samples collected in the field prior to sampling the monitoring wells near DuPont, Washington, 1998-99

[All samples except for suspended solids and acid neutralizing capacity are filtered. **Well No.:** See figure 2 for explanation of well-numbering system. **Abbreviations:** ANC, acid neutralizing capacity; mg/L, milligrams per liter; µg/L, micrograms per liter; –, not analyzed; E, estimated; <, less than]

Well No.	Date	Calcium (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)	ANC (mg/L)	Alkalinity (mg/L)	Chloride (mg/L)	Fluoride (mg/L)
19N/01E-35J01	04-16-99	E0.012	<0.004	<0.1	E0.042	1.67	–	<0.1	--
	06-21-99	0.02	0.004	<0.1	<0.06	1.90	–	<0.1	--
19N/01E-35J06	06-08-98	<0.02	<0.004	–	–	–	1.32	0.461	<0.1

Well No.	Date	Sulfate (mg/L)	Suspended solids (mg/L)	Dissolved solids (mg/L)	Nitrite plus nitrate as N (mg/L)	Cadmium (µg/L)	Copper (µg/L)	Lead (µg/L)	Zinc (µg/L)
19N/01E-35J01	04-16-99	<0.1	<1	<10	0.006	<8	<10	<100	<20
	06-21-99	<0.1	52	<10	0.006	<8	<10	<100	26.09
19N/01E-35J06	06-08-98	<0.1	1	<10	0.006	--	<10	<100	<20

Precision data obtained from the replicate samples are listed in table 3. Except for suspended solids and zinc, concentration differences within replicate sets ranged from 0 to 12 percent as measured by relative percentage of difference. The relative percentage of difference for the suspended solids ranged from 13 to 116 percent and the relative percentage of difference for zinc was 54 to 58 percent, which indicates a high variability for these two constituents.

Ground-Water-Level Measurements

Water levels in selected wells were measured manually using a steel tape during January 1998 to January 2000. Water levels in wells 19N/01E-35J01 and 19N/01E-35J06 were monitored with automatic monitoring systems during May 1998 to February 2000. The automatic ground-water-level monitoring systems each consisted of a submersible pressure transducer (table 4) and a data logger [model CR10, Campbell Scientific, Inc., Logan, Utah (CSI)]. The pressure transducers were calibrated to output their submersion depths, in feet, and water levels measured with a steel tape were used to convert transducer submersion depth to a water level that was the distance between the top of the well casing and the water surface. The signal from each pressure transducer was scanned every 2 minutes and water levels were stored in the data logger memory every 4 hours.

Water levels measured with a steel tape in wells 19N/01E-35J01 and 19N/01E-35J06 also were used to assess performance of the pressure transducers and to correct water levels that were measured using the pressure transducers. Water levels measured manually with a steel tape indicated that water levels measured using the pressure transducers generally were accurate to within 0.1 foot or less. Errors in water levels measured with a given transducer that were consistently greater than 0.1 foot were assumed to indicate that the transducer had malfunctioned. Pressure transducers in wells 19N/01E-35J01 and 19N/01E-35J06 began to malfunction during April 1999 and both were replaced during May 1999.

Table 3. Concentrations and precision data for detected inorganic constituents and properties in replicate samples from wells installed near retention basins near DuPont, Washington, 1998-99

[All concentrations are in milligrams per liter except for zinc which is in micrograms per liter. ANC, acid neutralizing capacity; <, less than; E, estimated]

Constituent or property	Concentration in replicates	Relative percentage of difference
Calcium	31.0 30.8	0.6
	27.8 27.6	0.7
	14.2 14.0	0
	17.3 19.6	12
Magnesium	8.23 8.26	0.4
	7.10 7.05	0.7
	3.64 3.64	0
	4.85 5.38	10
Potassium	0.4 0.4	0
	0.9 0.8	12
Sodium	18.5 18.6	0.5
	15.0 15.4	3
ANC	89 88	1
Alkalinity	95 96	1
	87 87	0
	66 66	0
Chloride	3.3 3.3	0
	3.3 3.3	0
	2.7 3.0	11
Sulfate	21.0 20.8	1
	18.2 18.1	0.6
	15.9 15.7	1
	18.2 19.3	6
Suspended solids	146 117	22
	8 7	13
	3,220 850	116
	5,995 3,700	47
Dissolved solids	178 180	1
	162 163	0.6
	138 137	0.7
Zinc	28 <20	–
	31 17	58
	E8 E14	54

Table 4. Automatically monitored water-level, meteorological, and other environmental variables, the sensors that were used to monitor them, and the manufacturer or distributor of the sensors

Variable monitored	Sensor	Manufacturer or distributor
Well water level	Pressure transducer, model WaterLOG H-310	Design Analysis Associates, Logan, Utah
Pond water level	Pressure transducer, model: PDCR-1230-8389	Druck, Inc., New Fairfield, Connecticut
Precipitation	Texas Electronics tipping-bucket rain gauge, model TE525	Campbell Scientific, Inc., Logan, Utah
Pond water temperature	Soil/water temperature probe, model 107B	Campbell Scientific, Inc., Logan, Utah
Air temperature and relative humidity	Vaisala air-temperature and relative humidity probe, model HMP35C	Campbell Scientific, Inc., Logan, Utah
Wind speed	Wind-speed sensor, model 014A	Met One Instruments, Inc., Grants Pass, Oregon
Incoming solar radiation	Pyranometer, model LI-200SZ	LI-COR, Inc., Lincoln, Nebraska
Net radiation	Total hemispherical net radiometer, model Q*7.1 or Q*6.7.1	Radiation and Energy Balance Systems, Inc., Seattle, Washington
Energy flux into the floor of the basin	Soil heat flux plate, model HFT-1	Radiation and Energy Balance Systems, Inc., Seattle, Washington

Replacing the pressure transducers restored the accuracy of the automatic water-level measurements to within 0.1 foot in both wells. Water levels computed with each of the pressure transducers were corrected using the manual measurements by assuming the error in the water level computed with the transducer changed linearly with time between any two manual measurements. The corrected water-level data also were screened to remove data that were considered to be unreliable, and the corrected and screened water-level data are referred to in this report as edited water-level data. Data were considered to be unreliable (1) when the pressure transducers malfunctioned during April and May 1999, and (2) during any period for which manual water-level measurements for assessing performance of the transducers were not made at both the beginning and end of the data-collection period. The latter screening criteria not only checked whether or not the pressure transducers were working properly during a given period, but also that the transducers were not ill-positioned during the period due to twists or kinks in the down-well suspension apparatus that held the transducers in place. Gaps in the water-level data occasionally were caused by a loss of battery power to the data loggers.

Pond Water-Level, Meteorological, and Other Environmental Data Collection

One of the important hydrologic processes controlling migration of contaminants from the gypsum-treated retention basin to the saturated ground-water system was downward seepage from the intermittent pond in that basin. Pond water-level, meteorological, and other environmental data were collected to enable estimation of evaporation and seepage rates from the pond. Estimation of evaporation and seepage rates is beyond the scope of this report; however, the data reported herein can be used to estimate evaporation and seepage rates by using techniques relying on mass-transfer theory and the water balance (Langbein and others, 1951; Harbeck, 1962; and Turner, 1966). In addition, evaporation estimation techniques that rely on the energy balance can be used with data described in this report to augment the record of evaporation that is estimated using mass-transfer theory and the water balance. One such energy-balance technique for estimating evaporation that might be adapted and used in concert with techniques based on mass-transfer theory and the water balance is the Priestley-Taylor technique (Priestley and Taylor, 1972).

The water level in the pond was intermittently read from a staff gage installed near the northern shore of the pond (fig. 1), and a more continuous record of the water level was obtained using a pressure transducer installed in a shallow hole dug into the gravelly floor of the basin (table 4). The pressure transducer was monitored by a data logger (model 21X or CR10, CSI) that sampled the sensor's dimensionless ratiometric signal every 30 seconds, performed a linear conversion to the signal, and recorded the 30-minute average of the converted value every 30 minutes. The ratiometric values, or their converted equivalents, were correlated with water levels measured using the staff gage to develop calibration functions for the pressure transducer. The calibration functions were applied to the record of ratiometric data to produce a time series of pond water level. The pressure transducer was first installed about 15 feet east of the investigation's meteorological station (fig. 1) during early June 1998.

The pressure transducer was removed during September 1998, after the basin had become dry. The pressure transducer was again installed by attaching it to the staff gage during November 1998 in anticipation of rainy weather that would again cause the basin to flood.

