United States
Department of
Agriculture

**Natural
Resources
Conservation
Service**

Part 650
Engineering Field Handbook

# Chapter 19 Hydrology Tools for Wetland Determination

Issued August 1997

# Preface

This chapter of the Engineering Field Handbook is an outgrowth of a meeting of hydraulic and water management engineers in Wilmington, Delaware, in October 1991. The participants developed a list of hydrology tools that help delineate wetlands. Various task groups were formed for each tool. Send comments to the Natural Resources Conservation Service (NRCS), Conservation Engineering Division, Washington, DC, or the Wetland Sciences Institute, Beltsville, Maryland.

The membership in the task group is as follows:

| | |
|---|---|
| Stream and Lake Gage | **Bill Merkel,** NRCS, Beltsville, MD |
| Runoff Volumes | **Bob Kluth**, NRCS, Lincoln, NE (retired)<br>**Rodney White,** NRCS, Fort Worth, TX (retired)<br>**Helen Moody,** NRCS, Beltsville, MD<br>**Don Woodward**, NRCS, Washington, DC |
| Remote Sensing | **R.H. Griffin,** NRCS, Fort Worth, TX<br>**Bill Merkel**, NRCS, Beltsville, MD<br>**Rodney White**, NRCS, Fort Worth, TX (retired) |
| DRAINMOD | **Virgil Backlund**, NRCS, Davis, CA<br>**Sal Palalay**, NRCS, Chester, PA (retired)<br>**Jeff Healy**, NRCS, Indianapolis, IN (retired)<br>**Frank Geter**, NRCS, Fort Collins, CO<br>**Ron Marlow,** NRCS, Washington, DC |
| Scope and Effect Equations | **Virgil Backlund**, NRCS, Davis, CA<br>**Frank Geter**, NRCS, Fort Collins, CO<br>**Sal Palalay**, NRCS, Chester, PA (retired)<br>**Jesse Wilson**, NRCS, Gainesville, FL<br>**Rodney White**, NRCS, Fort Worth, TX (retired) |
| Drainage Guides | **Don Woodward**, NRCS, Washington, DC |
| Observation Wells | **Don Woodward**, NRCS, Washington, DC<br>**Andrew Warne,** Corps of Engineers, Vicksburg, MS |

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# Chapter 19 Hydrology Tools for Wetland Determination

## 650.1900 Introduction

This chapter of the Engineering Field Handbook presents seven tools or procedures to use in the evaluating the hydrology of potential wetlands. Each tool is used in one or more states to assist in the determination of wetlands. These tools are analytical techniques that can be used to supplement the documentation of wetland hydrology determination.

The use of each tool depends on local conditions. The technical discipline leaders in each state office should determine the applicability of the individual tool(s) in their area. The selection of the appropriate tool(s) should be coordinated with the Environmental Protection Agency, Corps of Engineers, and Fish and Wildlife Service. Each procedure or tool is described in a separate section of this chapter.

The criteria for duration and frequency of inundation and saturation are in Section 527.4 of the National Food Security Act Manual (NFSAM). Different durations were used with the various procedures to indicate that the procedure is independent of the criteria.

The seven tools are:

- Stream gage data to establish the hydrology of over- or out-of-bank flooding.
- Water budget analysis to estimate daily runoff values, which can be used to determine the water balance of any wetland. A curve of drainage area versus depressional surface area to determine the frequency and duration of inundation of playas.
- Aerial photographic analysis to establish the frequency of occurrence and duration of inundation.
- DRAINMOD computer program to establish the degree of saturation of a wetland under a wide range of drained and nondrained conditions.
- Scope and effect equations to evaluate the effects of drainage measures on wetlands.
- Drainage guides, which provide useful information for evaluating drainage systems.
- Observation well data to establish the saturated conditions of a wetland.

## 650.1901 Use of stream and lake gages

### (a) Applicable situations for use

Stream and lake gage data can be used to document the timing duration and frequency of inundation of the area adjacent to streams and lakes. Daily flow or stage data are used to determine the duration and frequency of overbank inundation. For a riverine situation, duration and frequency information at stream gage locations may be extended upstream or downstream using water surface profile information. Procedures for gathering stream gage data and computing water surface profiles are found in standard references.

Even if a site near a stream gage does not have sufficient topographic or stream gage data, some knowledge of the site can be obtained from analyses of the stream gage.

### (b) Data required

The following data are required:

- Daily flow values or lake levels for a minimum of 10 years of data.
- Cross section information, and relationship of discharge versus stage if discharges are used.
- Topographic information for area of concern.
- Water surface profile information (if point of concern is not at the gage site).

### (c) Sources of data

Various Federal, State, and county agencies have placed gages on many streams and lakes. Stream and lake gage data are available from the Corps of Engineers (COE), Tennessee Valley Authority (TVA), U.S. Geological Survey (USGS), National Oceanic and Atmospheric Administration (NOAA), Bureau of Reclamation (BOR), various highway departments, and state or local public works agencies.

Various types of gage data are published. They include mean daily discharge, mean daily stage, peak stage and discharge for flood events, and mean daily lake level.

The primary source of data is the USGS Water Resources Data publication for each state.

## (d) Limitations

### (1) Knowledge and experience required

General knowledge of water surface profile computations and stream hydraulics and statistical techniques is required.

### (2) Climatic regions of applicability

This procedure is applicable to all climate regions.

### (3) Factors affecting the accuracy of results

The concept in this procedure is that the hydrograph can indicate what discharge or stage is exceeded for a particular duration, frequency, or both. At least 10 years of data are needed to apply this procedure. The accuracy of the procedure increases as the length of record increases.

If discharges are used, a relationship of stage versus discharge is needed to convert discharge into stage. The accuracy is a function of the cross section information. The stage is most accurately determined at the gage site. To accurately determine inundated areas using this information along the stream, the water surface profiles and topographic maps must be accurate. Even at the gage site, some topographic survey information may be needed to determine the limits of inundation if the topographic map is insufficient. The accuracy is a function of the contour interval of the map. Stream gage data may be extended upstream or downstream up to 1,000 feet without the use of a water surface profile.

Stream gage data may be used in the following situations:

1. A stream overflows and stays out of bank for the time required to meet wetland hydrology criteria.
2. A stream overflows and returns within banks in a time period less than the wetland hydrology criteria duration. The out-of-bank area must then be considered to confirm if over-bank-flow time plus time remaining ponded or saturated meets the wetland hydrology criteria. A simple water budget for the area may determine if ponding meets the ponding wetland criteria. This type of analysis is outside the scope of this chapter.
3. Areas next to a lake that may be subject to inundation because of periodic fluctuation in water level.
4. The water level in the lake may return to a normal level in less time than that required to meet the wetland hydrology criteria. The lake shore area must then be considered to confirm if the time flooded by the lake plus the time remaining ponded, saturated, or flooded meets the wetland hydrology criteria.

This section discusses situations 1 and 3. Situations 2 and 4 involve combining the methodology in situations 1 or 3 with analysis from other technical documents. Situations 2 and 4 involve analysis of the soil moisture in the soil profile using a standard water budget technique.

## (e) Methodology

Methodology is a 9-step process.

**Step 1.** Determine growing season and duration as defined in Part 527.4 of the National Food Security Act Manual. The WETS table can be used to determine the growing season.

**Step 2.** Obtain available data or develop data relating to stream hydrology and hydraulics. This includes gage records, both upstream and downstream (if possible), of the site being evaluated. If the gage records are daily discharges, data relating discharge to stage must be obtained. See National Engineering Handbook, Section 4 (NEH-4), Chapter 14, Stage-Discharge Relationships. Other useful data available on many streams include water surface profiles. Water surface profiles are important where only one stream gage is located on the stream or where the potential wetland is not close to the gaging station.

**Step 3.** Develop a water surface profile, which is a plot of water surface elevation versus distance along a stream. The water surface elevation can represent a specific discharge or a flow frequency, such as a 2-year or 100-year discharge. A water surface profile is developed using computer programs that use cross section data, roughness data, distance along a stream, and bridge and culvert information. WSP2 and HEC2 are typical water surface computer programs used by NRCS and COE respectively.

**Step 4.** Use as many continuous years of gage records as can be obtained. The record should be representative of current conditions. For example, if a major dam has been installed and flow conditions have changed or channel excavation has occurred that would influence gage readings, then the gage records may be invalid and should not be used.

**Step 5.** Determine the highest stage of each year that is exceeded for the duration set by NFSAM or relevant criteria. Consider only gage records during the growing season. For example, if the inundation criterion is 10 days, record the lowest stage occurring within 10 days of high flow. Next, move the 10-day period forward 1 day and record the lowest stage occurring during those 10 days of high flow. It is assumed that all flows larger than the smallest flow within the criteria duration will be out of bank. Repeat this process for the entire growing season. The highest of these recorded stages is the value to use for that year. This search could be done on the larger flood events that would be expected to produce the highest 10-day stages and not for every 10-day interval of the growing season.

Repeat this process for as many years of gage data as daily records are available. If the record is broken, then determine if the discontinuous record is really representative of the site's hydrology.

Example 19–1 illustrates the determination of the elevation exceeded for 10 consecutive days on the Smith River at Brooking, Oregon, for 1989. The growing season is from March 1 to October 31. Figure 19–1 is a plot of mean daily elevation for March and April 1989, which represents the part of the growing season with the highest overall stage levels.

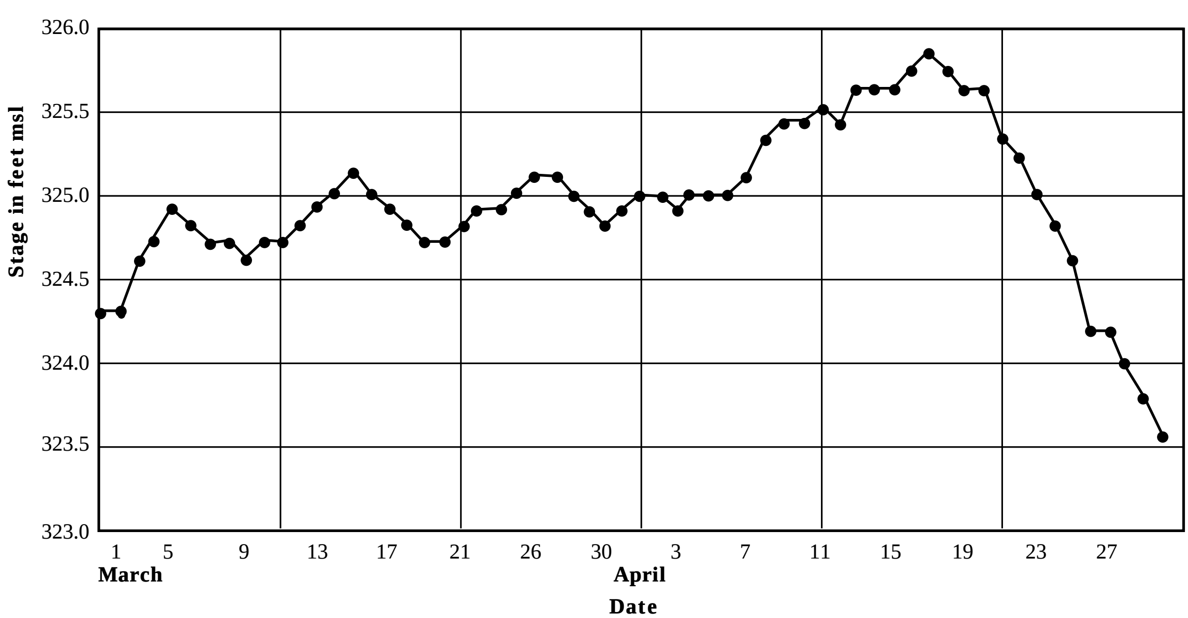
**Example 19–1** Determination of elevation exceeded for 10 consecutive days

March 1–10, the lowest elevation = 324.3 feet
March 2–11, the lowest elevation = 324.3 feet.

Elevations exceed 325 in April, so these days should be checked.
April 7–16, the lowest elevation = 325.1 feet.
April 8–17, the lowest elevation = 325.3 feet.

Thus the lowest elevation that was exceeded for 10 consecutive days during 1989 was 324.3 feet.

**Figure 19–1** Mean daily elevation for March and April 1989 for Smith River at Brookings, Oregon



**Step 6.** Tabulate the stage readings determined for each year of record for the gage in descending order (highest elevation first). The median value is the value where half of the stage readings are higher and half are lower. If an odd number of years of record is used, the middle event is the median elevation. If an even number of years of record is used, then compute the average elevation between the two middle years as the median. Example 19–2 shows the selection of the median.

**Step 7.** Repeat steps (4) through (6) for the second gage, if available.

**Step 8.** If there are two gages and if water surface profiles are not available, use the following procedure to determine median elevation. Measure the distance between the two gages along the stream and the distance from the site to the nearest of the two gages. Assume a straight line water surface between the gages and interpolate the elevation at the site based on the proportion of the distance to the gage and the distance between the two gages.

Using the data in table 19–1, the elevation at the site would be:

$$140 - [(5/20) \times 40] = 130 \text{ feet.}$$

If water surface profiles are available, interpolate the elevation at the site based on relationships of stage and discharge (and possibly frequency) at the gage locations and at the site.

**Step 9.** To relate the water level with the land surface, establish elevations at the site in question by a topographic survey or contour map.

**Example 19–2** Selection of median stage reading

11 years of data are available and ordered from highest to lowest.

335 329 326 325.3 324 323.5 320 319 317 314 308

The median is **323.5** because 5 values are higher and 5 are lower.

10 years of data are available and ordered from highest to lowest.

335 331 329 328 325 323 322 321 320 315

The median would be **324** because it is the average of the 5th and 6th value.

**Table 19–1** Example data to figure elevation

| Location | Distance (miles) | 15-day median elevation |
|---|---|---|
| Downstream gage | 0 | 100 |
| Site | 15 | ? |
| Upstream gage | 20 | 140 |

### (f) Sample documentation

An area on the banks of the Tar River near Rocky Mount, North Carolina, is to be evaluated. It is assumed that the area must be inundated for 15 days during the growing season of March 1 to October 31 to have wetland hydrology present.

A stream gage is located on the Tar River at North Carolina Highway 97 in Rocky Mount, North Carolina. The USGS Water Resources Data for North Carolina include records from August 1976 to the present time. Average daily discharge data are published along with peak discharges and associated stages.

The first step is to determine the 15-day duration elevation for each year of record. Normally, the complete record is used, but in this example only 6 years are shown (table 19–2). Data for 6 years (1986 to 1991) are duplicated in the following pages with the 15-day duration discharge marked.

Example 19–3 shows records for Pamlico River Basin. The selection of the lowest flow during the high flow period is shown on pages 19–7 through 19–12.

These discharges are then ranked and the median calculated. The values ranked are 2,529, 1,300, 1,240, 679, 513, and 444. Because the number of years is even, the average of the third and fourth values is calculated. The median is 960 cubic feet per second. Because of the large difference between these values, a better estimate would result if more years were analyzed.

The next steps are to determine the stage and elevation that apply to the discharge of 960 cubic feet per second. From the publications of USGS Water Resources Data, the stage versus discharge for peak discharges is plotted and a smooth curve drawn through the points (figure 19–2). The discharge-stage curves can also be obtained from the agency responsible for the gage.

The stage associated with 960 cubic feet per second is 6.1 feet. This stage is then added to the gage datum of 53.88 feet to get an elevation of 60 feet. This elevation is then compared to the elevation of the land where the wetland determination is to be made. Any land below the elevation 60 on the flood plain would be inundated for at least 15 days by out-of-bank flooding during the growing season in 50 percent of the years, thus meeting the wetland criterion used.

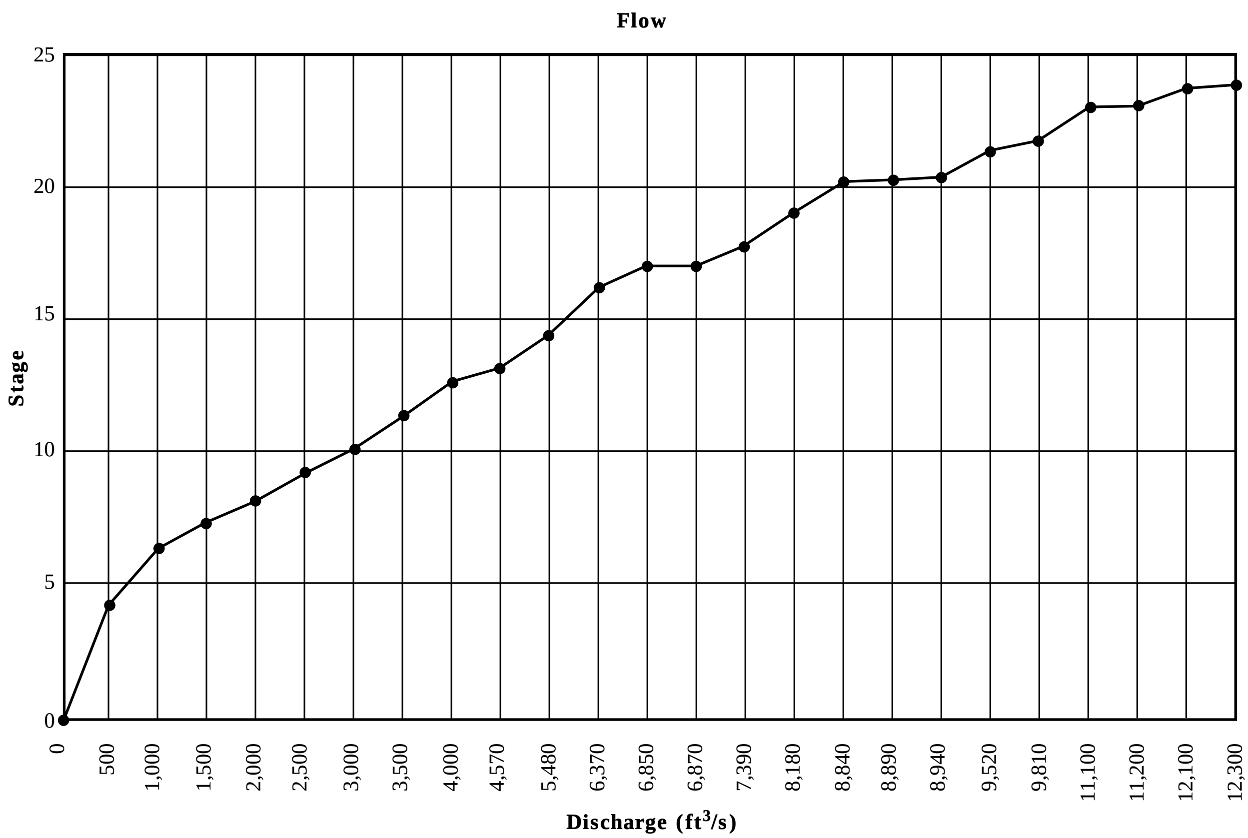
It should be noted that this elevation applies only in the immediate vicinity of the stream gage. If the area in question extends either far downstream or upstream of the road, water surface profiles would be required to determine the elevation.

In this procedure we assume that there are no levees between the stream and potential wetland.

**Table 19–2** 15-day duration elevation, 1986–1991

| Year | Month-day | Discharge | Ranked |
|---|---|---|---|
| 1986 | 3–25 | 444 | 2529 |
| 1987 | 4–15 | 1,300 | 1300 |
| 1988 | 4–27 | 513 | 1240 |
| 1989 | 5–11 | 2,529 | 679 |
| 1990 | 4–12 | 1,240 | 513 |
| 1991 | 3–12 | 679 | 444 |

**Figure 19–2** Stage versus discharge plot for Tar River at Rocky Mount, North Carolina



## Example 19–3 Water discharge records for Pamlico River Basin

Pamlico River Basin—02082585 Tar River at NC 97 at Rocky Mount, NC

Location—Lat 35°57’15", long 77°47’15", Edgecombe County, Hydrologic Unit 03020101, on left bank 20 feet downstream from bridge on NC 97, 0.5 mile upstream from Cowlick Branch, and 1.0 mile north-northeast of Rocky Mount.

Drainage area—925 square miles.

Water-Discharge Records

Period of Record—August 1976 to current year.

Revised Records—WDR NC-81-1: Drainage area.

Gage—Water-stage recorder. Datum of gage is 53.88 ft. above National Geodetic Vertical Datum of 1929.

Remarks—No estimated daily discharges. Records good except those below 10 ft$^3$/s, which are fair. Some regulation at low flow by mill above station. The city of Rocky Mount diverted an average of 17.8 ft$^3$/s for municipal water supply, most of which was returned as sewage below station.

Cooperation—Chemical and biological data shown in last table were provided by the North Carolina Department of Natural Resources and Community Development.

Average Discharge—10 years, 906 ft$^3$/s, 13.30 in/yr.

Extremes for Period of Record—Maximum discharge, 12,300 ft$^3$/s May 1, 1978, gage height, 23.66 ft; minimum, 6.1 ft$^3$/s Oct. 2, 1983, gage height, 2.84 ft.

Extremes for Current Year—Maximum discharge, 8,180 ft$^3$/s Nov. 26, gage height, 19.06 ft; minimum, 8.3 ft$^3$/s July 3, gage height, 2.96 ft.

Discharge, in cubic feet per second, water year October 1985 to September 1986 (mean values)

| Day | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 75 | 138 | 2670 | 403 | 655 | 897 | 494 | 249 | 264 | 101 | 46 | 696 |
| 2 | 242 | 140 | 3980 | 406 | 597 | 98 | 473 | 223 | 194 | 109 | 51 | 490 |
| 3 | 413 | 139 | 4430 | 444 | 542 | 710 | 459 | 211 | 164 | 20 | 210 | 368 |
| 4 | 234 | 419 | 2870 | 458 | 529 | 189 | 441 | 197 | 149 | 16 | 123 | 252 |
| 5 | 78 | 876 | 1280 | 472 | 512 | 102 | 440 | 158 | 139 | 26 | 77 | 202 |
| 6 | 116 | 2400 | 968 | 439 | 484 | 145 | 441 | 127 | 134 | 43 | 66 | 246 |
| 7 | 129 | 3200 | 834 | 378 | 495 | 152 | 502 | 138 | 135 | 54 | 226 | 197 |
| 8 | 139 | 2140 | 746 | 358 | 500 | 153 | 617 | 97 | 153 | 58 | 124 | 239 |
| 9 | 134 | 721 | 658 | 339 | 527 | 154 | 681 | 83 | 142 | 60 | 88 | 197 |
| 10 | 127 | 456 | 612 | 319 | 518 | 155 | 579 | 83 | 134 | 62 | 98 | 118 |
| 11 | 162 | 361 | 565 | 313 | 550 | 245 | 587 | 82 | 129 | 64 | 182 | 155 |
| 12 | 65 | 322 | 547 | 347 | 582 | 360 | 357 | 82 | 126 | 64 | 423 | 213 |
| 13 | 110 | 738 | 738 | 337 | 632 | 407 | 421 | 82 | 123 | 64 | 363 | 188 |
| 14 | 102 | 34 | 930 | 332 | 665 | 717 | 400 | 102 | 118 | 30 | 491 | 134 |
| 15 | 104 | 77 | 1650 | 313 | 597 | 1430 | 391 | 106 | 128 | 51 | 1060 | 210 |
| 16 | 104 | 119 | 1310 | 304 | 549 | 2880 | 330 | 106 | 106 | 50 | 823 | 58 |
| 17 | 104 | 148 | 907 | 298 | 532 | 3510 | 185 | 105 | 108 | 55 | 449 | 114 |
| 18 | 106 | 197 | 742 | 296 | 520 | 2440 | 240 | 112 | 106 | 53 | 313 | 109 |
| 19 | 109 | 136 | 630 | 344 | 1590 | 1160 | 302 | 113 | 105 | 54 | 715 | 106 |
| 20 | 111 | 247 | 571 | 467 | 932 | 1070 | 327 | 125 | 104 | 54 | 1230 | 108 |
| 21 | 141 | 369 | 528 | 553 | 1670 | 1420 | 344 | 175 | 106 | 53 | 1150 | 107 |
| 22 | 143 | 1670 | 499 | 512 | 1140 | 1580 | 338 | 840 | 93 | 54 | 2440 | 104 |
| 23 | 146 | 3990 | 474 | 423 | 675 | 1330 | 356 | 1410 | 57 | 49 | 3250 | 102 |
| 24 | 132 | 5250 | 481 | 374 | 576 | 883 | 341 | 790 | 61 | 47 | 2950 | 99 |
| 25 | 143 | 6640 | 482 | 361 | 549 | 444 | 323 | 441 | 83 | 46 | 899 | 96 |
| 26 | 159 | 7970 | 470 | 612 | 549 | 657 | 312 | 319 | 88 | 45 | 519 | 95 |
| 27 | 154 | 6170 | 425 | 1100 | 569 | 634 | 297 | 260 | 90 | 53 | 299 | 120 |
| 28 | 143 | 1300 | 393 | 1750 | 584 | 592 | 276 | 315 | 92 | 58 | 1260 | 73 |
| 29 | 133 | 868 | 395 | 1420 | — | 560 | 269 | 300 | 260 | 53 | 1260 | 173 |
| 30 | 128 | 1370 | 399 | 960 | — | 529 | 257 | 274 | 140 | 52 | 2520 | 55 |
| 31 | 128 | — | 391 | 757 | — | 505 | — | 299 | — | 48 | 1940 | — |
| Total | 4312 | 48605 | 32575 | 16189 | 18820 | 26977 | 11780 | 8004 | 3841 | 1676 | 25635 | 5454 |
| Mean | 139 | 1620 | 1051 | 522 | 672 | 870 | 393 | 258 | 128 | 54.1 | 827 | 182 |
| Max | 413 | 7970 | 4430 | 1750 | 1670 | 3510 | 681 | 1410 | 264 | 109 | 3250 | 696 |
| Min | 65 | 34 | 391 | 296 | 484 | 102 | 185 | 82 | 57 | 16 | 46 | 55 |
| CFSM | .15 | 1.75 | 1.14 | .56 | .73 | .94 | .42 | .28 | .14 | .06 | .89 | .20 |
| In | .17 | 2.0 | 1.3 | .65 | .76 | 1.1 | .47 | .32 | .15 | .07 | 1.0 | .22 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Cal YR 1985 | Total 275431 | Mean 755 | Max 7970 | Min 34 | CFSM .82 | In 11 |
| WRT YR 1986 | Total 203870 | Mean 559 | Max 7970 | Min 16 | CFSM .60 | In 8.2 |

**Example 19–3** Water discharge records for Pamlico River Basin—Continued

Pamlico River Basin—02082585 Tar River at NC 97 at Rocky Mount, NC

Location—Lat 35°57'15", long 77°47'15", Edgecombe County, Hydrologic Unit 03020101, on left bank 20 feet downstream from bridge on NC 97, 0.5 mile upstream from Cowlick Branch, and 1.0 mile north-northeast of Rocky Mount.

Drainage area—925 square miles.

Water-Discharge Records

Period of Record—August 1976 to current year.

Revised Records—WDR NC-81-1: Drainage area.

Gage—Water-stage recorder. Datum of gage is 53.88 ft above National Geodetic Vertical Datum of 1929.

Remarks—No estimated daily discharges. Records good. Some regulation at low flow by mill above station. The city of Rocky Mount diverted an average of 17.8 $ft^3/s$ for municipal water supply, most of which was returned as treated effluent below station.

Cooperation—Chemical and biological data shown in last table were provided by the North Carolina Department of Natural Resources and Community Development.

Average Discharge—11 years, 928 $ft^3/s$, 13.62 in/yr.

Extremes for Period of Record—Maximum discharge, 12,300 $ft^3/s$ May 1, 1978, gage height, 23.66 ft; minimum, 6.1 $ft^3/s$ Oct. 2, 1983, Oct 10, 1986; minimum gage height, 2.84 ft Oct 2, 1983.

Extremes for Current Year—Maximum discharge, 12,100 $ft^3/s$ Apr 18, gage height, 23.55 ft; minimum, 6.1 $ft^3/s$ Oct 10, minimum gage height, 2.86 ft Dec 4.

Discharge, in cubic feet per second, water year October 1986 to September 1987 (mean values)

| Day | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 56 | 74 | 161 | 713 | 1330 | 6660 | 1730 | 1080 | 313 | 228 | 100 | 69 |
| 2 | 79 | 80 | 122 | 1800 | 1660 | 8390 | 1670 | 951 | 247 | 197 | 102 | 45 |
| 3 | 139 | 134 | 139 | 2910 | 1480 | 8830 | 1310 | 996 | 296 | 144 | 101 | 46 |
| 4 | 28 | 11 | 27 | 3751 | 1450 | 8220 | 1150 | 976 | 379 | 116 | 100 | 46 |
| 5 | 87 | 145 | 283 | 2250 | 1370 | 8660 | 1170 | 935 | 395 | 57 | 94 | 268 |
| 6 | 81 | 34 | 437 | 1091 | 1150 | 8170 | 1230 | 857 | 456 | 287 | 91 | 115 |
| 7 | 81 | 86 | 355 | 791 | 959 | 3370 | 1110 | 728 | 345 | 346 | 102 | 77 |
| 8 | 85 | 158 | 283 | 634 | 846 | 1420 | 964 | 653 | 316 | 269 | 97 | 78 |
| 9 | 274 | 43 | 246 | 546 | 725 | 1290 | 569 | 613 | 260 | 210 | 98 | 63 |
| 10 | 63 | 156 | 260 | 518 | 673 | 2890 | 777 | 555 | 213 | 172 | 107 | 72 |
| 11 | 12 | 26 | 216 | 519 | 601 | 4300 | 725 | 497 | 190 | 164 | 89 | 80 |
| 12 | 17 | 46 | 310 | 484 | 562 | 5540 | 738 | 469 | 177 | 165 | 84 | 173 |
| 13 | 57 | 83 | 710 | 450 | 528 | 5750 | 844 | 448 | 165 | 144 | 84 | 331 |
| 14 | 94 | 85 | 959 | 420 | 524 | 4190 | 835 | 412 | 159 | 127 | 83 | 608 |
| 15 | 112 | 120 | 632 | 390 | 505 | 1820 | 1300 | 395 | 247 | 117 | 94 | 777 |
| 16 | 16 | 115 | 459 | 376 | 518 | 1410 | 6550 | 319 | 161 | 113 | 87 | 503 |
| 17 | 142 | 106 | 337 | 375 | 783 | 1270 | 10100 | 449 | 242 | 110 | 79 | 347 |
| 18 | 21 | 102 | 317 | 744 | 1140 | 1190 | 11800 | 428 | 415 | 116 | 75 | 211 |
| 19 | 80 | 109 | 294 | 4160 | 1490 | 1240 | 11200 | 356 | 948 | 113 | 75 | 155 |
| 20 | 79 | 111 | 275 | 6920 | 1700 | 1690 | 10700 | 605 | 635 | 109 | 72 | 664 |
| 21 | 78 | 111 | 255 | 7470 | 1710 | 1620 | 9490 | 762 | 414 | 105 | 70 | 514 |
| 22 | 76 | 110 | 248 | 8070 | 1940 | 1580 | 5620 | 902 | 322 | 103 | 71 | 418 |
| 23 | 73 | 111 | 231 | 9110 | 4110 | 1240 | 2080 | 730 | 325 | 103 | 66 | 273 |
| 24 | 72 | 193 | 653 | 9510 | 5160 | 1030 | 1560 | 553 | 350 | 101 | 57 | 226 |
| 25 | 78 | 25 | 1040 | 8850 | 5880 | 2000 | 2930 | 470 | 491 | 107 | 55 | 170 |
| 26 | 144 | 144 | 1890 | 6730 | 5900 | 156 | 4730 | 367 | 547 | 107 | 53 | 142 |
| 27 | 28 | 47 | 3100 | 3000 | 5890 | 466 | 4560 | 394 | 353 | 102 | 48 | 123 |
| 28 | 69 | 134 | 1950 | 1860 | 5770 | 1140 | 2730 | 405 | 428 | 102 | 44 | 105 |
| 29 | 84 | 111 | 855 | 1430 | — | 2270 | 1970 | 436 | 292 | 103 | 44 | 230 |
| 30 | 137 | 46 | 589 | 1250 | — | 3320 | 1260 | 320 | 270 | 99 | 49 | 88 |
| 31 | 14 | — | 459 | 1160 | — | 2400 | — | 109 | — | 98 | 99.2 | — |
| Total | 2456 | 2855 | 18092 | 88280 | 56354 | 103222 | 103402 | 18380 | 10261 | 4434 | 2470.2 | 7020 |
| Mean | 79.2 | 95.2 | 584 | 2848 | 2013 | 3330 | 3447 | 593 | 342 | 143 | 79.7 | 234 |
| Max | 274 | 193 | 3100 | 9510 | 5900 | 8830 | 11800 | 1080 | 948 | 346 | 407 | 777 |
| Min | 12 | 11 | 24 | 675 | 505 | 156 | 725 | 319 | 159 | 57 | 44 | 46 |
| CFSM | .09 | .10 | .63 | 3.08 | 2.18 | 3.60 | 3.73 | .64 | .37 | .15 | .09 | .25 |
| Inch | .10 | .11 | .73 | 3.55 | 2.27 | 4.15 | 4.16 | .74 | .41 | .18 | .10 | .28 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Cal Yr 1986 | Total 141779.0 | Mean 388 | Max 3510 | Min 11 | CFSM .42 | In. 5.70 |
| WTR Yr 1987 | Total 417226.2 | Mean 1143 | Max 11800 | Min 11 | CFSM 1.24 | In. 16.8 |

**Example 19–3** Water discharge records for Pamlico River Basin—Continued

Pamlico River Basin—02082585 Tar River at NC 97 at Rocky Mount, NC

Location—Lat 35°57'15", long 77°47'15", Edgecombe County, Hydrologic Unit 03020101, on left bank 20 feet downstream from bridge on NC 97, 0.5 mile upstream from Cowlick Branch, and 1.0 mile north-northeast of Rocky Mount.
Drainage area—925 square miles.
Period of Record—August 1976 to current year.
Revised Records—WDR NC-81-1: Drainage area.
Gage—Water-stage recorder. Datum of gage is 53.88 ft above National Geodetic Vertical Datum of 1929.
Remarks—Records good except for estimated daily discharges, which are fair. Some regulation at low flow by mill above station. The city of Rocky Mount diverted an average of 19.9 $ft^3/s$ for municipal water supply, most of which was returned as sewage below station. Minimum discharge for period of record and current water year also occurred on Sep. 24; result of temporary regulation.

Discharge, cubic feet per second, water year October 1987 to September 1988 (daily mean values)

| Day | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 21 | 70 | 499 | 1120* | 587 | 365 | 475 | 482 | 174 | 140 | 67 | 84 |
| 2 | 82 | 97 | 474 | *800 | 566 | 301 | 350 | 319 | 144 | 126 | 111 | 49 |
| 3 | 104 | 97 | 378 | *850 | 722 | 379 | 404 | 408 | 13 | 126 | 39 | 126 |
| 4 | 107 | 94 | 292 | *1300 | 916 | 407 | 457 | 278 | 207 | 242 | 111 | 98 |
| 5 | 102 | 140 | 243 | *1880 | 1229 | 43 | 416 | 600 | 225 | 168 | 118 | 113 |
| 6 | 103 | 115 | 211 | *2150 | 2160 | 510 | 396 | 751 | 230 | 82 | 79 | 87 |
| 7 | 123 | 100 | 170 | *1680 | 1970 | 488 | 415 | 916 | 209 | 59 | 80 | 86 |
| 8 | 110 | 96 | 78 | *1180 | 1210 | 472 | 460 | 816 | 162 | 65 | 93 | 73 |
| 9 | 109 | 81 | 69 | *780 | 924 | 470 | 365 | 668 | 175 | 97 | 130 | 77 |
| 10 | 119 | 75 | 101 | *750 | 815 | 460 | 482 | 530 | 179 | 73 | 83 | 85 |
| 11 | 126 | 78 | 133 | *692 | 876 | 546 | 444 | 474 | 142 | 169 | 26 | 114 |
| 12 | 114 | 75 | 175 | *600 | 1790 | 710 | 418 | 423 | 158 | 143 | 121 | 101 |
| 13 | 111 | 121 | 206 | *570 | 2210 | 736 | 523 | 239 | 218 | 127 | 100 | 76 |
| 14 | 109 | 140 | 208 | *560 | 2430 | 623 | 765 | 239 | 167 | 118 | 54 | 72 |
| 15 | 105 | 78 | 308 | 526 | 1840 | 560 | 872 | 276 | 124 | 121 | 60 | 90 |
| 16 | 108 | 69 | 350 | 377 | 1310 | 504 | 792 | 291 | 106 | 122 | 133 | 86 |
| 17 | 111 | 73 | 477 | 448 | 4080 | 458 | 668 | 315 | 102 | 120 | 121 | 85 |
| 18 | 111 | 63 | 564 | 695 | 952 | 415 | 520 | 362 | 248 | 103 | 62 | 71 |
| 19 | 104 | 98 | 458 | 956 | 891 | 484 | 669 | 274 | 250 | 54 | 75 | 57 |
| 20 | 102 | 96 | 364 | 1490 | 702 | 518 | 1190 | 570 | 190 | 107 | 88 | 59 |
| 21 | 101 | 108 | 342 | 1910 | 814 | 532 | 1840 | 486 | 281 | 104 | 99 | 64 |
| 22 | 102 | 81 | 342 | 2270 | 684 | 541 | 1640 | 402 | 358 | 123 | 116 | 162 |
| 23 | 104 | 79 | 383 | 1770 | 674 | 505 | 1071 | 268 | 372 | 124 | 131 | 101 |
| 24 | 108 | 132 | 415 | 1160 | 587 | 448 | 819 | 371 | 303 | 111 | 90 | 33 |
| 25 | 180 | 74 | 388 | 900 | 549 | 420 | 636 | 255 | 241 | 110 | 44 | 149 |
| 26 | 224 | 93 | 356 | 898 | 520 | 411 | 572 | 356 | 176 | 108 | 45 | 100 |
| 27 | 115 | 106 | 358 | 1000 | 510 | 503 | 513 | 243 | 194 | 120 | 47 | 233 |
| 28 | 107 | 156 | 638 | 1120 | 405 | 626 | 370 | 245 | 162 | 242 | 95 | 187 |
| 29 | 85 | 292 | 1030 | 948 | 454 | 655 | 560 | 243 | 141 | 126 | 64 | 137 |
| 30 | 20 | 465 | 1850 | 733 | — | 578 | 511 | 243 | 158 | 125 | 121 | 11 |
| 31 | 32 | — | 1720 | 567 | — | 509 | — | 240 | — | 93 | 64 | — |
| Mean | 105 | 155 | 438 | 1054 | 1047 | 505 | 654 | 406 | 200 | 120 | 86.1 | 98.9 |
| Max | 224 | 465 | 1850 | 2270 | 2430 | 736 | 1840 | 916 | 372 | 242 | 133 | 233 |
| Min | 20 | 63 | 69 | 377 | 405 | 301 | 350 | 239 | 102 | 54 | 26 | 33 |
| Inch | .13 | .01 | .55 | 1.31 | 1.22 | .63 | .79 | .51 | .24 | .15 | .11 | .12 |

*Estimated

Statistics of monthly flow data for period of record, by water year (WY)

| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 220.2 | 561.4 | 819.0 | 1568 | 1624 | 1994 | 1646 | 896.2 | 682.3 | 384.3 | 336.1 | 218.5 |
| Max | 566.8 | 1905 | 1720 | 3230 | 3280 | 3577 | 3447 | 2361 | 2238 | 1316 | 826.9 | 805.1 |
| (WY) | 1980 | 1980 | 1984 | 1978 | 1983 | 1983 | 1987 | 1978 | 1982 | 1984 | 1986 | 1979 |
| Min | 70.4 | 74.5 | 141.9 | 254.0 | 546.3 | 476.9 | 359.3 | 258.2 | 128.0 | 54.1 | 79.7 | 84.3 |
| (WY) | 1981 | 1981 | 1981 | 1981 | 1977 | 1981 | 1981 | 1986 | 1986 | 1986 | 1987 | 1980 |

| Summary statistics | 1988 water year | | Period of record | |
|---|---|---|---|---|
| Average flow | 400.4 | | 883.9 | |
| Highest annual mean | | | 1500 | 1984 |
| Lowest annual mean | | | 261.9 | 1981 |
| Highest daily mean | 2430 | Feb 14 | 12100 | May 1, 1978 |
| Lowest daily mean | 20 | Oct 30 | 6.6 | Oct 3, 1983 |
| Instantaneous peak flow | 2510 | Feb 14 | 12300 | May 1, 1978 |

| Summary statistics | 1988 water year | | Period of record | |
|---|---|---|---|---|
| Instantaneous peak stage | 8.94 | Feb 14 | 23.66 | May 1, 1978 |
| Instantaneous low flow | 5.7 | Sep 23 | 5.7 | Sep 23, 1988 |
| Annual runoff (inches) | 5.88 | | 13.0 | |
| 10 percentile | 890 | | 2190 | |
| 50 percentile | 238 | | 406 | |
| 98 percentile | 65 | | 70 | |

**Example 19–3** Water discharge records for Pamlico River Basin—Continued

Pamlico River Basin—02082585 Tar River at NC 97 at Rocky Mount, NC

Location—Lat 35°57'15", long 77°47'15", Edgecombe County, Hydrologic Unit 03020101, on left bank 20 feet downstream from bridge on NC 97, 0.5 mile upstream from Cowlick Branch, and 1.0 mile north-northeast of Rocky Mount.
Drainage area—925 square miles.
Period of Record—August 1976 to current year.
Revised Records—WDR NC-81-1: Drainage area.
Gage—Water-stage recorder. Datum of gage is 53.88 ft above National Geodetic Vertical Datum of 1929.
Remarks—Records good except for estimated daily discharges, which are fair. Some regulation at low flow caused by mill above station. The city of Rocky Mount diverted an average of 19.4 $ft^3/s$ for municipal water supply, most of which was returned as treated effluent below station. Minimum discharge for period of record and current water year, result of temporary regulation.