The meteorological variables of incoming solar and net radiation, air temperature and relative humidity, wind speed, and precipitation were monitored at a meteorological station installed near the center of the gypsum-treated basin (fig. 1). Incoming solar radiation was sensed with a pyranometer (table 4). Net radiation, which is equal to the sum of incoming solar and terrestrial radiation minus the sum of reflected solar radiation and outgoing terrestrial radiation, was sensed with a net radiometer (table 4). Sensed net radiation was corrected to account for effects of wind using instructions provided by the manufacturer (Radiation and Energy Balance Systems, Inc., written commun., April 1997).

Air temperature and relative humidity were sensed with an air-temperature and relative humidity probe (table 4). Wind speed was sensed with a wind speed sensor, and precipitation was sensed with a tipping-bucket rain gage (table 4). The air-temperature and relative humidity probe and the wind speed sensor were set at the same height above the basin floor and the height was varied with the intent of keeping the sensors about 6.6 feet above the pond water surface. The meteorological station data logger (model 21X, CSI) sampled incoming solar and net radiation, air temperature and relative humidity, and wind speed every 30 seconds and the logger recorded the averages of those variables every 30 minutes. Precipitation was totaled and recorded every 30 minutes. Recorded relative humidity (h_r) was used to compute air water-vapor-pressure deficit (D) using the equation

$$D = e_s(1 - h_r) \quad , \qquad (1)$$

where

D is in kilopascals;

e_s is air water-vapor pressure at saturation, in kilopascals; and

h_r ranges from 0 to 1.0 and is dimensionless.

Air water-vapor pressure at saturation was computed using the Lowe equation (Lowe, 1977), which can be written as

$$e_s = (A_0 + T(A_1 + T(A_2 + T(A_3 + T(A_4 + T(A_5 + TA_6))))))/10 \quad , \qquad (2)$$

where

T is air temperature, in degrees Celsius; and the coefficients are

A_0: 6.107799961
A_1: $4.436518521 \times 10^{-1}$
A_2: $1.428945805 \times 10^{-2}$
A_3: $2.650648471 \times 10^{-4}$
A_4: $3.031240396 \times 10^{-6}$
A_5: $2.034080948 \times 10^{-8}$
A_6: $6.136820929 \times 10^{-11}$

The meteorological station also recorded energy flux into the floor of the gypsum-treated basin. Soil heat flux plates (table 4) were buried about 1 inch beneath the surface of the basin floor at different places within a distance of about 10 feet from the meteorological station (fig. 1). As many as three soil heat flux plates were installed at any given time.

The original field-recorded meteorological data and data for energy flux into the floor of the gypsum-treated basin were edited to apply corrections to the field-recorded net radiation, as described previously, to compute *D*, to apply the correct pyranometer and net radiometer calibration coefficients, and to screen out spurious and unreliable data. As an example of spurious data, precipitation was recorded when water was poured through the tipping-bucket rain gage to test the function of that gage. As an example of unreliable data, some of the collected net radiation data were rejected when it was discovered that the net radiometer had been damaged during the period of collection of those data.

The meteorological station also monitored water temperature in the intermittent pond in the gypsum-treated basin. The first of four soil/water-temperature probes (table 4) was fixed to a float anchored about 25 feet northeast of the meteorological station. The float-mounted probe was about 0.4 inch below the water surface. The remaining three soil/water-temperature probes were fixed to a post that was driven into the floor of the basin about 15 feet east of the meteorological station. The post-mounted probes were fixed at different heights above the floor of the basin. Heights of the probes were adjusted during some site visits to measure water temperature at varying depths and to keep the probes immersed in water as the water level of the pond fluctuated. Temperature signals from the soil/water temperature probes were sampled every 30 seconds and the average temperature sensed by each probe during the final 4 minutes of every one-half hour was recorded. The computed record of pond water level was used to compute submersion depth of each probe at any given time. A set of edited water-temperature data was created from the original field-recorded data. The edited water-temperature data set includes computed submersion depth of each water-temperature probe. The edited water-temperature data set excludes temperature data collected when the probes were exposed to the atmosphere or the submersion depth of the probes could not be computed because of gaps in the pond water-level record.

The meteorological station was installed at the gypsum-treated basin during early June 1998. At that time, the station monitored pond water level, air temperature and relative humidity, wind speed, precipitation, and water temperature. Sensors for monitoring net radiation and energy flux into the floor of the basin were added during mid-June 1998, and a pyranometer was added during late August 1998. The meteorological station was removed from the basin in mid-July 1999.

GROUND-WATER QUALITY DATA

Ground-water quality data were collected from six wells from May 1998 to June 1999 (table 5). Concentrations of nitrite plus nitrate as N ranged from 1.17 to 5.15 mg/L, with a median concentration of 2.51 mg/L. The smallest concentrations were in water from wells 19N/01E-35J01 and 19N/01E-35J06, and the largest concentration was in water from well 19N/01E-35J04. Calcium, magnesium, potassium, sodium, chloride, sulfate, suspended solids, and zinc were detected in at least some of the samples from each well, although the detections of some of these constituents could have resulted from positive bias or sample contamination, as previously discussed in “Results of Quality-Control Samples.” Concentrations of fluoride, cadmium, copper, lead, and oil and grease were less than the detection limits in all ground-water samples.

Table 5. Field measurements and concentrations of inorganic and organic constituents and properties measured in water samples collected from monitoring wells installed near retention basins near DuPont, Washington, May 1998 through June 1999

[All samples except for suspended solids and acid neutralizing capacity are filtered. **Well No.**: See figure 2 for explanation of well-numbering system. **Suspended solids, Chloride, and Zinc concentrations**: Low concentrations of these constituents may be affected by positive bias due to contamination of blank samples (see section on Results of Quality-Control Samples and table 2). **Zinc concentrations**: Some of the zinc concentrations are estimated because the concentrations are less than the method detection limit. All E-coded data are considered reliable detections, but with greater than average uncertainty in quantification. Abbreviations: mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25°C; µg/L, micrograms per liter; –, not analyzed, E, estimated; <, less than; ANC, acid neutralizing capacity]

Well No.	Date	Dissolved oxygen (mg/L)	pH (standard units)	Specific conductance (µS/cm)	Calcium (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)
19N/01E-35J01	05-04-98	–	6.1	201	28.4	7.49	–	–
	06-08-98	–	5.9	214	26.5	7.03	–	–
	07-08-98	–	6.0	226	26.4	6.88	–	–
	08-11-98	6.1	6.5	209	27.6	7.05	–	–
	09-15-98	–	6.3	237	27.0	7.11	–	–
	02-18-99	–	5.9	192	14.2	3.64	0.42	18.6
	04-16-99	8.9	6.1	205	14.1	3.80	1.02	21.8
	06-21-99	6.0	5.9	238	19.6	5.38	0.78	15.4
19N/01E-35J02	05-04-98	–	6.2	344	32.8	8.26	–	–
	06-21-99	4.4	5.7	390	35.4	9.30	2.30	11.9
19N/01E-35J03	05-04-98	–	6.2	226	28.0	7.20	–	–
	06-21-99	8.4	5.7	227	25.0	6.68	1.29	7.3
19N/01E-35J04	05-04-98	–	6.1	206	25.6	7.49	–	–
	06-21-99	7.0	5.7	231	24.8	7.79	1.22	8.5
19N/01E-35J05	05-04-98	–	6.2	162	31.3	8.15	–	–
	07-08-98	–	6.0	262	30.8	8.26	–	–
	09-15-98	–	6.5	249	28.0	7.72	–	
	06-21-99	6.1	5.8	251	28.6	7.45	1.30	8.0
19N/01E-35J06	05-04-98	–	6.0	232	29.7	7.79	–	–
	06-08-98	–	5.9	230	29.2	7.64	–	–
	07-08-08	–	6.0	243	29.5	7.64	–	–
	08-11-98	4.8	6.2	242	29.1	7.51	–	–
	09-15-98	–	6.3	236	–	–	–	–
	02-18-99	–	6.0	168	20.9	4.54	0.86	6.1
	04-16-99	11.3	5.9	180	21.3	4.69	0.97	6.0
	06-21-99	4.9	5.8	256	30.6	7.88	1.30	7.8

Table 5. Field measurements and concentrations of inorganic and organic constituents and properties measured in water samples collected from monitoring wells installed near retention basins near DuPont, Washington, May 1998 through June 1999—*Continued*