Discharge, cubic feet per second, water year October 1988 to September 1989 (mean daily values)

| Day | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 143 | 631 | 1160 | 350 | 303 | 5960 | 2310 | 7310 | 60 | 1220 | 509 | 401 |
| 2 | 103 | 1440 | 730 | 483 | 302 | 6680 | 2890 | 9200 | 198 | 804 | 813 | 347 |
| 3 | 20 | 2900 | 563 | 772 | 306 | 3750 | 1940 | 8920 | 314 | 560 | 1290 | 301 |
| 4 | 331 | 2670 | 420 | 943 | 284 | 7260 | 1370 | 7950 | 338 | 509 | 1040 | 278 |
| 5 | 126 | 1240 | 364 | 727 | 340 | 5780 | 1300 | 6750 | 599 | 473 | 748 | 270 |
| 6 | 99 | 821 | 305 | 597 | 410 | 5150 | 2820 | 5590 | 1040 | 491 | 510 | 137 |
| 7 | 81 | 639 | 272 | 520 | 560 | 6200 | 4030 | 4590 | 1350 | 524 | 420 | 183 |
| 8 | 365 | 571 | 248 | 476 | 674 | 4850 | 6110 | 4860 | 1440 | 643 | 419 | 185 |
| 9 | 240 | 451 | 249 | 462 | 666 | 5310 | 6510 | 4100 | 1420 | 893 | 369 | 183 |
| 10 | 181 | 392 | 262 | 493 | 700 | 5630 | 6050 | 2948 | 1250 | 653 | 342 | 212 |
| 11 | 151 | 316 | 259 | 515 | 638 | 4560 | 5740 | 2529 | 1030 | 489 | 303 | 145 |
| 12 | 143 | 274 | 264 | 667 | 546 | 3060 | 3930 | 2298 | 775 | 389 | 312 | 155 |
| 13 | 101 | 249 | 272 | 754 | 472 | 2290 | 2090 | 1780 | 873 | 362 | 353 | *150 |
| 14 | 50 | 226 | 1100 | 872 | 436 | 2030 | 1620 | 1360 | 1030 | 402 | 413 | *160 |
| 15 | 50 | 210 | 624 | 1070 | 406 | 2510 | 1790 | 1100 | 1200 | 779 | 416 | *200 |
| 16 | 55 | 200 | 119 | 972 | 370 | 2720 | 2470 | 1480 | 1100 | 1160 | 751 | *250 |
| 17 | 67 | 233 | 69 | 809 | 411 | 2360 | 3400 | 1560 | 1770 | 1610 | 900 | *220 |
| 18 | 66 | 238 | 128 | 680 | 589 | 2970 | 2700 | 1400 | 2750 | 3310 | 1430 | *190 |
| 19 | 126 | 247 | 120 | 601 | 779 | 2320 | 1750 | 1180 | 2380 | 4250 | 2990 | *180 |
| 20 | 89 | 288 | 121 | 546 | 1040 | 1910 | 1450 | 909 | 1650 | 4540 | 4250 | *170 |
| 21 | 136 | 263 | 115 | 488 | 2010 | 1740 | 1130 | 794 | 2360 | 2160 | 2600 | *180 |
| 22 | 150 | 256 | 111 | 447 | 4920 | 1400 | 990 | 832 | 3390 | 872 | 1020 | *170 |
| 23 | 189 | 245 | 113 | 402 | 6870 | 2050 | 937 | 501 | 3320 | 674 | 711 | *180 |
| 24 | 201 | 235 | 149 | 387 | 7760 | 4950 | 864 | 725 | 2320 | 504 | 503 | *170 |
| 25 | 28 | 210 | 204 | 366 | 7760 | 6680 | 770 | 697 | 1900 | 477 | 463 | *160 |
| 26 | 240 | 204 | 237 | 359 | 8270 | 7500 | 1830 | 560 | 2000 | 415 | 1500 | *200 |
| 27 | 188 | 207 | 243 | 342 | 7080 | 7170 | 2590 | 570 | 1320 | 374 | 2160 | *300 |
| 28 | 151 | 243 | 259 | 331 | 5180 | 7070 | 3300 | 507 | 904 | 329 | 1090 | *240 |
| 29 | 130 | 780 | 224 | 329 | — | 4610 | 2610 | 459 | 720 | 335 | 694 | *220 |
| 30 | 120 | 1170 | 225 | 318 | — | 1790 | 4830 | 398 | 803 | 345 | 533 | *180 |
| 31 | 129 | — | 261 | 302 | — | 1750 | — | 433 | — | 392 | 443 | — |
| Mean | 148 | 592 | 316 | 561 | 2146 | 4301 | 2733 | 2725 | 1699 | 998 | 977 | 211 |
| Max | 365 | 2900 | 1160 | 1070 | 8270 | 7500 | 6510 | 9200 | 3390 | 4540 | 4250 | 401 |
| Min | 20 | 200 | 69 | 302 | 284 | 1400 | 770 | 398 | 198 | 329 | 303 | 137 |
| In. | .18 | .71 | .39 | .70 | 2.42 | 5.36 | 3.30 | 3.40 | 1.69 | 1.24 | 1.22 | .25 |

* Estimated

Statistics of monthly flow data for period of record, by water year (WY)

| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 214.7 | 563.8 | 780.3 | 1491 | 1664 | 2172 | 1452 | 1037 | 737.5 | 461.5 | 385.4 | 217.9 |
| Max | 566.8 | 1905 | 1720 | 3230 | 3280 | 4301 | 3447 | 2725 | 2238 | 1316 | 977.3 | 805.1 |
| (WY) | 1980 | 1980 | 1984 | 1978 | 1983 | 1989 | 1987 | 1989 | 1982 | 1984 | 1989 | 1979 |
| Min | 7034 | 74.5 | 141.9 | 254.0 | 546.3 | 476.9 | 359.3 | 258.2 | 128.0 | 54.1 | 79.7 | 84.3 |
| (WY) | 1981 | 1981 | 198=1 | 1981 | 1977 | 1981 | 1981 | 1986 | 1986 | 1986 | 1987 | 1980 |

| Summary statistics | 1989 water year | | Period of record | |
|---|---|---|---|---|
| Average flow | 1422 | | 925.3 | |
| Highest annual mean | | 1500 | 1984 | |
| Lowest annual mean | | 261.9 | 1981 | |
| Highest daily mean | 9200 | May 2 | 12100 | May 1, 1978 |
| Lowest daily mean | 20 | Oct | 6.6 | Oct 3, 1983 |
| Instantaneous peak flow | 9520 | May 2 | 12300 | May 1, 1978 |

| Summary statistics | 1989 water year | | Period of record | |
|---|---|---|---|---|
| Instantaneous peak stage | 21.23 | May 2 | 23.66 | May 1, 1978 |
| Instantaneous low flow | 5.9 | Oct 6 | 5.7 | Sep 23, 1988 |
| Annual runoff (inches) | 20.9 | | 13.6 | |
| 10 percentile | 4400 | | 2310 | |
| 50 Percentile | 579 | | 419 | |
| 95 percentile | 121 | | 72 | |

**Example 19–3** Water discharge records for Pamlico River Basin—Continued

Pamlico River Basin—02082585 Tar River at NC 97 at Rocky Mount, NC

Location—Lat 35°57'15", long 77°47'15", Edgecombe County, Hydrologic Unit 03020101, on left bank 20 feet downstream from bridge on NC 97, 0.5 mile upstream from Cowlick Branch, and 1.0 mile north-northeast of Rocky Mount.
Drainage area—925 square miles.
Period of Record—August 1976 to current year.
Revised Records—WDR NC-81-1: Drainage area.
Gage—Water-stage recorder. Datum of gage is 53.88 ft above National Geodetic Vertical Datum of 1929.
Remarks—Records good except for estimated daily discharges, which are fair. Some regulation at low flow caused by mill above station. The city of Rocky Mount diverted an average of 19.4 $ft^3/s$ for municipal water supply, most of which was returned as treated effluent below station. Minimum discharge for period of record and current water year, result of temporary regulation.

Discharge, cubic feet per second, water year October 1989 to September 1990 (mean daily values)

| Day | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | *513 | *388 | *410 | 1020 | 1350 | 1100 | 7160 | 1360 | 3140 | 160 | 64 | 1130 |
| 2 | 1010 | *400 | *320 | 1230 | 1180 | 1070 | 6330 | 2430 | 1390 | 170 | 59 | 657 |
| 3 | 2190 | *809 | *250 | 1730 | 1070 | 1440 | 6350 | 2340 | 860 | 222 | 89 | 382 |
| 4 | 3640 | *1480 | *200 | 1440 | 1040 | 1690 | 5600 | 2250 | 1100 | 315 | 76 | 286 |
| 5 | 4300 | *1860 | *460 | 1120 | 865 | 1830 | 5770 | 2250 | 880 | 367 | 101 | 245 |
| 6 | 2990 | *1270 | 864 | 1080 | 1330 | 1600 | 5750 | 2310 | 732 | 264 | 89 | 202 |
| 7 | 963 | *896 | 274 | 1110 | 1550 | 1220 | 3640 | 2330 | 596 | 278 | 79 | 187 |
| 8 | 673 | *608 | 1260 | 1720 | 1200 | 1070 | 2170 | 1850 | 485 | 145 | 73 | 163 |
| 9 | 798 | *758 | 1980 | 2300 | 1090 | 985 | 2430 | 1160 | 464 | 157 | 172 | 165 |
| 10 | 459 | *1210 | 3270 | 3130 | 1780 | 930 | 1750 | 952 | 414 | 136 | 2470 | 230 |
| 11 | *395 | *1990 | 2590 | 3440 | 2390 | 627 | 1650 | 1270 | 362 | 132 | 1700 | 231 |
| 12 | *372 | *1400 | 2140 | 2070 | 3530 | 890 | 1240 | 2510 | 343 | 127 | 971 | 235 |
| 13 | *340 | *966 | 3550 | 1390 | 370 | 855 | 1130 | 2160 | 320 | 123 | 514 | 01 |
| 14 | *319 | *722 | 4620 | 1160 | 2260 | 781 | 1030 | 1200 | 302 | 186 | 341 | 252 |
| 15 | *303 | *964 | 5400 | 1030 | 1400 | 751 | 973 | 963 | 280 | 318 | 290 | 280 |
| 16 | *296 | *869 | 5580 | 942 | 1240 | 767 | 978 | 805 | 270 | 329 | 246 | 153 |
| 17 | *289 | *1420 | 4140 | 905 | 1570 | 789 | 1450 | 705 | 263 | 387 | 283 | 158 |
| 18 | *309 | *1100 | 2260 | 869 | 3080 | 1450 | 1390 | 608 | 256 | 554 | 255 | 315 |
| 19 | *851 | *900 | 2040 | 827 | 4690 | 1920 | 1150 | 551 | 269 | 237 | 239 | 82 |
| 20 | *2690 | *780 | 1941 | 819 | 5100 | 1940 | 1020 | 447 | 248 | 373 | 316 | 289 |
| 21 | *2930 | *670 | 2770 | 1281 | 3990 | 1350 | 892 | 444 | 197 | 305 | 307 | 96 |
| 22 | *1940 | *900 | 1600 | 1620 | 2800 | 1050 | 822 | 586 | 256 | 238 | 252 | 31 |
| 23 | *1170 | *1200 | 1100 | 1720 | 1940 | 911 | 829 | 846 | 308 | 190 | 375 | 49 |
| 24 | *783 | *1600 | 923 | 1420 | 2140 | 828 | 840 | 1000 | 323 | 83 | 2620 | 77 |
| 25 | *608 | *2100 | 870 | 1140 | 2280 | 789 | 792 | 861 | 315 | 109 | 4440 | 88 |
| 26 | *515 | *2900 | 797 | 1260 | 1800 | 754 | 717 | 683 | 286 | 93 | 3590 | 135 |
| 27 | *462 | *1700 | 270 | 1990 | 1360 | 719 | 664 | 596 | 244 | 81 | 211 | 28 |
| 28 | *433 | *1050 | 211 | 3160 | 1170 | 712 | 608 | 663 | 172 | 76 | 1640 | 32 |
| 29 | *409 | *740 | 221 | 2820 | — | 2320 | 551 | 1580 | 206 | 92 | 972 | 46 |
| 30 | *400 | *530 | 162 | 1650 | — | 5680 | 829 | 2430 | 123 | 78 | 1290 | 74 |
| 31 | *401 | — | 774 | 1420 | — | 6930 | — | 3250 | — | 74 | 1270 | — |
| Mean | 1079 | 1130 | 1708 | 1575 | 2109 | 1485 | 2207 | 1401 | 513 | 205 | 880 | 217 |
| Max | 4300 | 2900 | 5580 | 3440 | 5100 | 6930 | 7160 | 3250 | 3140 | 554 | 4440 | 1130 |
| Min | 289 | 388 | 162 | 819 | 865 | 712 | 551 | 444 | 123 | 74 | 59 | 28 |
| In. | 1.35 | 1.36 | 2.13 | 1.96 | 2.38 | 1.85 | 2.66 | 1075 | .62 | .26 | 1.10 | .26 |

* Estimated

Statistics of monthly flow data for period of record, by water year (WY)

| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 276.4 | 604.2 | 846.6 | 12497 | 1696 | 2123 | 1805 | 1063 | 721.5 | 415.3 | 420.8 | 217.8 |
| Max | 1079 | 1905 | 1720 | 3230 | 3280 | 4301 | 3447 | 2725 | 2238 | 1316 | 977.3 | 805.1 |
| (WY) | 1990 | 1980 | 1984 | 1978 | 1983 | 1989 | 1987 | 1989 | 1982 | 1984 | 1989 | 1979 |
| Min | 70.1 | 74.5 | 141.9 | 254.0 | 546.3 | 476.9 | 359.3 | 258.2 | 128.0 | 5431 | 79.7 | 84.3 |
| (WY) | 1981 | 1981 | 1981 | 1981 | 1977 | 1981 | 1981 | 1986 | 1986 | 1986 | 1987 | 1980 |

| Summary statistics | 1990 water year | | Period of record | |
|---|---|---|---|---|
| Average flow | 1204 | | 945.2 | |
| Highest annual mean | | 1500 | 1981 | |
| Lowest annual mean | | 261.9 | 1981 | |
| Highest daily mean | 7160 | Apr 1 | 12100 | May 1, 1978 |
| Lowest daily mean | 28 | Sep 27 | 6.6 | Oct 3, 1983 |
| Instantaneous peak flow | 7390 | Apr 1 | 12300 | May 1, 1978 |

| Summary statistics | 1990 water year | | Period of record | |
|---|---|---|---|---|
| Instantaneous peak stage | 7.74 | Apr 1 | 23.66 | May 1, 1978 |
| Instantaneous low flow | 8.6 | Sep 19 | 5.7 | Sep 23, 1988 |
| Annual runoff (inches) | 17.7 | | 13.9 | |
| 10 percentile | 2670 | | 2350 | |
| 50 Percentile | 860 | | 437 | |
| 95 percentile | 86 | | 73 | |

**Example 19–3** Water discharge records for Pamlico River Basin—Continued

Pamlico River Basin—02082585 Tar River at NC 97 at Rocky Mount, NC

Location—Lat 35°57'15", long 77°47'15", Edgecombe County, Hydrologic Unit 03020101, on left bank 20 feet downstream from bridge on NC 97, 0.5 mile upstream from Cowlick Branch, and 1.0 mile north-northeast of Rocky Mount.
Drainage area—925 square miles. Period of Record—August 1976 to current year. Revised Records—WDR NC-81-1: Drainage area.
Gage—Water-stage recorder. Datum of gage is 53.88 ft above National Geodetic Vertical Datum of 1929.
Remarks—No estimated daily discharges. Records good. Some regulation at low flow caused by mill above station. The city of Rocky Mount diverted an average of 24.1 $ft^3/s$ for municipal water supply, most of which was returned as treated effluent below station. Minimum discharge for period of record and current water year, result of temporary regulation. Gage-height telemeter at station.

Discharge, cubic feet per second, water year October 1990 to September 1991 (mean daily values)

| Day | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 79 | 222 | 843 | 823 | 821 | 1990 | 4371 | 915 | 267 | 87 | 419 | 192 |
| 2 | 102 | 201 | 700 | 1410 | 767 | 667 | 4810 | 1290 | 175 | 94 | 413 | 128 |
| 3 | 58 | 191 | 526 | 1290 | 686 | 359 | 3838 | 877 | 212 | 133 | 226 | 98 |
| 4 | 64 | 177 | 449 | 4111 | 634 | 1470 | 1310 | 612 | 168 | 109 | 205 | 98 |
| 5 | 68 | 168 | 392 | 924 | 688 | 2791 | 957 | 468 | 301 | 123 | 175 | 98 |
| 6 | 192 | 161 | 512 | 805 | 58 | 3358 | 847 | 463 | 247 | 118 | 103 | 119 |
| 7 | 139 | 148 | 616 | 960 | 898 | 1930 | 813 | 342 | 282 | 113 | 118 | 210 |
| 8 | 119 | 147 | 632 | 1870 | 669 | 1200 | 744 | 369 | 185 | 105 | 93 | 164 |
| 9 | 117 | 141 | 601 | 3230 | 801 | 992 | 674 | 347 | 142 | 90 | 105 | 133 |
| 10 | 118 | 345 | 581 | 4000 | 762 | 858 | 670 | 323 | 128 | 85 | 162 | 102 |
| 11 | 136 | 308 | 558 | 3180 | 681 | 749 | 576 | 3873 | 105 | 131 | 165 | 101 |
| 12 | 93 | 338 | 509 | 2850 | 613 | 679 | 550 | 291 | 96 | 89 | 137 | 89 |
| 13 | 108 | 446 | 437 | 4200 | 582 | 679 | 495 | 286 | 96 | 101 | 341 | 106 |
| 14 | 107 | 381 | 375 | 5200 | 573 | 836 | 584 | 257 | 91 | 107 | 259 | 119 |
| 15 | 96 | 297 | 224 | 5471 | 496 | 1091 | 544 | 288 | 141 | 115 | 889 | 117 |
| 16 | 123 | 249 | 329 | 4391 | 585 | 1380 | 308 | 362 | 137 | 104 | 847 | 118 |
| 17 | 131 | 228 | 384 | 1690 | 472 | 1050 | 745 | 134 | 93 | 109 | 672 | 117 |
| 18 | 146 | 211 | 366 | 1610 | 477 | 1060 | 727 | 156 | 102 | 103 | 429 | 105 |
| 19 | 144 | 200 | 370 | 1520 | 489 | 1440 | 565 | 330 | 96 | 84 | 240 | 97 |
| 20 | 133 | 183 | 370 | 1630 | 527 | 2310 | 889 | 599 | 155 | 92 | 196 | 118 |
| 21 | 124 | 215 | 532 | 1930 | 612 | 1790 | 775 | 805 | 149 | 71 | 154 | 116 |
| 22 | 121 | 156 | 879 | 2780 | 654 | 1180 | 744 | 860 | 141 | 77 | 132 | 82 |
| 23 | 231 | 194 | 1220 | 2120 | 684 | 961 | 754 | 715 | 107 | 82 | 130 | 67 |
| 24 | 344 | 190 | 1140 | 1340 | 563 | 952 | 793 | 509 | 95 | 80 | 109 | 102 |
| 25 | 1510 | 197 | 842 | 1120 | 526 | 897 | 653 | 406 | 89 | 75 | 89 | 107 |
| 26 | 1490 | 198 | 652 | 969 | 515 | 796 | 511 | 327 | 99 | 69 | 8 | 117 |
| 27 | 822 | 198 | 521 | 886 | 517 | 129 | 471 | 274 | 108 | 77 | 141 | 111 |
| 28 | 610 | 209 | 601 | 824 | 562 | 662 | 477 | 272 | 101 | 100 | 135 | 105 |
| 29 | 454 | 416 | 637 | 784 | — | 689 | 453 | 340 | 89 | 305 | 132 | 104 |
| 30 | 313 | 895 | 687 | 779 | — | 1390 | 625 | 314 | 90 | 545 | 156 | 102 |
| 31 | 258 | — | 723 | 833 | — | 3150 | — | 287 | — | 423 | 184 | — |
| Total | 8550 | 7500 | 18200 | 32577 | 16983 | 39115 | 31474 | 14141 | 4209 | 4004 | 7633 | 3442 |
| Mean | 276 | 253 | 587 | 2019 | 607 | 1262 | 1049 | 456 | 140 | 129 | 246 | 115 |
| Max | 1510 | 865 | 1220 | 5470 | 521 | 3358 | 4810 | 1290 | 301 | 545 | 889 | 210 |
| Min | 58 | 141 | 224 | 779 | 472 | 359 | 453 | 134 | 89 | 69 | 87 | 67 |
| CFSM | .30 | .27 | .63 | 2.18 | .66 | 1.36 | 1.13 | .49 | .15 | .14 | .27 | .12 |
| In. | .34 | .30 | .73 | 2.52 | .68 | 1.57 | 1.27 | .57 | .17 | .16 | .31 | .14 |
| Mean | 276 | 501 | 829 | 1531 | 1623 | 2065 | 1476 | 1022 | 683 | 396 | 409 | 211 |
| Max | 1079 | 1905 | 1720 | 3230 | 3260 | 4301 | 3447 | 2725 | 2238 | 1316 | 977 | 805 |
| (WY) | 1990 | 1980 | 1984 | 1978 | 1983 | 1989 | 1987 | 1989 | 1982 | 1984 | 1989 | 1979 |
| Min | 70.4 | 74.5 | 142 | 254 | 546 | 477 | 359 | 258 | 128 | 54.1 | 79.7 | 84.3 |
| (WY) | 1981 | 1981 | 1981 | 1981 | 1977 | 1981 | 1981 | 1986 | 1986 | 1986 | 1987 | 1980 |

| Summary statistics | 1990 calendar year | | 1991 water year | | 1977-1991 water years | |
|---|---|---|---|---|---|---|
| Annual total | 353444 | | 217908 | | | |
| Annual mean | 9678 | | 597 | | 922 | |
| Highest annual mean | | | | 1500 | 1984 | |
| Lowest annual mean | | | | 262 | 1981 | |
| Highest daily mean | 7160 | Apr 1 | 5470 | Jan 15 | 12100 | May 1, 1978 |
| Lowest daily mean | 28 | Sep 27 | 58 | Oct 3 | 6.6 | Oct 3, 1983 |
| Annual 7-day minimum | 60 | Sep 27 | 76 | Jul 21 | 40 | Jul 3, 1986 |
| Instantaneous peak flow | | | 5480 | Jan 15 | 12300 | May 1, 1978 |
| Instantaneous peak stage | | | 14.43 | Jan 15 | 23.66 | May 1, 1978 |
| Instantaneous low flow | | | 7.2 | Nov 1 | 5.7 | Sep 23, 1988 |
| Annual runoff (CFSM) | 1.05 | | .68 | | 1.00 | |
| Annual runoff (inches) | 14.21 | | 8.76 | | 13.54 | |
| 10 percentile | 2290 | | 1250 | | 2280 | |
| 50 Percentile | 601 | | 344 | | 430 | |
| 95 percentile | 118 | | 98 | | 99 | |

# 650.1902 Runoff volumes

## (a) Introduction

Four tools are presented that deal with runoff volumes. Three of them can be used to compute surface runoff volumes on a daily, monthly, seasonal, or annual basis. Selection of the tool depends upon the data available and the intended use of the results. These tools are used to

- Obtain runoff data from stream gage records.
- Run SPAW or other daily simulation model, such as SWRRBWQ.
- Manually compute daily runoff using rainfall gage data and seasonally adjusted runoff curve numbers.
- Determine the duration and frequency of surface flooding of depressional areas.

Each tool is presented separately in its respective section. The first three tools generally are used to provide data for the fourth tool.

## (b) Tool to obtain runoff data from stream gage records

### (1) Applicable situations for use

Runoff data from a stream gage are appropriate for use if stream gage data are available. Daily, monthly, seasonal, or annual runoff volumes can be used directly as inflow into potential wetlands. A frequency curve of runoff volumes is generally developed and used with physical characteristics of a potential wetland to determine the frequency and duration of flooding from surface sources.

### (2) Data required

The drainage area of the stream gage should be in the same range of magnitude as the area for which runoff is needed. A maximum drainage area of the stream gage is 20 square miles. With significant differences in drainage areas, the chance is greater that base flow and total runoff volumes will differ.

Runoff varies significantly with differences in climate, land cover, and soils. The climate, land cover, and soils of the stream gage's drainage area should be similar to that of the area for which runoff is needed.

The data should be relatively long-term, current, complete, and error free. Generally, a minimum of 20 continuous years of data is considered to be long-term.

### (3) Sources of data

Gages have been operated on many streams and lakes by various Federal, State, and local agencies. Stream and lake gage readings are available from the Corps of Engineers, TVA, USGS, NOAA, BOR, various highway departments, and State or local public works agencies.

The gage data published include mean daily discharge, peak stage and discharge for flood events, and mean daily lake level. The primary source of these data is the USGS Water Resources Data publications. Private vendors have loaded these data on compact disks for sale or lease. NRCS National Water and Climate Center has archived some stream gaged data.

### (4) Limitations

***Knowledge and experience required***—A general knowledge of runoff is needed to use this tool.

***Factors affecting the accuracy of results*—**The drainage area of the stream gage is assumed to be representative of the drainage area of concern. Any significant differences will reduce the accuracy of the results of this tool. This tool does not have the capability to determine the impact of land cover on runoff. An advantage of using this tool is that runoff data from one stream gage may be usable for several sites. Caution should be used when transferring stream gage data from one watershed to another. However, this tool will provide information about the general hydrology of a site. A water budget of the site will provide information regarding the frequency and duration of inundation.

### (5) Methodology

***Step 1*—**Obtain the long-term daily surface runoff volumes for representative gages. Long-term is defined as 20 years or more of data. The stream drainage area should be limited to approximately 20 square miles or less.

***Step 2*—**Verify that the runoff data meet the limitations listed.

***Step 3***—If these data are not in inches of depth, perform the conversion. See National Engineering Handbook, Section 4 (NEH-4), Hydrology, chapter 22 for the appropriate conversion factor.

***Step 4***—If durations other than daily are required, sum the daily values for the period desired.

***Step 5***—Develop a frequency curve of runoff for the selected time period using the statistical techniques in chapter 18, NEH-4.

## (c) Tool to run daily simulation model, such as SPAW

### (1) Applicable situations for use

Runoff data from a daily simulation model are appropriate for use. Daily, monthly, seasonal, or annual runoff volumes can be used directly as inflow into potential wetlands. A frequency curve of runoff volumes is developed and used with physical characteristics of a potential wetland to determine the frequency and duration of flooding from surface sources.

### (2) Data required

The data required to use this tool are:

- Daily precipitation and temperature data from a nearby climate station.
- Soil, plant, land cover, and slope data.
- Planting and harvesting dates.
- Other data required by the selected model.

### (3) Sources of data

Data can be obtained from the NRCS National Water and Climate Center, Portland, Oregon.

Soil data can be obtained from the Soil Survey Report.

Plant, land cover, and slope data should be obtained during a visit to the site.

### (4) Limitations

***Knowledge and experience required***—A general knowledge of use of the selected model is needed.

***Climatic regions of applicability***—This tool is applicable in all climatic regions.

***Factors affecting the accuracy of results***—The accuracy is a function of the input data and the selected model. Most daily simulation models adjust the runoff curve number daily based on land cover, plant growth, and soil moisture accounting. Thus the accuracy is dependent on the soil moisture accounting procedure. The SPAW soil moisture accounting procedure has been evaluated and found satisfactory.

### (5) Methodology

***Step 1***—Obtain data required for selected model.

***Step 2***—Run the selected model.

***Step 3***—If the model results are not in inches of depth, perform the conversion. See NEH-4, chapter 22 for the appropriate conversion factor.

***Step 4***—If the model results are not summarized for the required durations, sum the daily values for the period desired.

***Step 5***—Develop a frequency curve of runoff for the selected time period using the statistical techniques in Chapter 18, National Engineering Handbook, Section 4, Hydrology.

## (d) Tool to manually compute daily runoff using precipitation data and seasonally adjusted runoff curve numbers

### (1) Applicable situations for use

Runoff data computed manually are appropriate for use if precipitation data are available. Daily, monthly, seasonal, or annual runoff volumes can be used as inflow into potential wetlands. A frequency curve of runoff volumes is generally developed and used with physical characteristics of a potential wetland to determine the frequency and duration of flooding from surface sources.

### (2) Data required

The data required to use this tool are:

- Daily precipitation data (30 years or more) from a representative climate station within the same climate area as the potential wetland site.
- Soil, plant, and land cover data.
- Planting and harvesting dates.

### (3) Sources of information

Data can be obtained from the NRCS National Water and Climate Center, Portland, Oregon, through the state climatic data liaison.

Soil data can be obtained from the Soil Survey Report.

Plant, land cover, and slope data should be obtained during a visit to the site.

### (4) Limitations

***Knowledge and experience required***—A general knowledge of NRCS Runoff Curve Number (RCN) procedure is needed. Chapter 9, NEH-4, will provide insights to RCN procedure. This procedure does not apply in areas with significant snowmelt.

***Factors affecting the accuracy of results***—The accuracy is a function of the input data. The runoff curve number is adjusted seasonally among six values depending upon land cover, plant growth, and the antecedent precipitation. The antecedent precipitation is used as an indicator of soil moisture. See table 19–3 for a relationship between antecedent precipitation and soil moisture.

This procedure assumes that the recorded rainfall for each day is from a separate storm. Thus, when a storm spans 2 days in the station record, the runoff is underestimated because the rainfall for the second and succeeding days is reduced by the initial abstraction. The error is partly compensated by increasing the RCN. Because it is most significant in humid climate areas, it is recommended that significant multiple-day rainfall events be considered to be single events.

Duration, frequency, and areal extent can be obtained using a detailed water budget of the potential site.

### (5) Methodology

***Step 1***—Obtain daily precipitation data (30 years or more) from a representative climate station within the same climate area as the potential wetland site.

***Step 2***—Compute the average RCN of the drainage area of the potential wetland site using the procedures in the EFH, Chapter 2.

***Step 3***—Compute the seasonally adjusted RCN's of the drainage area of the potential wetland site using the procedures in the NEH-4, chapter 10 for each major stage of plant growth.

- Use the fallow RCN (Engineering Field Handbook [EFH], chapter 2, table 2–3) for cultivated crops between initial tillage operations and planting and whenever two-thirds of the soil surface is exposed.
- Use the average RCN between planting and the time when only a third of the soil surface is exposed.
- Use the normal peak growth RCN between the time when only a third of the soil surface is exposed during plant growth and the time when more than a third of the soil surface is exposed after harvest. Use RCN normal peak growth as 2 (RCN average) – RCN fallow.
- For pasture, meadow, and range, estimate the seasonal RCN by adjusting the hydrologic condition based on the ground cover and grazing conditions (EFH table 2–3b and c).

***Step 4***—Obtain the RCN for dry, average, and wet antecedent runoff conditions from NEH–4, table 10.1 for average, fallow, and normal plant growth conditions.

***Step 5***—For each RCN obtained, obtain the rainfall required before runoff will occur. This can be found in the column titled, Curve starts where P =, of NEH-4, table 10.1.

***Step 6***—Actual soil moisture data usually are not available; therefore, use the antecedent precipitation as an indication of the antecedent runoff condition. The only relationship between antecedent precipitation and runoff condition known to exist is shown in table 19–3. Antecendent runoff condition ARC is a measure of the runoff potential of the watershed prior to an event.

**Table 19–3** Seasonal rainfall limits for ARC's

| ARC | - - Total 5-day antecedent rainfall - - dormant season (inches) | growing season (inches) |
|---|---|---|
| Dry | < 0.5 | < 1.4 |
| Average | 0.5 to 1.1 | 1.4 to 2.1 |
| Wet | > 1.1 | > 2.1 |

***Step 7***—Using the computed seasonally adjusted RCN's, compute the daily runoff for each day that the rainfall is great enough to produce runoff. (See step 5.)

### (6) Sample documentation

***(i) Procedures used to analyze runoff events***—The conventions used to determine runoff into depressional areas are the seasonal RCN for a wheat/fallow rotation on B hydrologic group soils. The procedure used to determine the change in runoff curve number for full growth is in NEH–4, chapter 10.

Full growth RCN equation:
RCN full growth = 2 (RCN average) – (RCN fallow)

Hydrologic soil group B curve numbers:
- Fallow RCN = 84
- Small grain RCN = 73.

$$\begin{aligned} RCN_{fg} &= 2(73) - 84 \\ &= 146 - 82 \\ &= 62 \end{aligned}$$

The full growth equation yields a $RCN_{fg} = 62$ for wheat.

The full growth RCN was used after harvest until the first fallow tillage operation was done or a third of the soil was exposed. The first tillage operation in western Kansas is typically not done until May of the year following harvest. It is expected that a third of the soil will not be exposed until November following a June harvest. Average RCN conditions may be used during periods after a third of the soil is exposed until the first tillage operation, and following planting until full plant growth. Fallow RCN conditions are used after the first tillage operation, or two-thirds of the soil is exposed until planting time. Table 19–4 displays the RCN used by month for wheat and fallow and the composite RCN used to determine runoff.

Also considered was the soil moisture condition when the rainfall event happened as to whether runoff would occur. Table 19–5 shows the RCN for dry ARC I, field capacity ARC II, wet ARC III, and the precipitation needed before runoff will occur.

Table 19–3 shows the precipitation amounts needed for dormant and growing season ARC conditions. Generally, a 5- to 10-day period of precipitation and other factors preceding the event were used to determine the ARC conditions.

**Table 19–4** Runoff curve number (RCN) for wheat and fallow (50/50 rotation)—western Kansas

| Month | Wheat | Fallow | Composite |
|---|---|---|---|
| Jun | 62 harvest | 84 | 73 |
| Jul | 62 | 84 | 73 |
| Aug | 62 | 84 | 73 |
| Sep | 62 | 84 plant | 73 |
| Oct | 62 | 73 | 68 |
| Nov | 62 | 73 | 68 |
| Dec | assumed all precipitation was snow | | |
| Jan | assumed all precipitation was snow | | |
| Feb | 73 | 73 | 73 |
| Mar | 73 | 73 | 73 |
| Apr | 73 | 62 | 68 |
| May | 73 | 62 | 68 |

**Table 19–5** Precipitation needed to produce runoff

| ARC group | RCN | Precipitation (inches) |
|---|---|---|
| **Dry conditions** | | |
| I | 54 | 2.0 |
| I | 48 | 2.5 |
| **Field capacity conditions** | | |
| II | 73 | 0.9 |
| II | 68 | 1.1 |
| **Wet conditions** | | |
| III | 87 | 0.5 |
| III | 84 | 0.5 |

Rainfall gage data were analyzed for runoff events at gage locations of Lakin, Kearny County, Kansas. The Lakin gage was analyzed using 51 years of records that covered a 52-year period (fig. 19–3). Table 19–6 shows the number of times that the maximum yearly event occurred in that month.

The records showed that 11 of the 51 years did not have any runoff events. Records were not available for 1950. Figure 19–3 gives the number of runoff events, maximum runoff event by month and amount, and the total runoff for each year.

A frequency analysis was made on the maximum yearly event (fig. 19–4) and the total yearly runoff (fig. 19–5). There is a fifty percent probability of having 0.21 inch of total runoff in any given year and 0.16 inch of runoff on any given year from the maximum yearly runoff event. This compares to 0.20 inches of average annual runoff from the USGS Average Annual Runoff Map of the United States for years 1951 through 1980.

**Table 19–6** Runoff event table, Lakin, Kansas

| Month | Events occurring by month |
|---|---|
| March | 1 |
| April | 2 |
| May | 10 |
| June | 10 |
| July | 5 |
| August | 7 |
| September | 2 |
| October | 3 |
| November | 0 |
| **Total** | **40** |

**Figure 19–3** Summary of runoff events, maximum runoff event, and total runoff for 52-year reporting period, Kearny County, Kansas

| | Runoff (in) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | No. of Events | Month | | | | | | | | | Total runoff for year |
| | | March | April | May | June | July | Aug. | Sept. | Oct. | Nov. | |
| 1990 | 3 | | | 0.54 | | | | | | | 0.87 |
| 1989 | 3 | | | 1.58 | | | | | | | 1.7 |
| 1988 | 0 | | | | | | | | | | 0 |
| 1987 | 2 | | | 0.16 | | | | | | | 0.24 |
| 1986 | 0 | | | | | | | | | | 0 |
| 1985 | 2 | | | | | | | 0.75 | | | 0.85 |
| 1984 | 1 | | | | | 0.25 | | | | | 0.25 |
| 1983 | 2 | | | | 0.01 | | | | | | 0.02 |
| 1982 | 3 | | | | | 0.25 | | | | | 0.29 |
| 1981 | 3 | | | | | | | 0.08 | | | 0.1 |
| 1980 | 4 | | | | | | 0.19 | | | | 0.24 |
| 1979 | 2 | | | | | | 0.13 | | | | 0.17 |
| 1978 | 2 | | | 0.33 | | | | | | | 0.37 |
| 1977 | 4 | | | 0.13 | | | | | | | 0.36 |
| 1976 | 0 | | | | | | | | | | 0 |
| 1975 | 3 | | | | 0.17 | | | | | | 0.23 |
| 1974 | 1 | | | | 0.3 | | | | | | 0.3 |
| 1973 | 2 | 0.17 | | | | | | | | | 0.22 |
| 1972 | 3 | | | | | | 0.14 | | | | 0.16 |
| 1971 | 1 | | | | 0.04 | | | | | | 0.04 |
| 1970 | 2 | | | | | | 0.12 | | | | 0.13 |
| 1969 | 7 | | | | 0.32 | | | | | | 0.81 |
| 1968 | 2 | | | | | 0.39 | | | | | 0.45 |
| 1967 | 2 | | | | 0.08 | | | | | | 0.12 |
| 1966 | 1 | | | | | 0.05 | | | | | 0.05 |
| 1965 | 4 | | | | | | | | 0.27 | | 0.4 |
| 1964 | 1 | | | 0.16 | | | | | | | 0.16 |
| 1963 | 1 | | | | 0.28 | | | | | | 0.28 |
| 1962 | 0 | | | | | | | | | | 0 |
| 1961 | 0 | | | | | | | | | | 0 |
| 1960 | 1 | | | 0.27 | | | | | | | 0.27 |
| 1959 | 1 | | | | | | | | 0.43 | | 0.43 |
| 1958 | 2 | | | | | 0.05 | | | | | 0.07 |
| 1957 | 1 | | | | 0.28 | | | | | | 0.28 |
| 1956 | 1 | | | 0.03 | | | | | | | 0.03 |
| 1955 | 1 | | 0.21 | | | | | | | | 0.28 |
| 1954 | 3 | | | | | | | | | | 0 |
| 1953 | 0 | | | | | | | | | | 0 |
| 1952 | 0 | | | | | | | | | | 0 |
| 1951 | 4 | | | 0.65 | | | | | | | 0.78 |
| 1950 | | | | | | No | data | | | | N/A |
| 1949 | 3 | | | | 3.85 | | | | | | 4.61 |
| 1948 | 3 | | | | 0.1 | | | | | | 0.27 |
| 1947 | 0 | | | | | | | | | | 0 |
| 1946 | 7 | | | | | | | | 0.7 | | 1.01 |
| 1945 | 2 | | | | | | 0.33 | | | | 0.35 |
| 1944 | 3 | | | 0.28 | | | | | | | 0.42 |
| 1943 | 0 | | | | | | | | | | 0 |
| 1942 | 4 | | 0.69 | | | | | | | | 0.8 |
| 1941 | 3 | | | | 0.15 | | | | | | 0.37 |
| 1940 | 2 | | | | | | 0.32 | | | | 0.57 |
| 1939 | 0 | | | | | | | | | | 0 |