Well No.	Date	ANC (mg/L)	Alkalinity (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Sulfate (mg/L)	Suspended solids (mg/L)	Dissolved solids (mg/L)
19N/01E-35J01	05-04-98	–	84	3.6	<0.1	19.8	128	169
	06-08-98	–	82	3.8	<.1	17.9	28	161
	07-08-98	–	81	3.5	<.1	18.1	16	159
	08-11-98	–	87	3.3	<.1	18.1	7	163
	09-15-98	–	91	3.3	<.1	16.2	13	162
	02-18-99	–	66	–	–	15.7	850	137
	04-16-99	66	–	3.4	–	20.7	4,550	148
	06-21-99	88	–	3.0	–	19.3	3,700	180
19N/01E-35J02	05-04-98	–	90	5.8	<.1	32.8	1,030	197
	06-21-99	111	–	5.5	–	33.7	560	210
19N/01E-35J03	05-04-98	–	79	3.7	<.1	22.0	41	172
	06-21-99	79	–	3.2	–	18.4	39	180
19N/01E-35J04	05-04-98	–	75	6.0	<.1	11.7	48	160
	06-21-99	84	–	4.7	–	14.1	29	164
19N/01E-35J05	05-04-98	–	96	3.7	<.1	22.1	94	181
	07-08-98	–	96	3.3	<.1	20.8	146	180
	09-15-98	–	–	3.5	<.1	22.6	61	175
	06-21-99	92	–	3.5	–	17.9	6	160
19N/01E-35J06	05-04-98	–	91	3.4	<.1	23.8	880	179
	06-08-98	–	85	3.7	<.1	23.8	108	177
	07-08-08	–	84	3.2	<.1	23.8	91	175
	08-11-98	–	83	3.3	<.1	24.4	49	170
	09-15-98	–	80	–	–	–	61	–
	02-18-99	–	59	3.1	–	13.4	34	127
	04-16-99	59	–	4.0	–	15.2	53	137
	06-21-99	91	–	3.0	–	25.2	40	175

Table 5. Field measurements and concentrations of inorganic and organic constituents and properties measured in water samples collected from monitoring wells installed near retention basins near DuPont, Washington, May 1998 through June 1999—*Continued*

Well No.	Date	Nitrite plus nitrate as N (mg/L)	Cadmium (μg/L)	Copper (μg/L)	Lead (μg/L)	Zinc (μg/L)	Oil and grease (μg/L)
19N/01E-35J01	05-04-98	2.51	–	<10	<100	<20	<1
	06-08-98	2.23	–	<10	<100	<20	–
	07-08-98	–	–	<10	<100	<20	–
	08-11-98	2.27	–	<10	<100	<20	–
	09-15-98	2.09	–	<10	<100	<20	–
	02-18-99	1.79	<1.0	<1.0	<1.0	17	–
	04-16-99	2.09	<8.0	<10	<100	<20	–
	06-21-99	1.17	<8.0	<10	<100	E14	–
19N/01E-35J02	05-04-98	2.53	–	<10	<100	<20	<1
	06-21-99	3.50	<8.0	<10	<100	E13	–
19N/01E-35J03	05-04-98	3.61	–	<10	<100	<20	<1
	06-21-99	2.92	<8.0	<10	<100	E13	–
19N/01E-35J04	05-04-98	5.15	–	<10	<100	<20	<1
	06-21-99	3.95	<8.0	<10	<100	37	–
19N/01E-35J05	05-04-98	2.81	–	<10	<100	<20	<1
	07-08-98	–	–	<10	<100	<20	–
	09-15-98	2.70	–	<10	<100	<20	–
	06-21-99	3.09	<8.0	<10	<100	E14	–
19N/01E-35J06	05-04-98	2.14	–	<10	<100	<20	<1
	06-08-98	2.31	–	<10	<100	<20	–
	07-08-08	–	–	<10	<100	34	–
	08-11-98	2.55	–	<10	<100	<20	–
	09-15-98	2.56	–	<10	<100	<20	–
	02-18-99	1.69	<8.0	<10	<100	<20	–
	04-16-99	2.38	<8.0	<10	<100	<20	–
	06-21-99	1.90	<8.0	<10	<100	<20	–

GROUND-WATER LEVEL DATA

Ground-water levels measured manually with a steel tape are shown in table 6. The original field-recorded and edited water-level data collected with the automatic measurement system for well 19N/01E-35J01 are contained in the file 470522122383501W.xls on the CD ROM that accompanies this report. The original field-recorded and edited water-level data collected with the automatic measurement system for well 19N/01E-35J06 are contained in the file 470519122384301W.xls on the CD ROM. Water-surface altitudes in wells 19N/01E-35J01 and 19N/01E-35J06 computed from the manual water-level measurements and from automatic measurements are shown in figure 3 for the period of automatic measurements. Water-surface altitudes from the automatic water-level measurement systems depicted in figure 3 are based on edited water-level data. Water-surface altitudes in the two wells ranged from about 208 to 230 feet above mean sea level.

The water-surface altitude was greater in well 19N/01E-35J01 than in well 19N/01E-35J06 (fig. 3). The available data indicate that the daily mean difference generally ranged from about 4.5 to 5.5 feet, although the differences varied erratically during periods when water levels were changing rapidly in both wells.

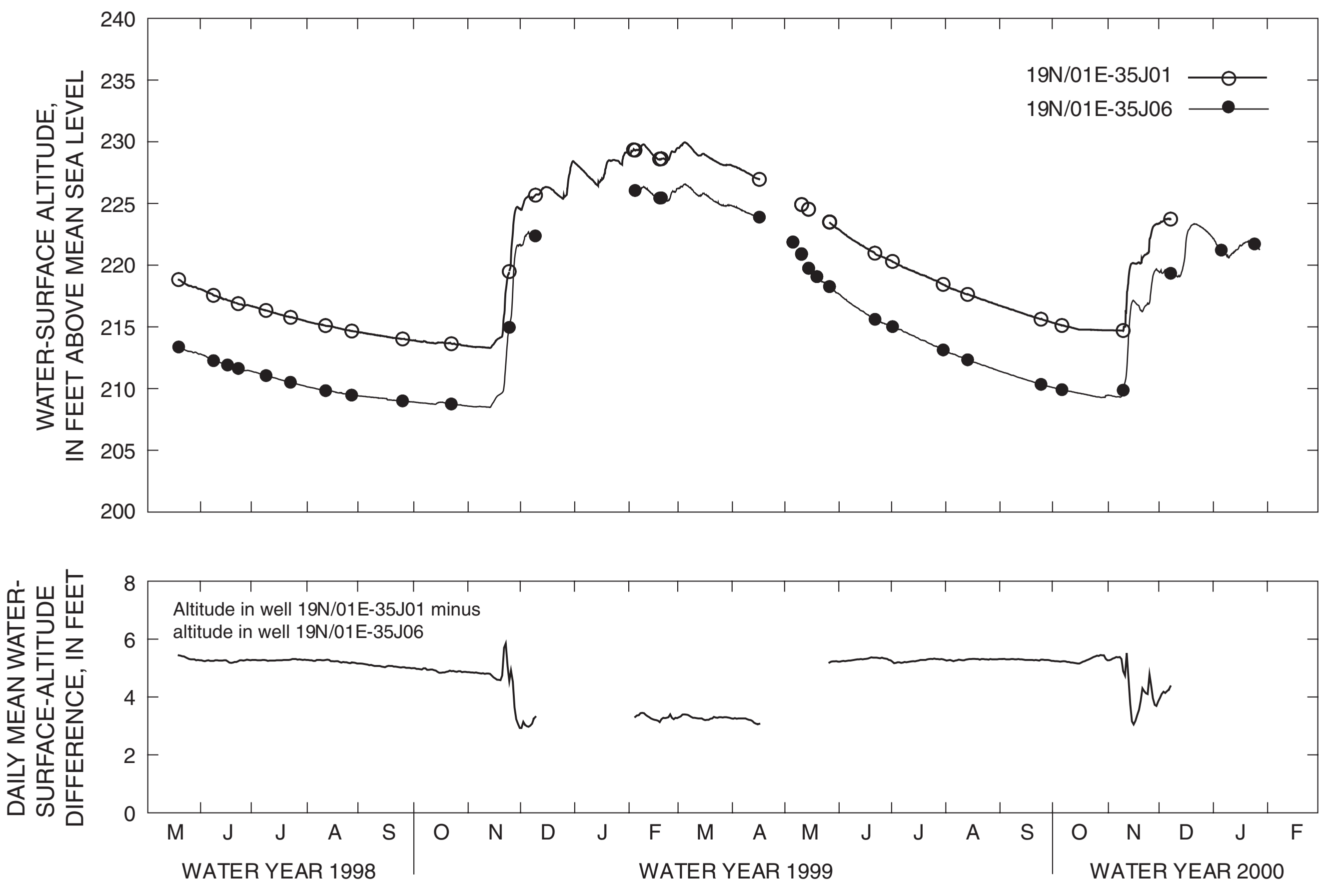


Figure 3. Water-surface altitudes in wells 19N/01E-35J01 and 19N/01E-35J06 near two retention basins near DuPont, Washington, during 1998-2000, and daily mean difference between water-surface altitudes in those same two wells.