**Figure 19–4** Annual runoff event probability for Lakin Gage, Kearny County, Kansas (estimated 50% chance annual runoff is 0.21 inch)

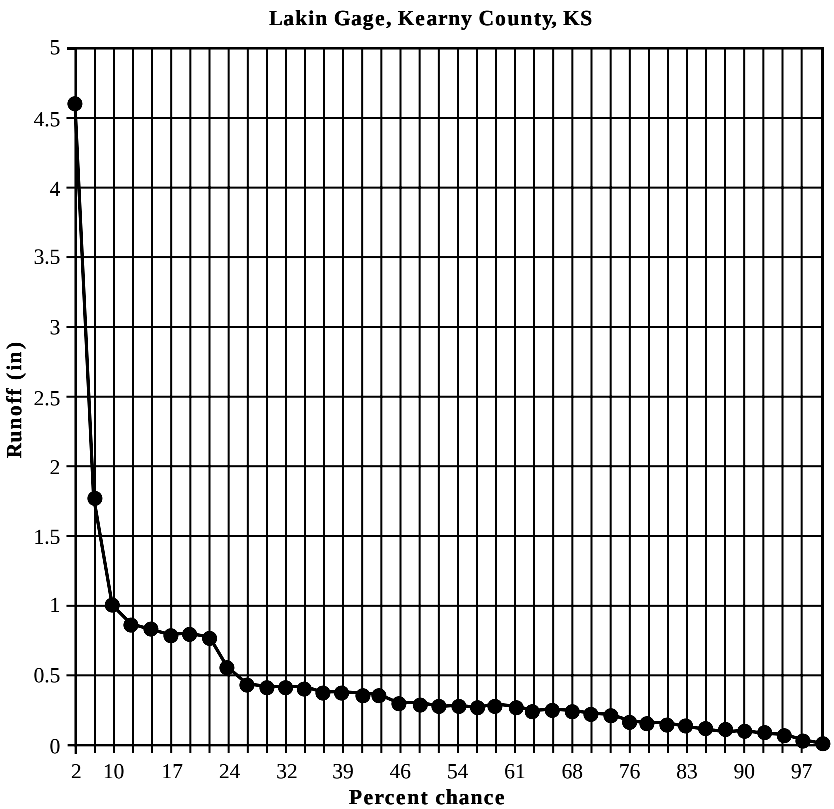
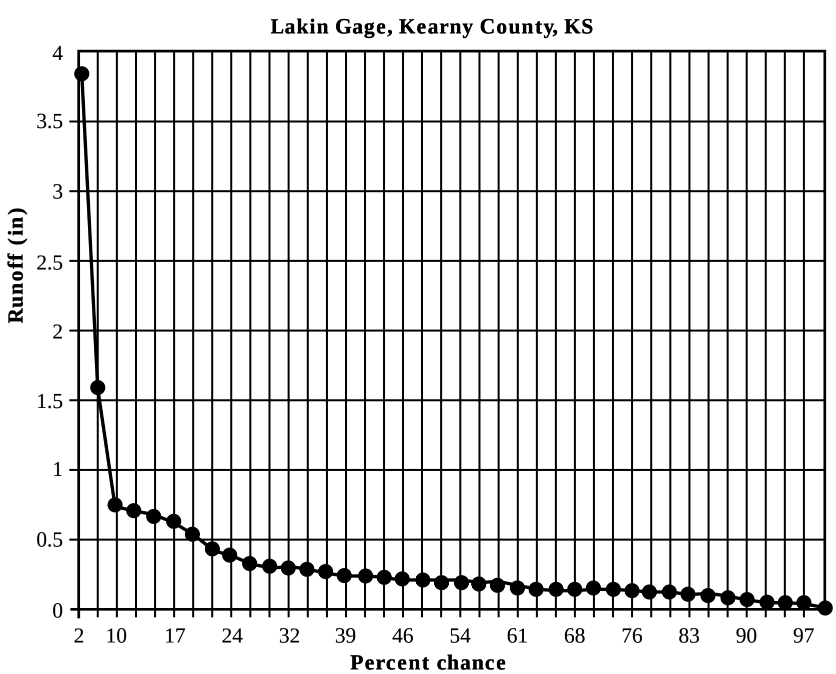



**Figure 19–5** Monthly runoff probability for Lakin Gage, Kearny County, Kansas (estimated 50% chance maximum runoff is 0.16 inch)



## (e) Tool to determine the duration and frequency of surface flooding of depressional areas

This tool can be used to determine the duration and frequency of surface flooding of depressional areas. It has two levels of application. The first level can be used to develop a relationship between a depressional area's drainage area and surface area. The second uses the relationship from the first level to determine if the depressional area clearly meets the wetland hydrology criteria or if additional study is needed.

### (1) Applicable situations for use

Runoff data computed manually are appropriate for use if precipitation data are available. Daily, monthly, seasonal, or annual runoff volumes can be used directly as inflow into potential wetlands. A frequency curve of runoff volumes is generally developed and used with physical characteristics of a potential wetland to determine the frequency and duration of flooding from surface sources.

### (2) Data required

The data required to use this tool are:

- Precipitation data (30 years or more) from a representative climate station within the same homogeneous climate area as the potential wetland site.
- Soil, plant, and land cover data.
- Planting and harvesting dates.

### (3) Sources of information

Data can be obtained from the NRCS National Water and Climate Center, Portland, Oregon.

Soil data can be obtained from the Soil Survey Report. Plant, land cover, and slope data should be obtained during a visit to the site.

### (4) Limitations

***Knowledge and experience required***—A general knowledge of the NRCS RCN procedure is needed.

***Climatic regions of applicability***—This tool is applicable in all climates.

***Factors affecting the accuracy of results***—The accuracy of results is dependent on the accuracy of the input data. The runoff curve number is adjusted seasonally among six values depending upon land cover, plant growth, and the antecedent precipitation. The antecedent precipitation is used as an indicator of soil moisture. See table 19-3 for a relationshop between antecendent precipitation and soil moisture.

### (5) Methodology

***Step 1***—Sum the daily runoff values to obtain total annual runoff for each year.

***Step 2***—Tabulate the maximum daily runoff for each year.

***Step 3***—Using the appropriate statistical analysis (see NEH-4, chapter 18), compute the 50 percent chance value for the two sets of data from Steps 1 and 2.

***Step 4***—Compute the average total water losses in the depressional area for the period of time specified by the wetland hydrology criterion. To do this,

- Develop a water budget for the depression on a daily basis for the critical duration. The water budget for the depressional area is

$$\Delta S = I - L$$

where:

$\Delta S$ = change in water storage in the depressional area
$I$ = inflow to the depressional area
$L$ = losses from the depressional area

The formula for losses to the depressional area is

$$L = S_w + F + O + E_d$$

where:

$L$ = total depressional water losses (in)
$O$ = outflow from area (in)
$S_w$ = soil-water holding capacity from 1/10 bar to 15 bar, or saturation to plant wilt (in) for a given depth (in) in soils
$F$ = total infiltration for critical duration (in)
$E_d$ = average evaporation from the depression for critical duration from growing season

The evaporation rates are from NOAA Technical Report NWS 34, December 1982. The soil infiltration rate and water holding capacity, at wilting point, are from soil survey data.

- Develop a relationship for the shape adjustment factor. This factor takes into account that the top area will always be greater than the base; thus, the base measurements are increased by the adjustment factor. The shape adjustment factor is explained further in section (6)(iii) on page 19–22.

- Solve the water budget equation for the 50 percent chance event.

  $$(50\% \text{ chance runoff}) (\Delta_M) = (P_s)(P_a)(L)$$

  where:
  $P_s$ = playa storage adjustment fuction
  $P_a$ = playa surface area
  L = playa loss
  $\Delta_M$ = minimum drainage area required to supply the runoff to satisfy duration criteria

  $\Delta_M = (P_s)(P_a)(L)$ / (50% chance runoff) or runoff from the drainage area needed to match the change in the storage in the depressional area.

- Develop a log-log inundation graph of drainage area (acres) needed versus playa size (acres).

***Step 5***—Determine the depressional area size and drainage area in acres. It is assumed that the critical duration of inundation for a pothole is 7 days.

***Step 6***—Place a dot on the inundation graph where the depressional area size and the drainage area needed intersect. If the dot is above the line, the depressional area is inundated for the time specified by the wetland criteria, and the depressional area meets the wetland hydrology criteria. If the dot is below the line, the depressional area is inundated for a shorter duration, and the depressional area does not meet the wetland hydrology criteria.

## (6) Sample documentation

The following is an example of the second procedure used to determine the drainage area required to meet the duration criteria in a playa in Kearny County, Kansas.

***(i) Procedure used to analyze playa lake losses***—Water losses to the playa areas include evaporation by month, infiltration rate, and soil-water holding capacity. The total losses for the playa can be expressed by the following equation:

$$L = E_d + S_w + F + O$$

where:
L = total playa water losses (in)
$E_d$ = average evaporation from the playa for 6.5 days for April through October (in)
O = outflow from area; playa outflow = zero
$S_w$ = soil-water holding capacity from 1/10 bar to 15 bar or saturation to plant wilt (in) for a given depth (in) in Ness soils
F = total infiltration at an infiltration rate of 0.004 inches per hour for a 7-day period (in)

The evaporation rates used are from NOAA Technical Report NWS 34, December 1982. The soil infiltration rate and water holding capacity, at wilting point, were from soil survey data for Ness soil. Table 19–7 shows evaporation by month ($E_m$), 6.5-day evaporation ($E_d$), and water holding capacity at different depths ($S_w$). It is assumed that the critical duration for inundation of a pothole is 7 days.

**Table 19–7** Evaporation, water holding capacity, by months

| Month | $E_m$ | $E_d$* | $S_w$ 12-inch | $S_w$ 18-inch | $S_w$ 24-inch | $S_w$ 36-inch |
|---|---|---|---|---|---|---|
| Mar | 4.3 | .9 | 1.1 | 1.9 | 2.9 | 4.7 |
| Apr | 6.7 | 1.5 | | | | |
| May | 8.0 | 1.7 | | | | |
| Jun | 9.6 | 2.1 | | | | |
| Jul | 10.3 | 2.2 | | | | |
| Aug | 8.3 | 1.7 | | | | |
| Sep | 6.2 | 1.3 | | | | |
| Oct | 5.1 | 1.1 | | | | |
| Nov | 2.8 | .6 | | | | |

* $E_d = \frac{(6.5)}{30}(E_m)$

The average 6.5-day evaporation ($E_d$ ) for April through October is 1.7 inches. The 6.5-day period was used to remove the freestanding water, and the other half day was used to reduce the soil saturation. The monthly evaporation rates shown in table 19–7 are from studies made on shallow lakes and reservoirs. Shallow is defined as a depth of 6 to 8 feet.

The total soil-water holding capacity is a function of the depths shown in the table ($S_w$). In an average (50% chance) year, a percentage of the total soil-water holding capacity is available for storing surface runoff before ponding occurs. It was felt the total drying depth would approach 36 inches in an average year before an event occurred. For this analysis, a depth of 18 inches was selected to account for the precipitation falling on the playa area. This represents about 50 percent of the soil-water holding capacity.

The assumed total infiltration F is equal to the infiltration rate times the duration times depth.

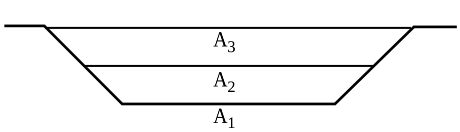
$$\begin{aligned} F &= (I)(\text{duration}) \\ &= (.004 \text{ in/hr})(24 \text{ hr/d})(7 \text{ days}) \\ &= .672 \text{ in, or } 0.7 \text{ in} \end{aligned}$$

***(ii) Total losses***—Total losses are based on a depth in inches over 1 acre of playa area. To find total losses, use the following equation:

$$\begin{aligned} L &= E_d + S_{wl8} + F \\ &= 1.7 + 1.9 + .7 \\ &= 4.3 \text{ inches} \end{aligned}$$

***(iii) Adjustment factor***—The playa shape factor takes into account that the top area is always greater than the base, thus, the base measurements are increased by 1.13 adjustment factor ($P_s$). The playa shape factor is developed for several playas in the general area. This factor is the ratio of the surface area for the playa ground surface area and the surface area for the next elevation.

$$P_s = \frac{\frac{A_2}{A_1} + \frac{A_3}{A_2} + \cdots \frac{A_n}{A_{n-1}}}{n}$$




***(iv) Procedure used to determine 7-day playa inundation***—The following steps need to be followed to determine whether the playa area is inundated for a 7-day period:

- Determine playa size ($P_a$) in acres.
- Determine losses in acre-inches by multiplying $P_a$ times losses in inches L then times the adjustment ($P_s$).
- Determine the contributing drainage area ($\Delta_m$) necessary to satisfy losses, divide the total losses determined above by the 50 percent chance runoff.

The equation becomes:

$$\Delta_M = \frac{(P_s) \times (P_a) \times (L)}{(50\% \text{ chance runoff})}$$

$$= \frac{1.13 \times P_a \times 4.3}{0.16} = 30.5 P_a$$

where:

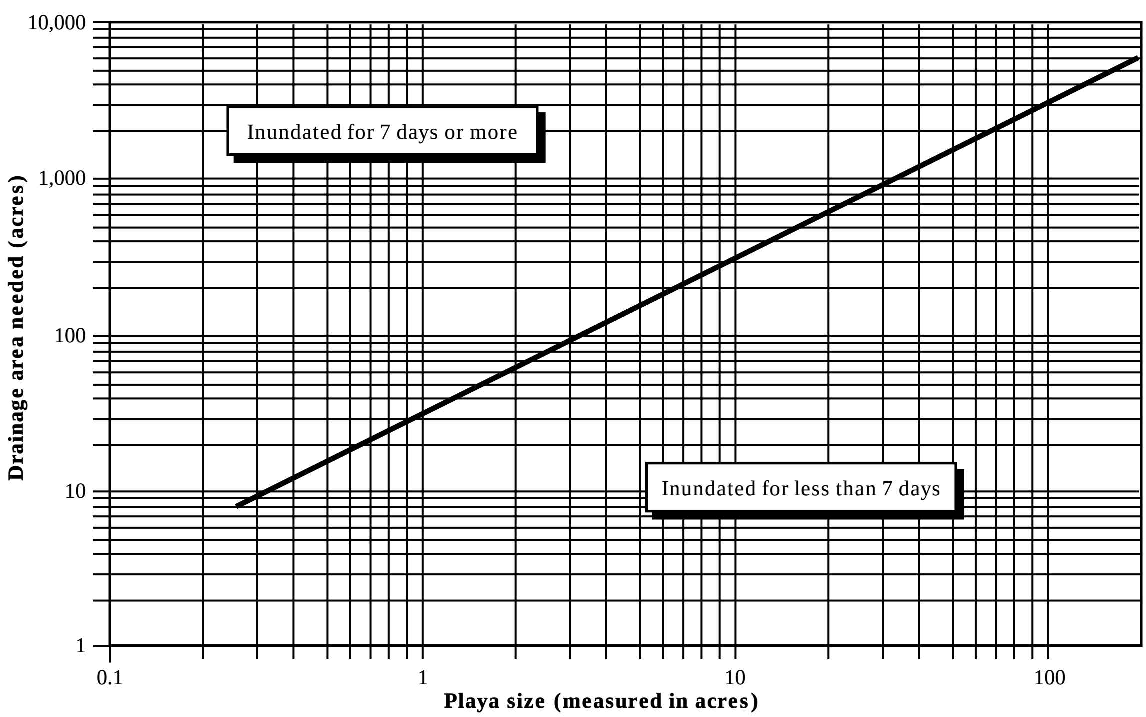
$\Delta_M$ = minimum drainage area required to supply the required runoff to satisfy duration criteria
$P_s$ = playa storage adjustment factor (normally 1.15)
$L$ = playa loss (inches)
$P_a$ = playa surface area acres

When the actual drainage acres are less than required to satisfy the losses, it would be assumed not to be inundated for a 7-day period from a hydrologic standpoint. When the actual drainage acres are larger than needed to satisfy the losses, it would be assumed to be inundated for a 7-day period.

Figure 19–6 shows the 7-day inundation graph for Kearny County, Kansas. The drainage area needed to satisfy the playa losses can be determined using this graph by knowing the playa acres, moving up to the diagonal line, and then moving left horizontally to read drainage area in acres. If the drainage area is above the line, it is inundated for 7 days or more; and if it is below the line, it is inundated for less than 7 days. The graph is based on an 18-inch soil depth, a 50 percent chance maximum runoff event, evaporation, and soil-water holding capacity. A graph is needed for each playa type, soil, and county or climatic zone. Figure 19–6 is the graph of runoff events versus graph of playa size.

Thus for a 1-acre playa area wetland, 30 acres of drainage area would be required to provide sufficient water to meet assumed wetland criteria. If 15 acres of drainage area were uncontrolled, 0.5 acres of playa wetland would meet the assumed criteria.

**Figure 19–6** 7-Day inundation graph, Kearny County, Kansas



## 650.1903 Supplemental data for remote sensing

### (a) Applicable situations for use

Remote sensing provides procedures to help document the wetland hydrology associated with mapping conventions. This documentation also helps to determine which years of aerial photograph signatures can be correlated with hydrology of natural wetlands and thus provides independent validation of the wetland hydrology. The procedures are:

Procedure 1 Use of precipitation data to help select the years that signatures indicating wet conditions might be seen on aerial photos.

Procedure 2 Use of precipitation data to document the frequency of signature in humid climates.

Procedure 3 Use of runoff volumes to document wetland hydrology in semiarid areas, such as western Kansas.

### (b) Data required

The data required are:

- Daily or monthly precipitation from a long-term, nearby climatic station is needed for procedures 1 and 2.
- Long-term daily or monthly runoff volume is needed for procedure 3.

### (c) Limitations

**(1) Knowledge and experience required**
General knowledge of climate, wetland signatures, and how to interpret rain and runoff data is required. Knowledge of the local agricultural practices improves the quality of photo interpretation.

**(2) Climatic regions of applicability**
Procedures 1 and 2 are applicable to all climate regions. Procedure 3 is applicable in semiarid regions only.

**(3) Factors affecting the accuracy of results**
The accuracy of the meteorological data has a significant impact on the results. Saturation and/or inundation has to be observed for a specified duration and frequency during the growing season to establish that the wetland hydrology criterion has been met. An aerial photograph only represents conditions at that point in time. An aerial photograph used alone does not provide sufficient information to establish that the wetland hydrology criterion has been met.

The hydrological conditions need to be established for proper interpretation of wetland signatures on aerial photographs. Precipitation data are widely available for long periods of time and may be used to determine the antecedent moisture conditions.

### (d) Sources of information

Precipitation data can be obtained from the NRCS National Water and Climate Center, Portland, Oregon.

Various stream gage data are published. They include mean daily discharge, mean daily stage, peak stage and discharge for flood events, and mean daily lake level. The primary sources for these data are the USGS Water Resources Data publications for each state. Stream and lake gage readings are also available from Corps of Engineers, TVA, USGS, NOAA, BOR, various highway departments, and state or local public works agencies.

Various computer models can also be used to determine the daily runoff volumes. This approach is discussed in the previous section.

### (e) Methodology

**(1) Rainfall data for procedures 1 and 2**
Determine the climate station nearest to the site that has sufficient records to have had statistical information calculated for it. Obtain precipitation data for the site. For procedure 1, annual data are sought. For procedure 2, monthly rainfall totals during the growing season are the desired data. Both procedures require use of the WETS table available on the Internet. The internet address for WETS table and associated documentation is www.wcc.nrcs.usda.gov. The WETS table

is on the National Water and Climate Center's home page of NRCS. This table identifies the boundary where 3 in 10 of the precipitation amounts are wetter than normal value and the boundary where 3 in 10 values are drier than normal. Normal is considered to be values that fall between these two boundaries.

### (2) Procedure 1

Precipitation data are used to help select years that signatures might be seen on aerial slides.

***Step 1***—Determine what aerial photographs are available. Plan to use at least 5 years for the analysis so 5 to 10 years will be examined, depending on how many normal years are anticipated.

***Step 2***—Compare the annual rainfall total for each year to the annual boundaries for wet and dry as mentioned above in the rainfall data section.

***Step 3***—Select years where normal precipitation was experienced for the year. These years will be key in determining whether wetland hydrology is present or not on a site. If less than 5 normal years are available, use an equal number of wet and dry years after discarding years where the rainfall was extremely high or low. Review the signatures in all the available years of flights, but concentrate on the normal years. Note slides where further records may need to be checked in case an extreme event occurred that was within normal for the year, but may have been extreme as a single event for a single month.

***Step 4***—If state mapping conventions are to be developed from the years selected in this process, study data from several sites before determining which years are to be used for the valuation. If a wet signature appears for a site only in wet years, a good probability exists that wetland hydrology is not present under normal circumstances. If a wet signature is seen in both dry and wet years, the site may well meet wetland hydrology criteria. Where the signatures appear in wet and normal years, further study is needed to determine whether wetland hydrology exists on the site.

### (3) Procedure 2

Precipitation data are used to document the frequency of wet signatures in humid climates.

***Step 1***—Complete the general information on figure 19–7 for the year to be evaluated. Determine the date the photograph was taken or estimate it based on information available. Decide which three months will be used to represent the climatic conditions that existed prior to the time the photograph was taken. For example, if a photo was taken July 1, April, May, and June would be the most likely choices for the three prior months. However, if the photo was taken July 22, May, June, and July would be logical choices, provided no extreme events occurred in late July that would alter the wetness condition for that month. Enter the chosen months in the first column in figure 19–7.

***Step 2***—Enter the monthly rainfall totals in column 5. Enter the wet and dry boundaries and the monthly normal from the WETS table in columns 4, 2, and 3 respectively.

***Step 3***—Compare the actual rainfall in column 5 to the boundary values in columns 2 and 4 and determine if the actual rainfall was more than the upper boundary (thereby wet), less than the lower boundary (thereby dry), or between the two boundary values (thereby normal). Enter this condition in column 6.

***Step 4***—Using the small table of condition values in figure 19–7, enter the correct number (1, 2, or 3) in column 7 to correspond to the condition in column 6.

***Step 5***—Multiply the condition value in column 7 by the monthly weight value in column 8 and place the result in column 9. Sum the three values in column 9 and place the total below the three boxes.

***Step 6***—Compare this total to the sums in the small table in figure 19–7 to determine whether the evaluation for that year's slide is wet, normal, or dry.

**Figure 19–7** Rainfall documentation worksheet

## Rainfall Documentation
## (use with photographs)

Date: _____________

Weather station: ______________________ Landowner: _____________________________ Tract no.: ___________

County: ______________________ State:___________________

Soil name: ___________________ Growing season: _______________________

Photo date: ______________

| | | Long-term rainfall records | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Month | 3 yrs. in 10 less than | Normal | 3 yrs. in 10 more than | Rain fall | Condition dry, wet, normal | Condition value | Month weight value | Product of previous two columns |
| 1st prior month* | | | | | | | | 3 | |
| 2nd prior month* | | | | | | | | 2 | |
| 3rd prior month* | | | | | | | | 1 | |
| | | | | | | | | Sum | |

* Compared to photo date

Note: If sum is
- 6 - 9 then prior period has been drier than normal
- 10 - 14 then prior period has been normal
- 15 - 18 then prior period has been wetter than normal

Condition value:
- Dry =1
- Normal =2
- Wet =3

Conclusions:

Using the worksheet, Wetland Hydrology Determination, Summary and Conclusion (fig. 19–8), summarize the years of information recorded on each Rainfall Documentation worksheet. This will help document the process for concluding if wetland hydrology exists. The following steps should be used to complete the summary worksheet:

***Step 1***—Complete general information.

***Step 2***—Complete the first five columns using information from the Rainfall Documentation worksheet. After entering the weighted sum in column 2, place an **X** in columns 3, 4, or 5, as appropriate being certain to mark only one box. View appropriate photo and indicate in column 6 if wetland hydrology signature was observed. Comments should be entered in column 7.

***Step 3***—Complete the three narrative paragraphs using the data in the summary table. Circle either **does** or **does not** in the fourth narrative paragraph. Correlate mapping conventions (signature) with the precipitation data. If the signature occurred in both wet and dry years, the area is wet. If the signature only occurred in wet years, additional review of the signature is needed. If the signature occurred in wet and normal years, the area needs additional study.

### (4) Procedure 3

The methodology for procedure 3 follows. This procedure should be used in those areas where the growing season precipitation is random and limited. A good example is western Kansas.

***Step 1***—Generate the long-term monthly surface runoff volumes using one of the runoff volume tools described in the previous section. Sum the monthly runoff volumes for the growing season for each year.

***Step 2***—Develop a frequency curve of growing season surface runoff volumes using statistical techniques. The statistical techniques are outlined in chapter 18, NEH-4.

***Step 3***—Obtain the available FSA aerial photographs and note the flight dates. Use only one photograph per year. The selected photograph should represent the growing season, if possible.

***Step 4***—Determine the percent chance of occurrence for the seasonal surface runoff for each selected year.

***Step 5***—Determine surface runoff for the period of concern before the date of photograph using the procedures in step 2.

***Step 6***—Determine the percent chance of occurrence for the period from the frequency curves developed in step 2.

***Step 7***—Develop a table for the selected events using a format similar to that shown in table 19–8.

***Step 8***—A wet runoff season exists if the percent chance of occurrence is smaller than 50 percent. Record a mark in the Hit column if a positive hit can be identified for the year. A positive hit on the FSA slide indicates ponding, saturation, or flooding.

***Step 9***—If there are more hits than wet years, the wetland may be caused by imported water or supported by groundwater. If the number of hits is less than the number of wet years, the wetland is being starved or drained, or the drainage area may not be large enough to support a wetland.

**Table 19–8** Selected runoff events

| Year | Surface runoff occurrence (%) | Wet year | Hits |
|---|---|---|---|
| 1990 | 10 | X | H |
| 1989 | 5 | X | H |
| 1988 | 75 | | |
| 1987 | 65 | | |
| 1986 | 30 | X | H |
| **Number** | | **3** | **3** |

**Figure 19–8** Wetland hydrology determination worksheet

**Wetland Hydrology Determination**
**Summary & Conclusion**

Date: ______________________________ Prepared by: ____________________________

County: ____________________________ Landowner: _____________________________

State: ______________________________ Tract no.: ______________________________

**Summary**

| Year (1) | Weighted sum (2) | Rainfall condition Dry (3) | Normal (4) | Wet (5) | Photo record wetness (6) | Comments (7) |
|---|---|---|---|---|---|---|
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The above is a tabulation of __________ years of record. There were _______ years of normal rainfall conditions and wetness was observed in ________ of those normal years.

There were ________ years with drier than normal condition, and wetness was observed in ___________ of those dry years.

There were ________ years with wetter than normal condition, and wetness was observed in __________ of those wet years.

It is my determination that the area (*does* or *does not*) meet wetland hydrology frequency requirements.

The duration of flooding or ponding is estimated to be ___________ days.

Comments:

## (f) Sample documentation

### (1) Sample 1

Sample 1 is documentation for procedure 1. In Nelson County, several years of aerial photographs with wetland signatures need correlation with hydrology. The normal annual precipitation for Nelsonville in Nelson County is 23.6 inches for 1961 to 1990 (table 19–9). The 3 year in 10 year precipitation is 17.7 and 29.5 inches, respectively.

In sample 1, 1984, 1985, 1988, 1989, and 1990 were selected to correlate signature with precipitation. This would be the minimum number of flights to use. The correlation of the signatures with the information would be improved by using all the available flights. The sample years selected for analysis encompass normal, wet, and dry condition.

### (2) Sample 2

Sample 2 is the documentation for procedure 2. D. Wood selected the available photo during the growing season for a farm in Washington County, Oregon. Five years of flights were available for the D. Wood farm (fig. 19–9 and 19–10).

**Table 19–9** Precipitation in Nelsonville, Nelson County, 1982 to 1990

| Year | Total precipi-tation (inches) | 3 in 10 year condition D = dry N = normal W = wet | Photos N = no Y = yes |
|---|---|---|---|
| 1982 | 25.4 | N | |
| 1983 | 22.1 | N | |
| 1984 | 17.5 | D | Y |
| 1985 | 16.2 | D | Y |
| 1986 | 24.8 | N | Y |
| 1987 | 23.8 | N | Y |
| 1988 | 29.6 | W | Y |
| 1989 | 23.1 | N | Y |
| 1990 | 31.3 | W | Y |
| **Normal** | **23.6** | | |

**Figure 19–9** Completed rainfall documentation worksheet

**Rainfall Documentation**
**(use with photographs)**

Date: 5-31-93

Weather station: Hillsboro

Landowner: D. Wood

Tract no.: ____

County: Washington

State: OR

Soil name: ____

Growing season: 3/7 - 11/15

Photo date: 6/86

| | Month | Long-term rainfall records: 3 yrs. in 10 less than | Normal | 3 yrs. in 10 more than | Rain fall | Condition dry, wet, normal | Condition value | Month weight value | Product of previous two columns |
|---|---|---|---|---|---|---|---|---|---|
| 1st prior month* | May | 1.06 | 1.62 | 1.94 | 2.04 | W | 3 | 3 | 9 |
| 2nd prior month* | Apr. | 1.50 | 2.15 | 2.56 | 1.47 | D | 1 | 2 | 2 |
| 3rd prior month* | Mar. | 2.67 | 4.02 | 4.81 | 3.47 | N | 2 | 1 | 2 |
| | | | | | | | | Sum | 13 |

* Compared to photo date

Note: If sum is
- 6 - 9 then prior period has been drier than normal
- 10 - 14 then prior period has been normal
- 15 - 18 then prior period has been wetter than normal

Condition value:
- Dry =1
- Normal =2
- Wet =3

Conclusions: This year represents normal conditions.

Similar sheets were completed for the other years shown on the next page.

**Figure 19–10** Completed wetland hydrology documentation worksheet

**Wetland Hydrology Determination**
**Summary & Conclusion**

Date: 5-31-93 Prepared by: [illegible]

County: Washington Landowner: D. Wood

State: OR Tract no.: ______

**Summary**

| Year (1) | Weighted sum (2) | Rainfall condition Dry (3) | Normal (4) | Wet (5) | Photo record wetness (6) | Comments (7) |
|---|---|---|---|---|---|---|
| | | | | | | |
| 1986 | 13 | | x | | yes | |
| 1987 | 11 | | x | | yes | |
| 1988 | 16 | | | x | yes | |
| 1989 | 11 | | x | | yes | |
| 1991 | 17 | | | x | yes | |
| | | | | | | |
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| | | | | | | |

The above is a tabulation of 5 years of record. There were 3 years of normal rainfall conditions and wetness was observed in 2 of those normal years.

There were 0 years with drier than normal condition, and wetness was observed in 0 of those dry years.

There were 2 years with wetter than normal condition, and wetness was observed in 2 of those wet years.

It is my determination that the area (*does* or *does not)* meet wetland hydrology frequency requirements.

Comments:

# 650.1904 DRAINMOD

## (a) Applicable situations for use

DRAINMOD (version 4.6) was developed for describing the water balance between parallel drainage ditches or drain tubes. Thus, it is reliable for wetland analysis only for those lands that have parallel drainage systems.

DRAINMOD was developed by Dr. R.W. Skaggs to simulate the performance of water table management systems. It was first used as a research tool to investigate the performance of drainage and subirrigation systems and their effects on water use and crop response. DRAINMOD has been modified to facilitate its use for wetland analysis.

Version 4.6 incorporates a counting procedure that determines how many days the area is wet and the number of occurrences in a given year. This information helps document the frequency and duration of saturated field condition.

Technology used in DRAINMOD—The equations used in DRAINMOD were developed by Hooghoudt, Cuthin, Kirkham, and Ernst to calculate drainage rates. Infiltration rates are predicted by the Green and Ampt equation. Surface drainage is characterized by the average depth of depressional storage. Kirkham's equation is used for developing the effects of ponded water.

## (b) Data required

The data required to successfully run DRAINMOD are:

- Hourly precipitation data.
- Daily minimum and maximum temperatures or potential evapotranspiration data.
- Drainage parameters:
  - — depth from the soil surface to the drain
  - — drain spacing
  - — effective radius of the drains
  - — distance from the drain to the restrictive layer
  - — drainage coefficient
  - — storage in local depressions
  - — maximum surface storage
- Soil parameters:
  - — lateral saturated hydraulic conductivity by soil layers
  - — soil water characteristic by soil layers
  - — volume of water free to drain by soil layers
  - — upward flux
  - — Green and Ampt parameters
  - — water content at permanent wilting point
- Growing season information:
  - — threshold water table depth
  - — required duration of high water
  - — beginning and ending dates for growing season

## (c) Sources of information

Climatic data are available from the National Water and Climate Center in Portland, Oregon. The climatic data liaison in each NRCS state office can access the data in the proper format for the program.

The soils information necessary to run DRAINMOD is available on disk from the National Soil Survey Laboratory, Lincoln, Nebraska. A soil preparation program, DMSOIL, is needed to convert the data from the Soil Interpretation Records into format for DRAINMOD.

Information about DRAINMOD software and training can be obtained at http://www.bae.ncsu.edu/research/soil-water/www/watmngmnt/drainmod.

## (d) Limitations

### (1) Knowledge and experience required

Knowledge of the input requirement and output of the computer program and its limitations and applications is required. Normally this involves at least 1 week of training.

### (2) Climatic regions of applicability

DRAINMOD is applicable to humid and subhumid regions.

### (3) Factors affecting the accuracy of results

The reliability of the model predictions is verified in extensive field experiments. Tests in North Carolina indicate that daily water table depths can be predicted within 0.1 meter of the actual depth on the average. However, DRAINMOD cannot be directly applied to lands that receive runoff from adjacent areas, such as potholes or large depressions.

## (e) Methodology

Appendix F to the DRAINMOD user guide sets forth the modifications made to produce version 4.6, which can be used for wetland analysis. Full details on the use of DRAINMOD are set forth in the user guide. Appendix F is reproduced here for your use.

# Appendix F DRAINMOD 4.6, Hydrologic Analysis of Wetlands

DRAINMOD describes the soil-water balance for shallow water table soils. Water table depth is predicted on a day-by-day basis. Thus, it can be used to characterize the hydrology of certain types of wetlands. Further, DRAINMOD simulations can be used to determine if the hydrology of a particular site has been modified so that wetland hydrology is no longer satisfied.

This appendix presents a brief description of modifications made to DRAINMOD to facilitate its use for wetland analysis.

***Note:*** DRAINMOD was developed for describing the water balance between parallel drainage ditches or drain tubes. Thus, it will be reliable for WETLAND analysis only for those lands that have parallel drainage systems. With careful attention to the inputs, it is possible to analyze some lands that have very poor natural drainage. However, DRAINMOD cannot be directly applied to lands that receive runoff from adjacent areas, such as potholes or large depressions.

## Inputs

Inputs for wetlands analysis are needed on four data screens that are accessed through DMSHELL. Two of the screens are the General Information screens that have been modified to include information necessary for wetland analysis. Screen 1 (fig. 19–11) allows a constant monthly potential evapotranspiration (PET) value to be read in as a weather data option. Screen 2 (fig. 19–12) provides a choice for making hydrologic analyses for wetlands. If yes (Y) is chosen for the hydrologic analysis for wet soil conditions, a third screen requests information required for the analysis (fig. 19–13).

Wetland hydrologic criteria are entered in the following general form.

A site has wetland hydrology if the water table is less than a given depth (WTDWET) for a certain number of consecutive days (DAYSWET) during the growing season under average conditions. Average conditions are generally interpreted to mean that the criteria are met in at least 50 percent of the years (10 out of 20, 15 out of 30, etc.)

The inputs required in DRAINMOD are given in figure 19–12. They are:

- The first day of the growing season, IWST (Julian Day)
- The last day of the growing season, IWEND (Julian Day)
- The threshold water table depth, WTDWET (cm)
- The number of consecutive days required, DAYSWET

The other modification allows daily average PET values to be read in for each month (fig. 19–14). These values are read as centimeters. ***Note:*** A temperature file is still required, but the PET values read in will be used in the calculations.

## Outputs

All outputs available for the general DRAINMOD program are also available for this application. In addition an output with the extension WET is printed in the output file. An example is given in figure 19–15. The summary includes a year-by-year list of the number of periods meeting the criteria and the longest period in each year that satisfies the water table depth criterion. In the example given in figure 19–15, the water table is at the soil surface 11 out of 20 years.

**Appendix F** DRAINMOD 4.6, Hydrologic Analysis of Wetlands—Continued

**Figure 19–11** General inputs screen 1

```
File:     c:\dm46\inputs\wetintro.gen
Screen:   General Information - 1 of 2

Title to Identify Run:

Printing Options (Y/N):

          (N)  Rankings Only
          (N)  Yearly and Rankings
          (Y)  Monthly, Yearly and Rankings
          (N)  Daily, Monthly, Yearly and Rankings
          (N)  Mrank Version of Rankings (Adv. Option)

(N) Output for each year for daily water table graphs (Y/N)

Weather Data Options (Y/N):
          (Y)  Temperature File";
          (N)  Potential Evapotranspiration File ";
          (N)  Constant Monthly PET ";

 F1     F2     F3   F4   F5    F6     F7     F8      F9      F10
HELP   RESET                  EXIT  ABORT  CLEAR  LASTSCR  NEXTSCR
```

**Figure 19–12** General inputs screen 2

```
File:     c:\dm46\inputs\wetintro.gen
Screen:   General Information - 2 of 2"

Subsurface Water Management Options:

          (Y)  Conventional Drainage        Move cursor to select option
          (N)  Controlled Drainage          and press <Y>
          (N)  Subirrigation
          (N)  Combo: Drainage-Controlled Drainage-Subirrigation
                 NOTE: COMBO Must be on in Config.dm (Advanced Option)

Surface Water Management Option (Y/N)    :

          (N)  Waste Water Irrigation Application

          (Y)  Hydrologic Analysis for Wet Soil Conditions (Advance Option)

 F1     F2     F3   F4   F5    F6     F7     F8      F9      F10
HELP   RESET                  EXIT  ABORT  CLEAR  LASTSCR  NEXTSCR
```

**Appendix F** DRAINMOD 4.6, Hydrologic Analysis of Wetlands—Continued

**Figure 19–13** Inputs required for wetland analysis

```
File:    c:\dm46\inputs\wetintro.gen
Screen:  Hydrology Analysis for Wet Conditions 1 of 1

         Name   Value    Description


Starting and Ending days for Checking:
         IWST   66       Starting Day of the Year
         IWEND  332      Ending Day of the Year

Maximum Allowable Water Table Depth and Lenth of Period:

         WTDWET          30        Water Table Depth in cm
         DAYSWET         14        Length of period to count in days

************************************************************************************
***WARNING===> This is an experimental release. Tests and        ***
*** evaluations of this version of DRAINMOD are being done       ***
************************************************************************************

F1    F2     F3   F4   F5    F6    F7     F8     F9       F10
HELP  RESET                  EXIT  ABORT  CLEAR  LASTSCR  NEXTSCR
```

**Figure 19–14** Average daily PET values may be read in for each month

```
File:    c:\dm46\inputs\wetintro.gen
Screen:  Weather Inputs (Monthly PET Option) - 2 of 2


         Average Daily PET (cm)

          January        0.08
          February       0.15
          March          0.23     ***************************************************
          April          0.31     *NOTE:  VALID TEMPERATURE FILES  *
          May            0.38     *       ARE REQUIRED.  THIS      *
          June           0.43     *       SCREEN PROVIDES THE      *
          July           0.40     *       ACTUAL PET VALUES USED   *
          August         0.36     *       BY DRAINMOD              *
          September      0.31     ***************************************************
          October        0.18
          November       0.13
          December       0.08

F1    F2     F3   F4   F5    F6    F7     F8     F9       F10
HELP  RESET                  EXIT  ABORT  CLEAR  LASTSCR  NEXTSCR
```

**Appendix F** DRAINMOD 4.6, Hydrologic Analysis of Wetlands—Continued

**Figure 19–15** Sample output for wetland analysis

```
            -------------------------------------------------------------------
            *              DRAINMOD version 4.60a                             *
            *              Copyright 1990-91 North Carolina State University  *
            -------------------------------------------------------------------

  ANALYSIS OF WETLAND HYDROLOGIC CRITERIA FOR portswet SOIL AT WILMINGTON N.C. for
  FOREST:100m D/SPACING, STMAX=4.0cm, thwtd=3ocm/14days, Ksat=6
  ***************************************************************************************************


  ------------RUN STATISTICS-------------                 time: 10/ 6/1991  @ 22:46
  input file:                           c:\DM46\INPUT45\P10S4D4.LIS
  parameters:      free drainage                          and yields not calculat
              drain spacing= 10000. cm                    drain depth= 120.0 cm
  ---------------------------------------------------------------------------------------------------


                             D R A I N M O D --- HYDROLOGY EVALUATION
                            ******** INTERIM EXPERIMENTAL RELEASE*****

                      Number of periods with water table closer than 30.00 cm
                           for at least 14 days.  Counting starts on day
                                68 and ends on day 332 of each year


   YEAR            Number of Periods              Longest Consecutive
                     of 14 days or                  Period in Days
                     more with WTD
                       <30.00 cm

   1968                     0.                            0.
   1969                     2.                           26.
   1970                     2.                           37.
   1971                     1.                           16.
   1972                     0.                            0.
   1973                     2.                           21.
   1974                     2.                           28.
   1975                     0.                            7.
   1976                     0.                           12.
   1977                     0.                           11.
   1978                     0.                            8.
   1979                     2.                           34.
   1980                     1.                           26.
   1981                     0.                           13.
   1982                     0.                           13.
   1983                     1.                           28.
   1984                     2.                           25.
   1985                     0.                            0.
   1986                     1.                           14.
   1987                     1.                           14.

   Number of Years with at least one period =            11.
```

# 650.1905 Scope and effect equations

## (a) Applicable situations for use

Numerous water table drawdown equations are available. These equations will not help to determine the extent of natural wetlands, but can be used to determine whether existing drainage systems are sufficient to remove wetland hydrology from a site.