Table 6. Water levels for selected wells installed near retention basins near DuPont, Washington, 1998-99

[Time: Pacific Standard Time or Pacific Daylight Saving Time, in 24-hour format. Water levels are in feet below land surface. –, not recorded]

19N/01E-35J01		
Date	Time	Water level
01-08-1998	–	30.41
05-19-1998	1155	35.37
06-08-1998	0940	36.65
06-22-1998	1335	37.32
07-08-1998	1055	37.87
07-22-1998	1305	38.43
08-11-1998	1145	39.10
08-26-1998	1215	39.54
09-24-1998	1405	40.18
10-22-1998	1030	40.57
11-24-1998	1155	34.72
12-09-1998	1210	28.53
02-03-1999	1215	24.86
02-04-1999	0925	24.88
02-18-1999	1035	25.60
02-19-1999	1110	25.58
04-16-1999	1220	27.25
05-10-1999	1609	29.29
05-10-1999	1620	29.29
05-14-1999	1458	29.67
05-14-1999	1503	29.67
05-26-1999	1536	30.71
05-26-1999	1540	30.70
05-26-1999	1728	30.70
05-26-1999	1731	30.72
06-21-1999	1335	33.23
07-01-1999	1510	33.90
07-30-1999	1420	35.76
08-13-1999	1345	36.57
09-24-1999	1235	38.58
10-06-1999	1140	39.09
11-10-1999	1110	39.50
12-07-1999	1420	30.47

19N/01E-35J02		
Date	Time	Water level
01-08-1998	–	31.59

19N/01E-35J03		
Date	Time	Water level
01-08-1998	–	32.13

19N/01E-35J04		
Date	Time	Water level
01-08-1998	–	31.41

19N/01E-35J05		
Date	Time	Water level
01-08-1998	–	31.45

19N/01E-35J06		
Date	Time	Water level
01-08-1998	–	35.69
05-19-1998	–	41.05
06-08-1998	1115	42.16
06-16-1998	1110	42.51
06-22-1998	1450	42.79
07-08-1998	1200	43.37
07-22-1998	1010	43.91
08-11-1998	1320	44.59
08-26-1998	0950	44.95
09-24-1998	1240	45.42
10-22-1998	0935	45.67
11-24-1998	1330	39.46
12-09-1998	0930	32.05
02-04-1999	0955	28.37
02-18-1999	1210	28.98
02-19-1999	1145	28.97
04-16-1999	1230	30.53
05-05-1999	1651	32.56
05-05-1999	1658	32.54
05-05-1999	1704	32.55
05-10-1999	1427	33.55
05-10-1999	1441	33.49
05-10-1999	1446	33.51
05-10-1999	1427	33.55
05-10-1999	1441	33.49
05-10-1999	1446	33.51
05-14-1999	1626	34.66
05-14-1999	1631	34.68
05-19-1999	0943	35.35
05-19-1999	0949	35.35
05-26-1999	1430	36.16
05-26-1999	1441	36.15
06-21-1999	1520	38.81
07-01-1999	1550	39.40
07-30-1999	1450	41.29
08-13-1999	1400	42.09
09-24-1999	1255	44.08
10-06-1999	1200	44.51
11-10-1999	1130	44.55
12-07-1999	1455	35.08
01-05-2000	1350	33.20
01-24-2000	1310	32.70

POND WATER-LEVEL DATA

Both the original field-recorded data from the pressure transducer that was installed in the intermittent pond in the gypsum-treated basin and the computed pond water level are stored on the accompanying CD ROM. Data from the first installation of the pressure transducer are in the file 470519122384201P.xls and data from the second installation are in the file 470519122384301P.xls. The water level of the intermittent pond in the gypsum-treated basin and depth of the pond near the site of the meterological station are shown in figure 4. The water level declined from 0.98 foot at the start of monitoring on June 3, 1998, until the basin was completely dry, which was the case prior to September 24, 1998. The floor of the basin was not completely level, and different areas of the floor became exposed as the water level declined. For example, on July 29, 1998, when the pond water level averaged 0.30 foot, the water surface had only retreated by about 2 feet horizontally along the shore. However, by August 26, 1998, for which the daily average water level was -0.15 foot, about 20 to 30 percent of the basin floor had become exposed that had been submerged during June, and the exposed basin floor included both islands and peninsulas. The staff gage was not in the topographically lowest part in the basin, and negative water levels resulted when the water-surface altitude was below that of the staff gage. Concurrent measurements of pond depth near the site of the meteorological station and water level at the near-shore staff gage indicated that the pond depth near the meteorological station could be computed by adding 0.32 foot to the water level (fig. 4). Neither the relation between water level and surface-water area nor the water level at which the pond was reduced to isolated puddles are known.

The pond re-appeared during mid-November 1998, and pond water level rose rapidly thereafter (fig. 4). The maximum water level was limited by an overflow channel in the dike that bordered the basin on the southeast side. The maximum measured water level of 1.55 feet was read from the staff gage on December 28, 1998. An overall decreasing trend in the pond water level began in late March 1999, and the basin was again completely dry prior to September 24, 1999.

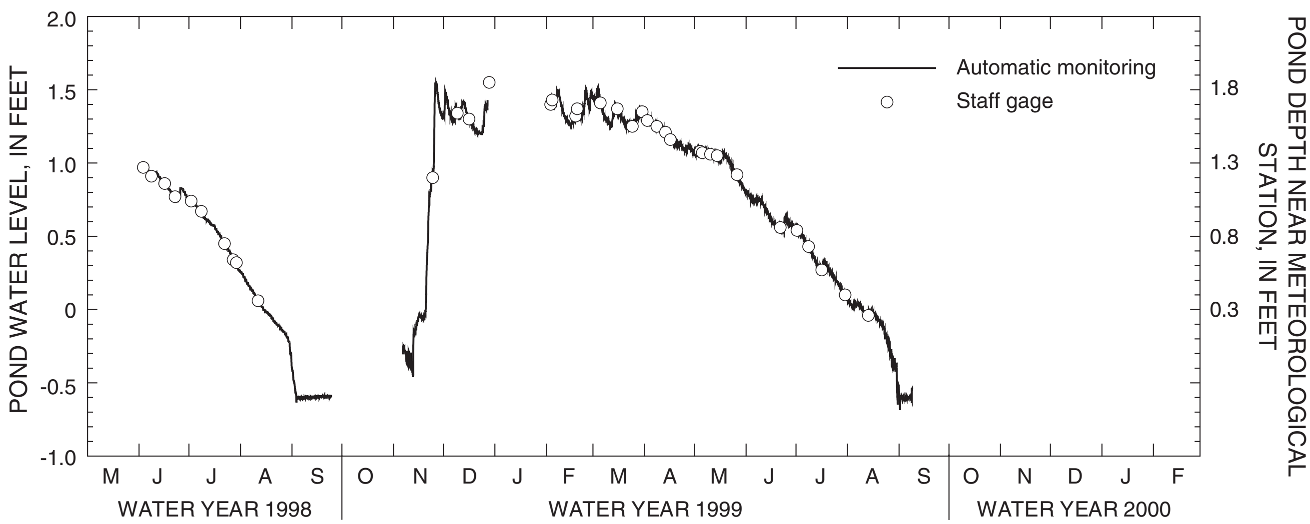


Figure 4. Water level of pond in the gypsum-treated retention basin, and depth of the pond near the site of the meteorological station near DuPont, Washington, June 1998 to September 1999.

OTHER METEOROLOGICAL AND ENVIRONMENTAL DATA

The original field-recorded data for incoming solar and net radiation, air temperature and relative humidity, wind speed, and precipitation are stored in the file WA414_METfield.xls on the CD ROM that accompanies this report. The edited data comprising incoming solar and net radiation, air temperature and relative humidity, air water-vapor-pressure deficit, wind speed and precipitation are stored in the file WA414_AIRAD.xls on the CD ROM. Summaries and figures for incoming solar and net radiation, air temperature and relative humidity, air water-vapor-pressure deficit, wind speed, and precipitation presented in this report are based on edited data as previously described in "Pond Water-Level, Meteorological, and Other Environmental Data Collection."