The impact or effectiveness of a surface drainage system can be evaluated using the procedures outlined in Drainage of Agricultural Lands, National Engineering Handbook, section 16 (NEH 16).

The ellipse equation may be used where wetland hydrology is the result of a high water table with a restrictive soil layer and the hydrology has been altered with drains. If lowering of the water table for specified duration is all that is required to define wetland hydrology, then the ellipse equation is satisfactory to approximate this situation.

## (b) Data required

The following parameters for the ellipse equation are required:

- average saturated hydraulic conductivity K
- parallel drain or ditch spacing
- depth of barrier or impervious layer
- drainage rate
- depth to drain
- vertical distance, after drawdown, of water table above the drain and at midpoint between drains

## (c) Limitations

### (1) Knowledge and experience required

General knowledge of the ellipse equation and its application is required.

### (2) Climatic regions of applicability

The ellipse equation is applicable to humid climates.

### (3) Factors affecting the accuracy of results

This equation assumes no inflow to the wetland from surface flow. It is also assumed the outlet is adequate and has been maintained. Significant surface inflow reduces the accuracy of the answer.

After the water table starts to drop, rainfall can occur any time between the first and last day of the evaluation period. The ellipse equation as developed considered the volume of water removed as equivalent to the rainfall volume during the removal period. In its application here, the volume of water removed in lowering of the water table during the removal period is substituted for rainfall volume. Rainfall during this period decreases the accuracy of the answer.

When rainfall occurs, a certain amount infiltrates into the soil; a certain amount leaves the wetland area as surface runoff, and a certain amount accumulates in depressions, remaining available for infiltration at some later time. Major factors affecting these various components are rainfall amount and intensity, surface roughness, initial soil moisture, and vertical hydraulic conductivity. The spacing or impact of the drains may be approximate because infiltration was not considered.

The ellipse equation does not consider the effect of evaporation on the water table. During the height of the growing season, the influence of evapotranspiration (ET) on the water table drawdown is equal to or greater than that caused by drainage. ET is not usually significant early in the growing season when many of the wetter periods may occur.

Assumptions made in the development of the ellipse equation make it important to use this equation under the following conditions:

- Where ground water flow is known to be largely in the horizontal direction.
- Where the barrier to flow lies at twice the depth of the drain or less to restrict natural flow and flow water to move horizontally toward the drain.
- Where open ditches or drains with sand and gravel filters are used so that restrictions to flow into drains are managed.

## (d) Sources of data

The depth to the impermeable layer below the drain is estimated from local soil information or, in the field, it is generally determined by boring holes. The holes generally are dug to a depth approximately one and one-half times the actual depth of the drain. The textural changes that occur between horizons are observed. The changes in texture may be determined by feeling the soil. The layer considered impermeable is high in clay content, continuous over a major portion of the site, and of such thickness as to provide a positive deterrent to the downward flow of water.

A commonly used rule of thumb is that the estimated hydraulic conductivity of the barrier must be less than 10 percent of the overlying layer. Other potential sources for determining the depth to the barrier are available; however, professional judgment must be exercised when using these sources if they are not adjacent to the site in question. Other sources include:

- Observation well logs
- Logs from geological investigations
- Road and channel cuts

Hydraulic conductivity is the saturated horizontal hydraulic conductivity, as the flow to the drains is generally horizontal. In soils that have strata of differing textures and structures, the difference between horizontal and vertical hydraulic saturated conductivities can be significant. The horizontal K generally is larger than the vertical K. For layered soils, equivalent K may be computed using the following equation:

$$\text{Equivalent K} = \frac{K1T1 + K2T2 + K3T3}{T1 + T2 + T3}$$

where:
K = the hydraulic conductivity
T = thickness of each layer

Specific measurements of K should be made where possible. Numerous methods have been developed to measure saturated K in the field. The method most commonly used is the auger hole method described in NEH-16, chapter 2.

In the absence of onsite measurements, the hydraulic conductivity may be calculated using the computer program DMSOILS.

The volume of water drained at various water table depths can be measured directly from large soil cores. However, it is not usually practical to collect large soil cores in many sites, so the drainage volume is derived from the soil moisture retention data. The DMSOILS computer program can provide an estimate of this parameter, which can also be estimated using the soil drainage porosity. Soil information in the DMSOILS computer program can be obained from the local NRCS office.

## (e) Methodology

### (1) Ellipse equation

The equation was originally developed to approximate economical spacings and depths of agricultural drain tubing and ditches for agricultural crops. It is also used to determine if the hydrology of the wetland has been modified by existing drainage measures for optimal crop production. The usual requirement is to lower the water table below the root zone in 24 to 48 hours after saturation. The ellipse equation is:

$$S = \sqrt{(4K)\frac{\left(m^2 + 2am\right)}{q}}$$

where:
S = parallel drain spacing (ft) (see fig. 19–16)
K = weighted hydraulic conductivity above the restrictive layer (in/hr)
m = vertical distance (d – c), after drawdown, of water table above drain and at midpoint between drains (ft)
where:
d = depth to drain from the surface (ft)
c = depth to the water table drawdown after the evaluation period (ft)
a = depth of barrier (impermeable layer) below drains (ft)
q = drainage rate (in/hr)

This equation was developed for parallel drains. The drainable rate q as used for this application is the volume of water that will drain from a known volume of saturated soil through the forces of gravity (g) divided by the duration of saturation (t).

$$q = \frac{v}{t}$$

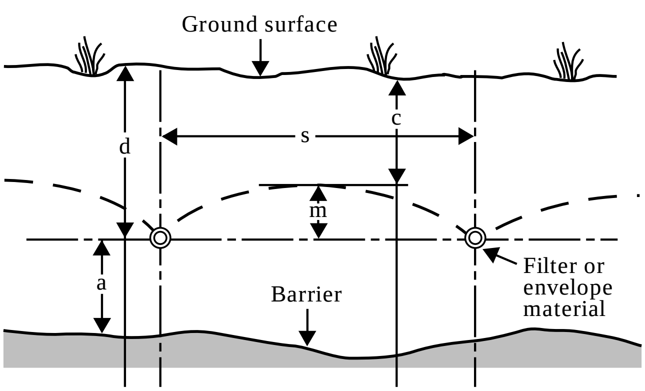
A more accurate analysis of the scope and effect of drainage systems on wetland hydrology can be obtained by using the ellipse equation with drainage coefficients developed from field trials combined with mathematical modeling, such as DRAINMOD.

## (f) Sample documentation

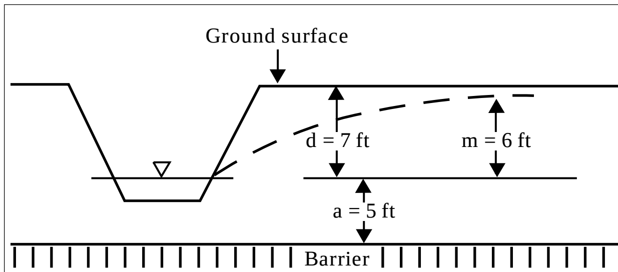
Example 19–4 shows the steps to determine the effects of a drain on the hydrology of the wetland. For this example, assume the duration of drawdown is 14 days, the drainage porosity (F) is 0.05 foot per foot, and the depth (c) of drawdown at the midpoint is 1 foot.

With the given values of the parameter, the water table midway between the drains would be lowered by 1 foot from the soil surface during a 14-day period if the drains were spaced at 494 feet apart. If the drains were spaced at or closer than 494 feet, the entire strip of land between the drains is effectively drained and will not have wetland hydrology. On the other hand, if the drains were spaced farther apart, there would be a strip between the drains bounded by a line 247 feet from each drain that would still have wetland hydrology. If only one drain exists, areas outside a line 247 feet from the drain would still have wetland hydrology.

**Figure 19–16** Parallel drain spacing




**Example 19–4** Steps to determine effects of a drain on hydrology of wetland




**Step 1** $m = d - c = 7 - 1 = 6$ ft

**Step 2** $K = 1.14$ in/hr (24 hr/d) = 27.36 in/d

**Step 3** v = (F)(c) or v may be obtained from the soil properties

q = (0.05 ft/ft)(1 ft) = 0.05 ft

Converted to inches:

q = (0.05 ft)(12 in/ft/ft) = 0.6 inch

**Step 4** $$q = \frac{v}{t} = \frac{0.6 \text{ in}}{14 \text{ d}} = 0.043 \text{ in / d}$$

**Step 5** $$S = \sqrt{(4K)\frac{\left(m^2 + 2am\right)}{q}}$$

**Step 6** $$S = \sqrt{4(27.36 \text{ in / d})\frac{\left[(6)^2 + 2(5 \text{ ft})(6 \text{ ft})\right]}{0.043 \text{ in / d}}}$$

$S = 494$ ft

#### (2) Other equations

***Hooghoudt equation***—This equation is similar to the ellipse equation except the parameter **a**, depth to the impermeable layer from the free water surface in the drain, is replaced by $\mathbf{d_e}$, or the effective depth. Many researchers agree that this substitution makes the equation more accurate and widely applicable. This equation is meant to be applied with no standing water above the tile line(s).

***van Schilfgaarde equation***—While the ellipse equation uses steady state assumptions, the van Schilfgaarde equation was developed for nonsteady state. It includes a parameter for time so that different lengths of time for the duration of saturation can be examined. It is most easily applied using a spreadsheet, as a two-step iteration process is recommended to use the effective depth in place of actual depth, such as was described for the Hooghoudt equation. The van Schilfgaarde equation is meant to be applied with no standing water above the tile line(s).

***Kirkham's equation***—Kirkham's equation simulates the gradual lowering of the water ponded above a tile line or system. It is often combined with the Hooghoudt or van Schilfgaarde equation to describe the total removal of the water. Kirkham's equation calculates the time to remove the ponded water, and the other drainage equation determines the time to remove the saturation to the specified depth. Kirkham's equation is meant to be applied where the tile line(s) lies directly under the wetland, but the site has no surface intake and water ponds.

## 650.1906 NRCS drainage guides

### (a) Applicable situations for use

NRCS state drainage guides, developed by a committee composed of soil scientists, engineers, technicians, and agronomists, contain information that can help in the determination of wetlands. Drainage guides help define and interpret some of the soil-water characteristics. Drainage guides are in NRCS field offices in each county where drainage measures have been installed. If the tile or ditch spacing is equal to or less than suggested spacing in the guide, it can be assumed on a screening basis that the wetland hydrology has been removed.

### (b) Data required

The data required to use NRCS drainage guides include:

- Soil name and the depth and spacing of drainage measures.
- The adequacy of the outlet conditions.

### (c) Limitations

#### (1) Knowledge and experience required

An understanding of the guide and its use is required.

#### (2) Climatic regions of applicability

The NRCS drainage guides are applicable to all climate regions for which they were developed.

#### (3) Factors affecting the accuracy of results

Drainage guides can be an effective screening tool to help to establish the presence or absence of hydrology in a potential wetland. The drainage guide should be up-to-date. Where the drainage system is properly maintained with an adequate outlet, drainage guides can be used by the field office to help determine if the wetland hydrology has been removed.

Soils listed in the guides generally are grouped according to the soil characteristics that are most relevant to natural and manmade drainage. The information in drainage guides is based on field tests and experience of managing conservation cropping systems on each soil listed.

The two soil characteristics described are the rate at which water will move through the soil (saturated hydraulic conductivity) and the degree of wetness before any drainage practices are applied. Another characteristic described that also is important to define wetland areas is general soil depth.

### (d) Sources of information

Section 2 of the Field Office Technical Guide gives up-to-date drainage guide information.

### (e) Methodology

This procedure involves the following steps:

***Step 1***—Determine the soil series for the wetland.

***Step 2***—Determine the drainage measure spacing.

***Step 3***—Determine the adequacy of the outlet.

***Step 4***—Determine if the actual spacing is greater or less than the spacing proposed in the guide. If the actual spacing is less than that proposed and the outlet conditions are adequate, the system has the potential to remove the wetland hydrology. If the actual spacing is greater than that proposed, then only the portion of the wetland within the zone of influence may be affected.

The information gathered in following these steps can be used in conjunction with the conservation plan files to determine if the installed drainage is adequate. If a drainage system is in a poor state of repair, calculations may show the system has the potential to remove the wetland hydrology, but aerial slides may show wet signatures in normal years.

## 650.1907 Observation wells

### (a) Applicable situation for use

An observation well in a potential wetland area indicates ground water depths over time. Thus, durations of saturation (ground water levels) above or below a specific elevation can be determined.

Water level records provide an index of the duration and frequency of saturation of the area. These records are obtained on either a continuous or a fixed time interval basis.

### (b) Data required

The following data are required:
- Location of the observation well
- Ground level and the reference elevation of the measurements
- Depth from the reference elevation to the water surface in the observation on a continuous or regular basis during the growing season

### (c) Limitations

#### (1) Knowledge and experience required
General knowledge of statistical procedures and specific knowledge of soil, hydrology, and observation well installation are required.

#### (2) Climatic regions of applicability
This hydrology tool is applicable to all climate regions.

#### (3) Factors affecting the accuracy of results
Wells that have been properly installed and maintained provide the best data.

Artesian or flowing wells provide information about a confined aquifer and may not represent the shallow water table under a wetland. Water levels in nonartesian or nonflowing wells may not represent the local shallow water table, depending on intake screen location and seal. Piezometers are not to be used to measure water table levels.

Water levels that have been obtained on a continuous basis are the best data. Continuous records indicate both the duration and frequency of saturation. The information on a fixed time interval provides an index of the frequency and duration if the sampling interval is equal to or shorter than the minimum duration of wetland saturation.

If there are 10 or more years of continuous data, then a statistical analysis can be made. The statistical analysis determines how often the wetland has been saturated in the past. It can be assumed that the same frequency of saturation will happen in the future if no alterations occur.

If the record length is between 5 and 10 years, the number of years of saturation of the wetland is used. It would then be necessary to determine if these years are representative of the average conditions.

If the record length is less than 3 years, additional analysis must be made to support the conclusions.

## (d) Sources of information

Observation well data may be available from local and state agencies responsible for regulating well drilling. State agencies include geologic survey, water right, or water resource agencies. Local agencies may also have copies of the water levels. The state geologist can provide assistance in obtaining the record of water levels. The data should be used with great care because most water level data were established for another purpose.

## (e) Methodology

The following steps are involved in the analysis of the observation well data:

***Step 1***—Determine the growing season.

***Step 2***—Obtain the observation well data or water levels for the growing season.

***Step 3***—Determine the maximum water level for the critical duration for each year.

***Step 4***—Determine if the critical duration was met 50 percent of the time for the period of record.

- If the record length is 10 years or more, statistical inferences about the mean conditions can be made.
- If the record length is between 5 and 10 years, determine the number of years the criteria were met, for example, 4 out of the 10 years.
- If the record length is less than 5 years, determine if the record can be correlated with other corroborating data.
- If no other well data are available, correlate the well observations with precipitation to determine if the precipitation for the recharge period was wet, average, or dry. If the recharge period precipitation is less than the lower 3 out of 10 year value, the period is dry. If it is greater than the higher 3 out of 10 year value, the period is wet. If the water level elevation met the criteria during a dry period, the area is most likely a wetland. If the water level elevation met the criteria during a wet period, additional analysis is needed.

## (f) Establishing an observation well

An observation well can be established in a wetland to verify the wetland mapping convention or initial identification. The well needs to be observed for 10 years to establish the average conditions. The observations should be on a continuous basis during the growing season.

The state geologist or hydraulic engineer should be consulted before an observation well is established in a wetland. The state geologist has specifications and information on how to install, case, and seal the well and how to take and record the measurements. Sprecher (1993) provides guidelines on installation of wetland observation wells.

## (g) Sample documentation

### (1) 14 years of records

This analysis is of the well records from a state agency data base. The records indicate 14 years of records and that the water levels were obtained on a continuous basis. The values are feet below the ground level. Thus a value of zero indicates the water in the well is at ground level. This well is in the wetland. It was installed for observation purposes, and no pumping has occurred. The soil is not sandy, so the criteria indicate if the water level is within 1 foot of the surface for the specified duration, the area meets the wetland hydrology criteria for saturation. For this example, duration criterion is assumed to be 15 days.

The record has been analyzed, and the water level of 1 foot or less for a continuous 15-day period during the growing season (March 1 through October 15) has been determined. The tabulated values (table 19–10) represent the highest water level or the smallest reading in that 15-day period. For example, in 1975 the 15-day consecutive values were 0.9, 1.0, 0.9, 0.95, 0.9, 1.0, 1.0, 0.9, 0.9, 0.9, 0.9, 0.9, 0.9, 0.9, and 0.9, thus the value used in the analysis is 0.9. It should be remembered that the highest water level in the well would be the smallest depth to water from the ground surface.

If the yearly values are arrayed from the largest to the smallest the median value is 1 foot below the ground surface. The median or the value in the middle of the array is a good representative of the average conditions. This well indicated that on the average, or 11 out of the 14 years, the water in the well would be within 1 foot of the ground surface. The wetland hydrology indicator is met for this situation.

### (2) 5-year records where water level taken every 5 days

This analysis is of the observation well records from state data base. A search of the data base indicates that there are 5 years of records (tables 19–11 to 19–15) and that the water levels were obtained every 5 days on a regular basis. The values are in feet below ground level. This means that a value of zero indicates the water in the well is at ground level. This well is located at the edge of a potential wetland. The record is for water years 1980 through 1984. For this example the wetland criteria are water level at the surface and the duration of 15 consecutive days. The growing season is from March 15 to September 15.

Analysis of the data indicates the following:

***Water Year 1980*—**The water level in the well is at ground level during one period 16 to 24 consecutive days in length and three periods 6 to 14 consecutive days in length.

***Water Year 1981*—**The water level in the well is at ground level for one period of 6 to 14 consecutive days in length and two periods of 1 to 9 days.