Daily average incoming solar and net radiation for the periods those variables were monitored are shown in figure 5. Monthly average incoming solar radiation ranged from 34 watts per square meter (W/m^2) during both December 1998 and January 1999 to 281 W/m^2 during August 1998, although the average for August 1998 was computed from less than a full month of data. Because embankments that formed the gypsum-treated basin on its northwest and east sides blocked some of the solar energy from reaching the pyranometer, incoming solar radiation reported in this report likely under-represents solar radiation received on expansive, level surfaces near the investigation site.

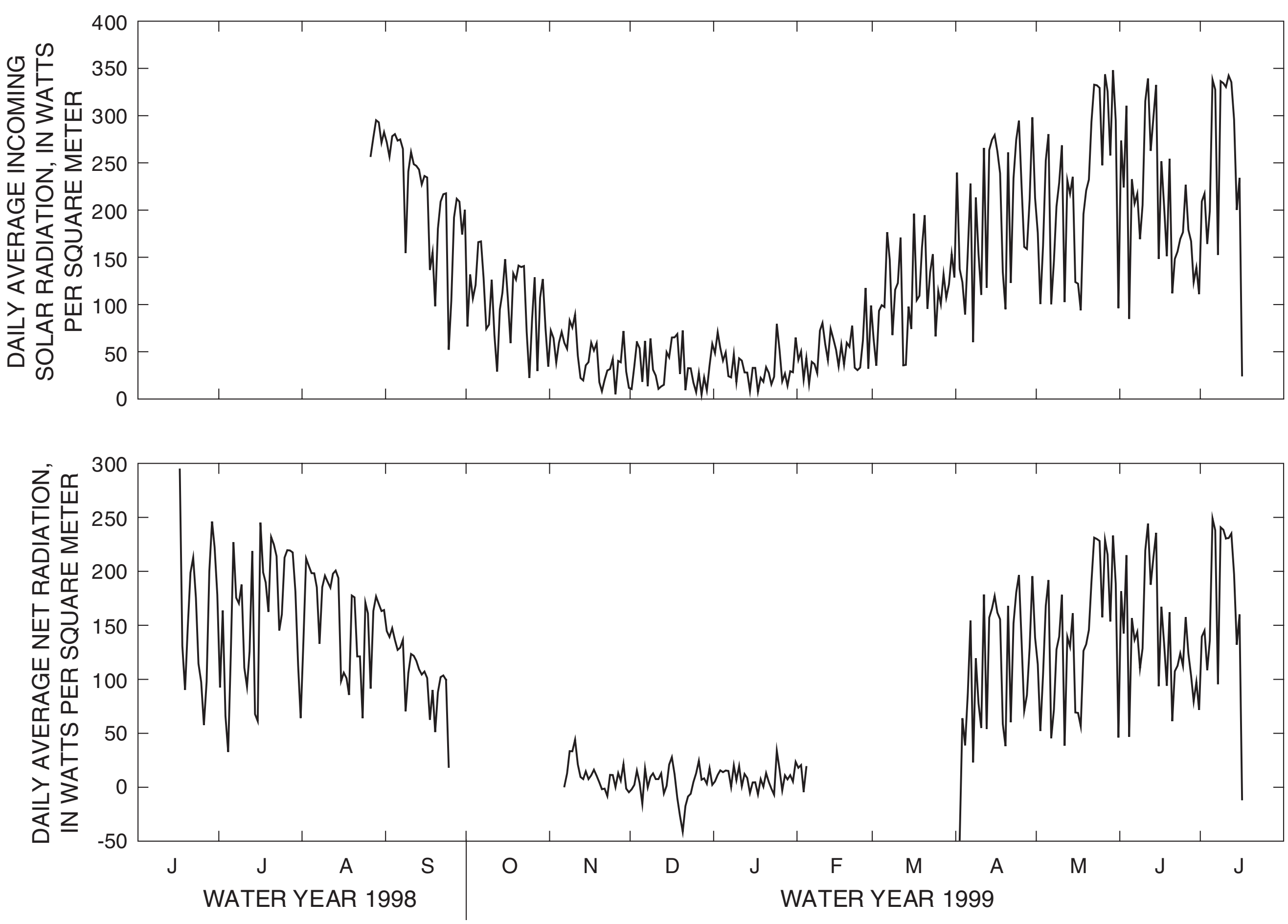


Figure 5. Daily average incoming solar radiation and net radiation at the gypsum-treated retention basin near DuPont, Washington, 1998-99.

The net radiation record contains two large gaps that were caused by damage to the net radiometers. The damage, which included collapsed radiometer windshields and damage from moisture that seeped into the radiometers, was detected during routine inspections. Monthly average net radiation ranged from 3 W/m^2 for December 1998 to 181 W/m^2 for July 1999, although the average for July 1999 was computed from less than a full month of data. The day-to-day variations of daily average incoming solar and net radiation were largely caused by day-to-day variations of cloudiness.

Daily average air temperature and water-vapor-pressure deficit, and daily average wind speed in the gypsum-treated basin during June 1998 to July 1999 are shown in figure 6. Daily average air temperature ranged from -9 degrees Celsius (°C) on December 22, 1998, to 27°C on July 28, 1998. Air temperature during December 1998, the coldest month, averaged 4°C, and air temperature during July 1998, the warmest month, averaged 19°C. Monthly average *D* was smallest for January 1999 (0.07 kilopascals (kPa)) and the monthly average *D* was largest for August 1998 (0.78 kPa). The maximum daily average wind speed of 9.8 miles per hour (mi/h) occurred on February 2, 1999 (fig. 6). Monthly average wind speed was smallest during September 1998 (2.7 mi/h), and it was largest during December 1998 (4.2 mi/h).

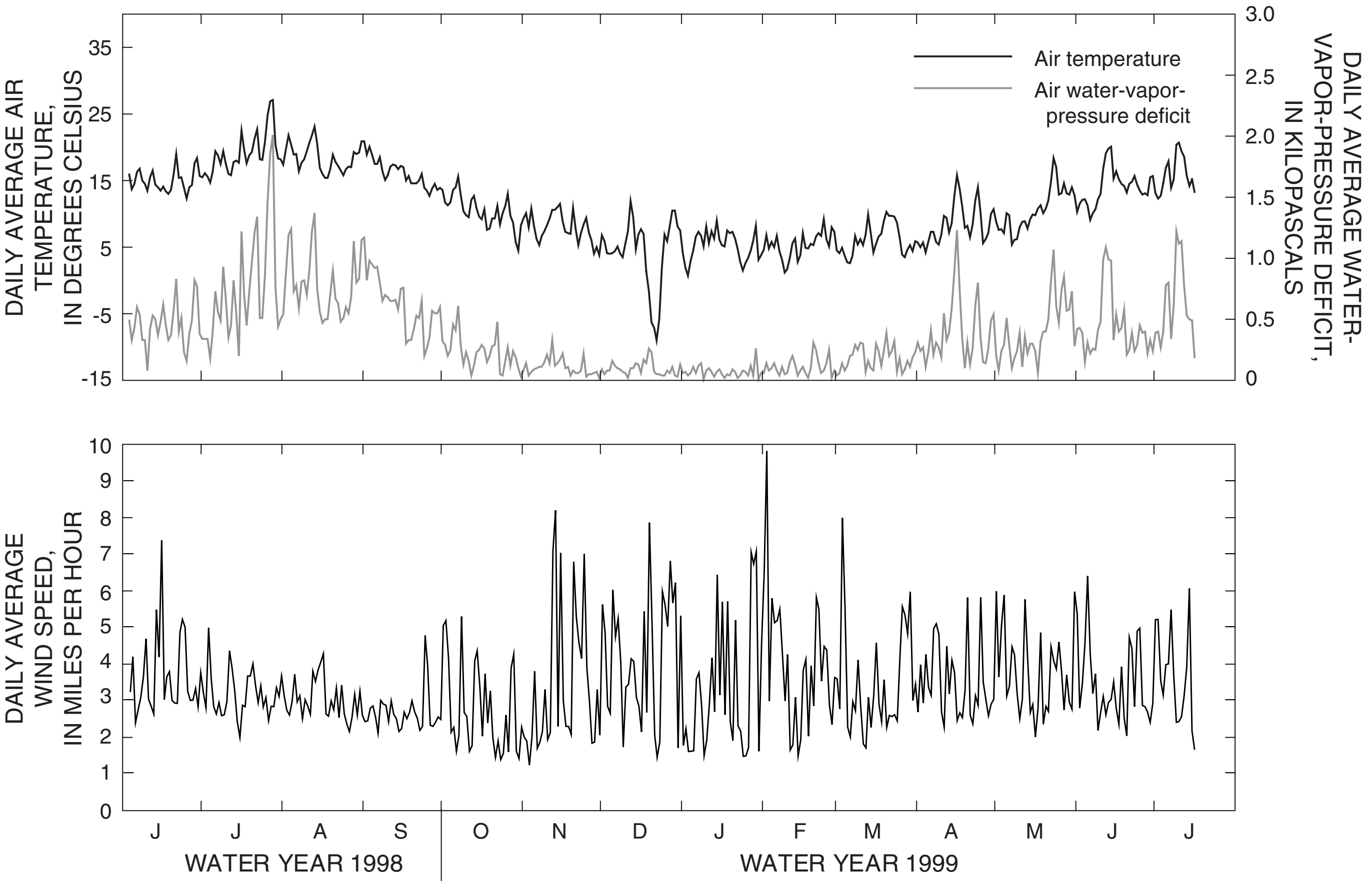


Figure 6. Daily average air temperature and water-vapor-pressure deficit, and daily average wind speed at the gypsum-treated retention basin near DuPont, Washington, 1998-99.

The original field-recorded precipitation data are stored in the file WA414_METfield.xls on the CD ROM that accompanies this report. The edited precipitation data are stored in the file WA414_AIRAD.xls on the CD ROM and daily precipitation totals based on the edited data are shown in figure 7. Total precipitation measured from June 3, 1998 to July 16, 1999, was 53.23 inches. Eighty-three percent of the precipitation fell during November 1998 through March 1999. The largest amount of precipitation measured during any month was 11.02 inches during November 1998, and the smallest amount for any month with a complete record was 0.03 inch during August 1998. The maximum total daily precipitation of 2.72 inches occurred on November 25, 1998.

The original field-recorded water-temperature data from each of the four soil/water temperature probes that were installed in the gypsum-treated basin are stored in the file WA414_METfield.xls on the CD ROM that accompanies this report. The edited water-temperature data are stored in the file WA414_WTDEPTH.xls on the CD ROM. Summaries and figures for water temperature presented in this report are based on the edited data. Submersion depth of each of the four soil/water temperature probes that were installed in the gypsum-treated basin and daily average water temperature sensed by each probe are shown in figure 8. The timing and duration of water-temperature data collected with the four probes varied substantially because of the fluctuating pond water level. However, data from periods when one or more of the probes were immersed in the pond indicate that the water column near the meteorological station generally was almost isothermal on a daily basis. An exception to the generally isothermal nature of the pond near the meteorological station occurred during late December 1998, when the pond froze to an unknown depth. The pond surface was first noted to be frozen on December 23, 1998. Daily average temperature sensed by the float-mounted probe ranged from -0.7°C to -0.2°C from December 20 to 24, 1998, and that probe might have been encased in ice during at least part of that period. Daily average temperature sensed by the float-mounted probe from December 20 to 24, 1998, was as much as 4.2°C less than the daily average temperature sensed by deepest probe (probe #4). A general warming began on December 24, 1998, and the pond was free of ice by December 28, 1998.

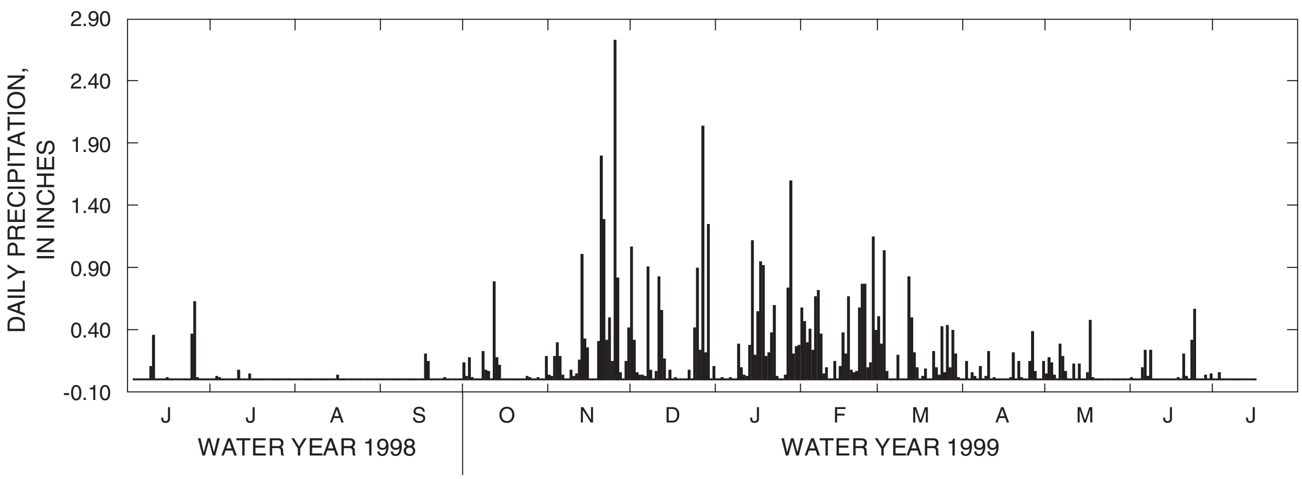
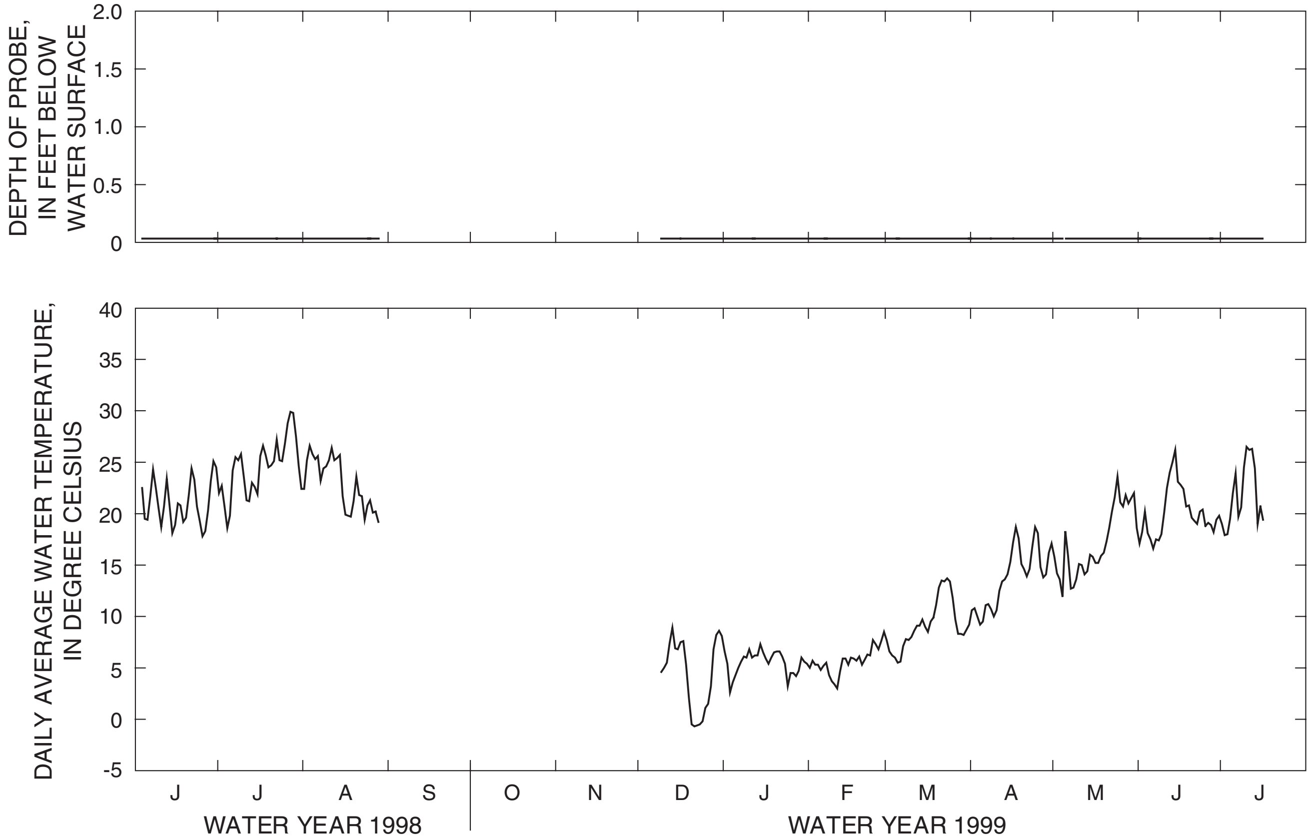
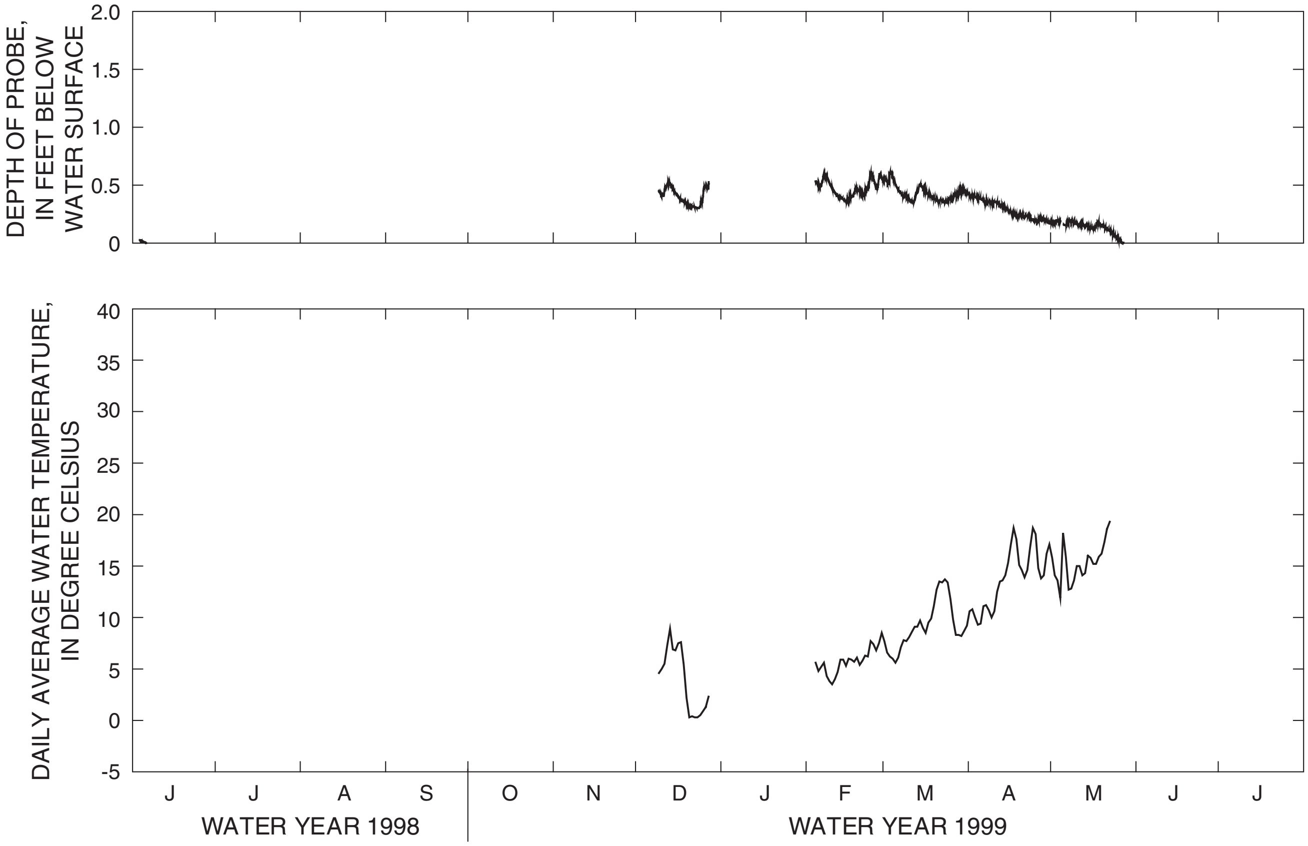


Figure 7. Daily precipitation at the gypsum-treated retention basin near DuPont, Washington, June 1998 to July 1999.



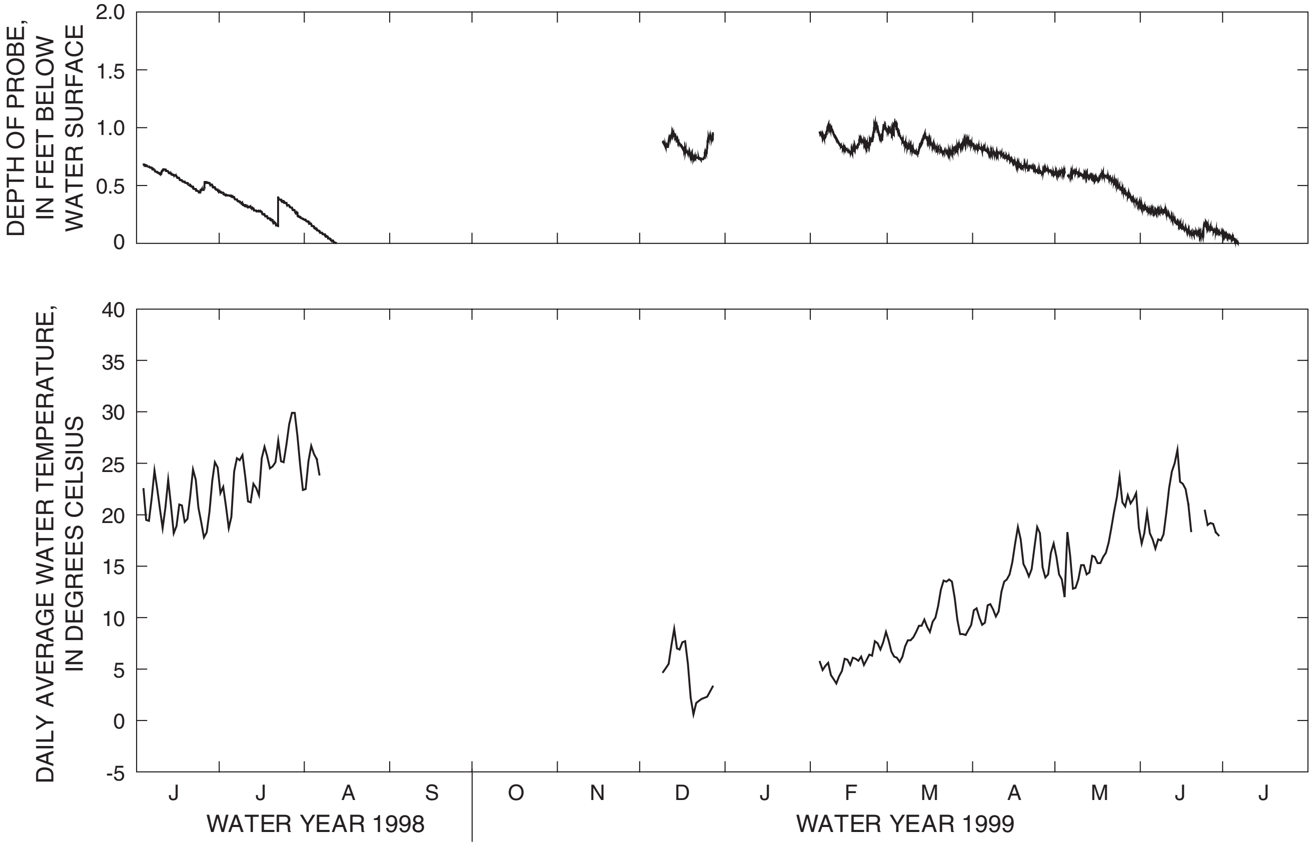
A. Depth of the float-mounted soil/water temperature probe (#1) and daily average water temperature

Figure 8. Measured and estimated submersion depths of each of the four soil/water-temperature probes and daily average water temperatures sensed by the submerged probes in the intermittent pond in the gypsum-treated retention basin near DuPont, Washington, 1998-99.



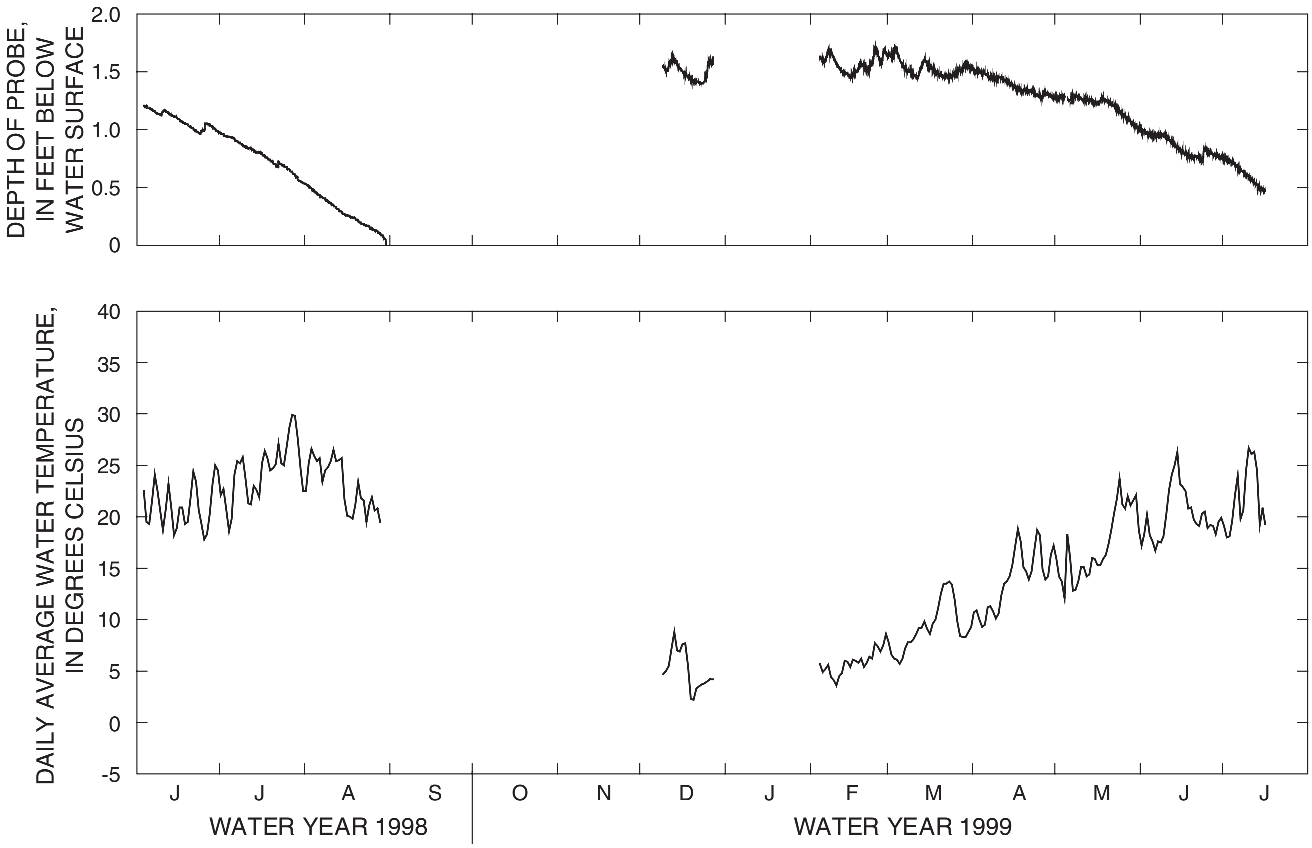
B. Depth of the highest post-mounted soil/water temperature probe (#2) and daily average water temperature

Figure 8.—*Continued*



C. Depth of the middle post-mounted soil/water temperature probe (#3) and daily average water temperature

Figure 8.—*Continued*



D. Depth of the lowest post-mounted soil/water temperature probe (#4) and daily average water temperature

Figure 8.—*Continued*

The original field-recorded data for energy flux into the floor of the gypsum-treated basin near the meteorological station are stored in the file WA414_METfield.xls on the CD ROM that accompanies this report. The edited data for energy flux into the floor of the gypsum-treated basin are stored in the file WA414_G.xls on the CD ROM. Depth of water near the meteorological station and daily average energy flux into the basin floor measured with three soil heat flux plates, where each plate was at a different place near that station, are shown in figure 9. Excluding data from days when the data record from each plate is incomplete, the minimum and maximum daily average energy flux measured by the three soil heat flux plates were:

Soil heat flux plate	Daily average energy flux (W/m^2)	
	Minimum	Maximum
1	-23.0	28.1
2	-27.3	27.4
3	-16.3	20.2

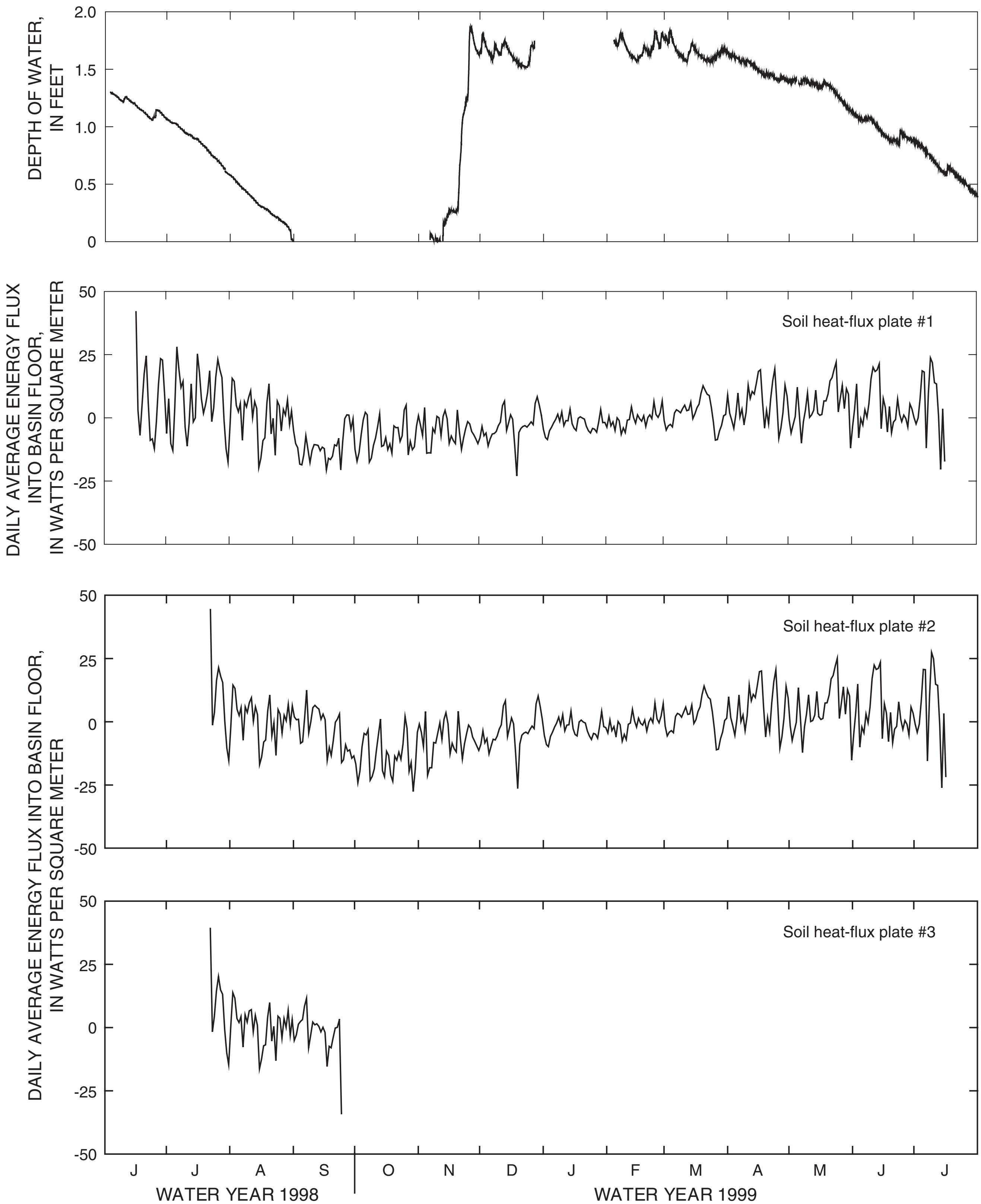


Figure 9. Pond water depth and daily average energy flux into the basin floor as sensed with soil heat flux plates near the meteorological station in the gypsum-treated retention basin near DuPont, Washington, 1998-99.

SUMMARY

Hydrologic, meteorological, and other environmental data were collected at two storm-water retention basins near DuPont, Washington, during water years 1998-2000. Soils of one of the basins were treated with a mixture of gypsum, grass seeds, and mulch. Data for ground-water quality and ground-water levels were collected from six wells that were installed in and near the basins. The water level of an intermittent pond in the gypsum-treated basin was monitored, as were incoming solar and net radiation, air temperature and water-vapor-pressure deficit, wind speed, precipitation, temperature of water in the pond, and energy flux into the floor of the basin. This report presents the data so they will be available for future investigations of hydrologic effects of highway storm-water retention systems.

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