***Water Year 1982*—**The water is at the soil surface for one period of 6 to 14 consecutive days in length, and two periods of 1 to 9 consecutive days in length.

***Water Year 1983*—**The water does not reach the soil surface.

***Water Year 1984*—**The water does not reach the soil surface.

This analysis indicates that water level has been at the ground surface for 3 out of the 5 years of record. In water year 1980, the water was at ground level for longer than the minimum of 15 days.

**Table 19–10** Observation well records for 1970 to 1983

| Year | Highest level during 15 days | Array from largest to smallest |
|---|---|---|
| 1970 | 1.0 | 1.3 |
| 1971 | 1.1 | 1.2 |
| 1972 | 0.9 | 1.1 |
| 1973 | 0.9 | 1.0 |
| 1974 | 1.0 | 1.0 |
| 1975 | 1.0 | 1.0 |
| 1976 | 1.3 | 1.0 |
| 1977 | 0.9 | 1.0 |
| 1978 | 1.0 | 1.0 |
| 1979 | 0.9 | 0.9 |
| 1980 | 1.0 | 0.9 |
| 1981 | 0.9 | 0.9 |
| 1982 | 1.0 | 0.9 |
| 1983 | 1.2 | 0.9 |

This analysis also illustrates the problem of making conclusions if the observations are not taken every day; i.e., no conclusions can be made regarding the duration of the water table during the noted periods.

For example, in 1982 the record shows:

| | |
|---|---|
| May 20 | 0.10 |
| May 25 | 0.00 |
| May 31 | 0.00 |
| June 5 | 0.20 |

The shortest period is May 25 to 31, 7 days, and the maximum is May 21 to June 4, 15 days.

**Table 19–11** Water level, in feet below land-surface datum, for October 1979 to September 1980

Pittsburg County

350422095341901. local Number, 07W-16E-24 B&B 1
Location—Lat 35 4’22" Long 95 34’19", Hydrologic unit 11090204
Owner:
Aquifer—Local aquifer
Well characteristics—Observation well
Datum—Altitude of land-surface is unavailable

Water level, in feet below land-surface datum, for October 1979 to September 1980

| Date | Water level | Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|---|---|
| Oct 5 | 2.00 | Jan 5 | 0.55 | Apr 5 | 0.10 | Jul 5 | 0.05 |
| Oct 10 | 1.90 | Jan 10 | 0.40 | Apr 10 | 0.05 | Jul 10 | 0.00 |
| Oct 15 | 1.80 | Jan 15 | 0.30 | Apr 15 | 0.00 | Jul 15 | 0.10 |
| Oct 20 | 1.75 | Jan 20 | 0.20 | Apr 20 | 0.00 | Jul 20 | 0.20 |
| Oct 25 | 1.70 | Jan 25 | 0.10 | Apr 25 | 0.05 | Jul 25 | 0.30 |
| Oct 31 | 1.65 | Jan 31 | 0.00 | Apr 30 | 0.10 | Jul 31 | 0.50 |
| Nov 5 | 1.60 | Feb 5 | 0.00 | May 5 | 0.05 | Aug 5 | 0.80 |
| Nov 10 | 1.55 | Feb 10 | 0.05 | May 10 | 0.00 | Aug 10 | 1.00 |
| Nov 15 | 1.54 | Feb 15 | 0.00 | May 15 | 0.00 | Aug 15 | 1.20 |
| Nov 20 | 1.50 | Feb 20 | 0.05 | May 20 | 0.00 | Aug 20 | 1.40 |
| Nov 25 | 1.45 | Mar 5 | 0.00 | May 25 | 0.00 | Aug 25 | 1.60 |
| Nov 30 | 1.40 | Mar 10 | 0.00 | May 31 | 0.10 | Aug 30 | 1.80 |
| Dec 5 | 1.35 | Mar 15 | 0.05 | Jun 5 | 0.20 | Sep 5 | 1.85 |
| Dec 10 | 1.30 | Mar 20 | 0.00 | Jun 10 | 0.15 | Sep 10 | 1.90 |
| Dec 15 | 1.25 | Mar 25 | 0.00 | Jun 15 | 0.10 | Sep 15 | 2.00 |
| Dec 20 | 1.00 | Mar 30 | 0.05 | Jun 20 | 0.05 | Sep 20 | 2.05 |
| Dec 25 | 0.90 | | | Jun 25 | 0.00 | Sep 25 | 2.00 |
| Dec 31 | 0.80 | | | Jun 30 | 0.00 | Sep 30 | 2.10 |

**Table 19–12** Water level, in feet below land-surface datum, for October 1980 to September 1981

Pittsburg County

350422095341901. local Number, 07W-16E-24 B&B 1
Location—Lat 35 4'22" Long 95 34'19", Hydrologic unit 11090204
Owner:
Aquifer—Local aquifer
Well characteristics—Observation well
Datum—Altitude of land-surface is unavailable

Water level, in feet below land-surface datum, for October 1980 to September 1981

| Date | Water level | Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|---|---|
| Oct 5 | 2.00 | Jan 5 | 0.80 | Apr 5 | 0.10 | Jul 5 | 0.05 |
| Oct 10 | 2.00 | Jan 10 | 0.70 | Apr 10 | 0.05 | Jul 10 | 0.20 |
| Oct 15 | 1.90 | Jan 15 | 0.60 | Apr 15 | 0.05 | Jul 15 | 0.10 |
| Oct 20 | 1.75 | Jan 20 | 0.50 | Apr 20 | 0.05 | Jul 20 | 0.20 |
| Oct 25 | 1.70 | Jan 25 | 0.40 | Apr 25 | 0.05 | Jul 25 | 0.30 |
| Oct 31 | 1.60 | Jan 31 | 0.30 | Apr 30 | 0.10 | Jul 31 | 0.50 |
| Nov 5 | 1.60 | Feb 5 | 0.20 | May 5 | 0.05 | Aug 5 | 0.90 |
| Nov 10 | 1.50 | Feb 10 | 0.10 | May 10 | 0.00 | Aug 10 | 1.10 |
| Nov 15 | 1.50 | Feb 15 | 0.20 | May 15 | 0.05 | Aug 15 | 1.20 |
| Nov 20 | 1.50 | Feb 20 | 0.15 | May 20 | 0.05 | Aug 20 | 1.40 |
| Nov 25 | 1.40 | Mar 5 | 0.10 | May 25 | 0.00 | Aug 25 | 1.60 |
| Nov 30 | 1.40 | Mar 10 | 0.00 | May 31 | 0.15 | Aug 30 | 1.80 |
| Dec 5 | 1.30 | Mar 15 | 0.05 | Jun 5 | 0.25 | Sep 5 | 1.85 |
| Dec 10 | 1.30 | Mar 20 | 0.00 | Jun 10 | 0.25 | Sep 10 | 1.90 |
| Dec 15 | 1.25 | Mar 25 | 0.00 | Jun 15 | 0.20 | Sep 15 | 2.10 |
| Dec 20 | 1.00 | Mar 30 | 0.05 | Jun 20 | 0.15 | Sep 20 | 2.25 |
| Dec 25 | 0.95 | | | Jun 25 | 0.10 | Sep 25 | 2.20 |
| Dec 31 | 0.80 | | | Jun 30 | 0.10 | Sep 30 | 2.20 |

**Table 19–13** Water level, in feet below land-surface datum, for October 1981 to September 1982

Pittsburg County

350422095341901. local Number, 07W-16E-24 B&B 1
Location—Lat 35 4’22" Long 95 34’19", Hydrologic unit 11090204
Owner:
Aquifer—Local aquifer
Well characteristics—Observation well
Datum—Altitude of land-surface is unavailable

Water level, in feet below land-surface datum, for October 1981 to September 1982

| Date | Water level | Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|---|---|
| Oct 5 | 2.20 | Jan 5 | 1.85 | Apr 5 | 0.20 | Jul 5 | 0.05 |
| Oct 10 | 2.30 | Jan 10 | 1.70 | Apr 10 | 0.15 | Jul 10 | 0.00 |
| Oct 15 | 2.25 | Jan 15 | 1.60 | Apr 15 | 0.10 | Jul 15 | 0.10 |
| Oct 20 | 2.15 | Jan 20 | 1.50 | Apr 20 | 0.05 | Jul 20 | 0.20 |
| Oct 25 | 2.00 | Jan 25 | 1.30 | Apr 25 | 0.05 | Jul 25 | 0.30 |
| Oct 31 | 2.15 | Jan 31 | 1.10 | Apr 30 | 0.10 | Jul 31 | 0.50 |
| Nov 5 | 2.20 | Feb 5 | 1.00 | May 5 | 0.05 | Aug 5 | 0.60 |
| Nov 10 | 2.35 | Feb 10 | 0.85 | May 10 | 0.05 | Aug 10 | 0.70 |
| Nov 15 | 2.30 | Feb 15 | 0.80 | May 15 | 0.05 | Aug 15 | 0.80 |
| Nov 20 | 2.20 | Feb 20 | 0.75 | May 20 | 0.10 | Aug 20 | 0.90 |
| Nov 25 | 2.15 | Mar 5 | 0.60 | May 25 | 0.00 | Aug 25 | 1.00 |
| Nov 30 | 2.10 | Mar 10 | 0.50 | May 31 | 0.00 | Aug 30 | 1.10 |
| Dec 5 | 2.05 | Mar 15 | 0.45 | Jun 5 | 0.20 | Sep 5 | 1.25 |
| Dec 10 | 2.30 | Mar 20 | 0.40 | Jun 10 | 0.15 | Sep 10 | 1.40 |
| Dec 15 | 2.20 | Mar 25 | 0.30 | Jun 15 | 0.10 | Sep 15 | 1.60 |
| Dec 20 | 2.00 | Mar 30 | 0.25 | Jun 20 | 0.05 | Sep 20 | 1.75 |
| Dec 25 | 1.90 | | | Jun 25 | 0.00 | Sep 25 | 1.80 |
| Dec 31 | 0.80 | | | Jun 30 | 0.10 | Sep 30 | 1.90 |

**Table 19–14** Water level, in feet below land-surface datum, for October 1982 to September 1983

Pittsburg County

350422095341901. local Number, 07W-16E-24 B&B 1
Location—Lat 35 4’22" Long 95 34’19", Hydrologic unit 11090204
Owner:
Aquifer—Local aquifer
Well characteristics—Observation well
Datum—Altitude of land-surface is unavailable

Water level, in feet below land-surface datum, for October 1982 to September 1983

| Date | Water level | Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|---|---|
| Oct 5 | 2.00 | Jan 5 | 2.30 | Apr 5 | 0.80 | Jul 5 | 0.45 |
| Oct 10 | 2.00 | Jan 10 | 2.40 | Apr 10 | 0.65 | Jul 10 | 0.40 |
| Oct 15 | 2.10 | Jan 15 | 2.30 | Apr 15 | 0.50 | Jul 15 | 0.30 |
| Oct 20 | 2.25 | Jan 20 | 2.20 | Apr 20 | 0.40 | Jul 20 | 0.20 |
| Oct 25 | 2.30 | Jan 25 | 2.10 | Apr 25 | 0.45 | Jul 25 | 0.30 |
| Oct 31 | 2.45 | Jan 31 | 2.00 | Apr 30 | 0.40 | Jul 31 | 0.40 |
| Nov 5 | 2.60 | Feb 5 | 1.90 | May 5 | 0.45 | Aug 5 | 0.60 |
| Nov 10 | 2.55 | Feb 10 | 1.80 | May 10 | 0.50 | Aug 10 | 0.80 |
| Nov 15 | 2.45 | Feb 15 | 1.70 | May 15 | 0.60 | Aug 15 | 0.90 |
| Nov 20 | 2.30 | Feb 20 | 1.60 | May 20 | 0.70 | Aug 20 | 1.00 |
| Nov 25 | 2.20 | Mar 5 | 1.50 | May 25 | 0.60 | Aug 25 | 1.00 |
| Nov 30 | 2.10 | Mar 10 | 1.40 | May 31 | 0.50 | Aug 30 | 1.00 |
| Dec 5 | 2.00 | Mar 15 | 1.30 | Jun 5 | 0.30 | Sep 5 | 1.00 |
| Dec 10 | 2.10 | Mar 20 | 1.10 | Jun 10 | 0.45 | Sep 10 | 1.10 |
| Dec 15 | 2.20 | Mar 25 | 1.00 | Jun 15 | 0.40 | Sep 15 | 1.00 |
| Dec 20 | 2.30 | Mar 30 | 0.90 | Jun 20 | 0.45 | Sep 20 | 1.00 |
| Dec 25 | 2.40 | | | Jun 25 | 0.40 | Sep 25 | 1.50 |
| Dec 31 | 2.30 | | | Jun 30 | 0.40 | Sep 30 | 1.80 |

**Table 19–15** Water level, in feet below land-surface datum, for October 1983 to September 1984

Pittsburg County

350422095341901. local Number, 07W-16E-24 B&B 1
Location—Lat 35 4’22" Long 95 34’19", Hydrologic unit 11090204
Owner:
Aquifer—Local aquifer
Well characteristics—Observation well
Datum—Altitude of land-surface is unavailable

Water level, in feet below land-surface datum, for October 1983 to September 1984

| Date | Water level | Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|---|---|
| Oct 5 | 1.90 | Jan 5 | 2.30 | Apr 5 | 0.80 | Jul 5 | 0.45 |
| Oct 10 | 2.00 | Jan 10 | 2.40 | Apr 10 | 0.65 | Jul 10 | 0.40 |
| Oct 15 | 2.10 | Jan 15 | 2.30 | Apr 15 | 0.50 | Jul 15 | 0.30 |
| Oct 20 | 2.25 | Jan 20 | 2.20 | Apr 20 | 0.40 | Jul 20 | 0.20 |
| Oct 25 | 2.30 | Jan 25 | 2.10 | Apr 25 | 0.45 | Jul 25 | 0.30 |
| Oct 31 | 2.45 | Jan 31 | 2.00 | Apr 30 | 0.40 | Jul 31 | 0.40 |
| Nov 5 | 2.60 | Feb 5 | 1.90 | May 5 | 0.45 | Aug 5 | 0.60 |
| Nov 10 | 2.55 | Feb 10 | 1.80 | May 10 | 0.50 | Aug 10 | 0.80 |
| Nov 15 | 2.45 | Feb 15 | 1.70 | May 15 | 0.60 | Aug 15 | 0.90 |
| Nov 20 | 2.30 | Feb 20 | 1.60 | May 20 | 0.70 | Aug 20 | 1.00 |
| Nov 25 | 2.20 | Mar 5 | 1.50 | May 25 | 0.60 | Aug 25 | 1.00 |
| Nov 30 | 2.10 | Mar 10 | 1.40 | May 31 | 0.50 | Aug 30 | 1.00 |
| Dec 5 | 2.00 | Mar 15 | 1.30 | Jun 5 | 0.30 | Sep 5 | 1.00 |
| Dec 10 | 2.10 | Mar 20 | 1.10 | Jun 10 | 0.45 | Sep 10 | 1.10 |
| Dec 15 | 2.20 | Mar 25 | 1.00 | Jun 15 | 0.40 | Sep 15 | 1.00 |
| Dec 20 | 2.30 | Mar 30 | 0.90 | Jun 20 | 0.45 | Sep 20 | 1.00 |
| Dec 25 | 2.40 | | | Jun 25 | 0.40 | Sep 25 | 1.50 |
| Dec 31 | 2.30 | | | Jun 30 | 0.40 | Sep 30 | 1.80 |

### (3) 5-year records where water level taken daily

This analysis is of the well records from a state data base. A search of the data base indicates that there are 5 years of records (tables 19–16 to 19–20) and that the water levels were obtained every day. Only the data for March through October are shown in the example. For this example, it is assumed that the growing season is March 15 through September 15. The values are feet below ground level. This means that a value of zero indicates the water in the well is at ground level. This well is located at the edge of a potential wetland. The record is for water years 1980 though 1984. Two assumptions for this example are that the wetland criterion is 10-day duration for saturation and water must be at the surface for the entire duration.

Analysis of the data indicates the following:

***Water Year 1980*—**The water level in the well is at ground level during two periods 10 days in length.

***Water Year 1981*—**The water level in the well is at ground level during three periods, two periods of 5 days and one of 20 days.

***Water Year 1982*—**The water is at the soil surface during two periods. One period is 10 days, and the other is 5 days.

***Water Year 1983*—**The water reaches the soil surface for one period of 10 days.

***Water Year 1984*—**The water does not reach the soil surface.

This analysis indicates that for this potential wetland, the water surface has been at the ground level for 4 out of the 5 years of record. Water is at the ground surface for a period of at least 10 days in 1980, 1981, 1982, and 1983. It would be helpful to correlate the 5 years of well data with climate data to make sure the well data represents normal conditions.

**Table 19–16** Water level, in feet below land-surface datum, for October 1979 to September 1980

Washington County
350422095341901. local number, 08W-15E-254
Location—Lat 45 4'22" Long 122 34' 19"
Well characteristics—Observation well
Datum—Altitude of land-surface is unavailable

| Date | Water level | Date | Water level | Date | Water level | Date | Water level | Date | Water level | Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mar 1 | 0.50 | Apr 1 | 0.04 | May 1 | 0.10 | Jun 1 | 0.18 | Jul 1 | 0.10 | Aug 1 | 0.41 | Sep 1 | 0.60 | Oct 1 | 0.85 |
| Mar 2 | 0.50 | Apr 2 | 0.05 | May 2 | 0.11 | Jun 2 | 0.19 | Jul 2 | 0.15 | Aug 2 | 0.42 | Sep 2 | 0.61 | Oct 2 | 0.86 |
| Mar 3 | 0.49 | Apr 3 | 0.06 | May 3 | 0.12 | Jun 3 | 0.20 | Jul 3 | 0.20 | Aug 3 | 0.42 | Sep 3 | 0.62 | Oct 3 | 0.86 |
| Mar 4 | 0.48 | Apr 4 | 0.05 | May 4 | 0.13 | Jun 4 | 0.20 | Jul 4 | 0.22 | Aug 4 | 0.44 | Sep 4 | 0.63 | Oct 4 | 0.86 |
| Mar 5 | 0.47 | Apr 5 | 0.05 | May 5 | 0.15 | Jun 5 | 0.21 | Jul 5 | 0.25 | Aug 5 | 0.45 | Sep 5 | 0.61 | Oct 5 | 0.87 |
| Mar 6 | 0.47 | Apr 6 | 0.10 | May 6 | 0.18 | Jun 6 | 0.22 | Jul 6 | 0.26 | Aug 6 | 0.45 | Sep 6 | 0.60 | Oct 6 | 0.89 |
| Mar 7 | 0.44 | Apr 7 | 0.10 | May 7 | 0.29 | Jun 7 | 0.20 | Jul 7 | 0.27 | Aug 7 | 0.46 | Sep 7 | 0.61 | Oct 7 | 0.90 |
| Mar 8 | 0.43 | Apr 8 | 0.10 | May 8 | 0.25 | Jun 8 | 0.19 | Jul 8 | 0.30 | Aug 8 | 0.47 | Sep 8 | 0.62 | Oct 8 | 0.91 |
| Mar 9 | 0.42 | Apr 9 | 0.05 | May 9 | 0.28 | Jun 9 | 0.18 | Jul 9 | 0.35 | Aug 9 | 0.48 | Sep 9 | 0.63 | Oct 9 | 0.93 |
| Mar 10 | 0.40 | Apr 10 | 0.03 | May 10 | 0.25 | Jun 10 | 0.16 | Jul 10 | 0.33 | Aug 10 | 0.49 | Sep 10 | 0.65 | Oct 10 | 0.94 |
| Mar 11 | 0.38 | Apr 11 | 0.05 | May 11 | 0.28 | Jun 11 | 0.14 | Jul 11 | 0.35 | Aug 11 | 0.48 | Sep 11 | 0.66 | Oct 11 | 0.95 |
| Mar 12 | 0.37 | Apr 12 | 0.03 | May 12 | 0.37 | Jun 12 | 0.13 | Jul 12 | 0.37 | Aug 12 | 0.48 | Sep 12 | 0.65 | Oct 12 | 0.97 |
| Mar 13 | 0.35 | Apr 13 | 0.05 | May 13 | 0.33 | Jun 13 | 0.12 | Jul 13 | 0.38 | Aug 13 | 0.49 | Sep 13 | 0.67 | Oct 13 | 0.95 |
| Mar 14 | 0.32 | Apr 14 | 0.06 | May 14 | 0.35 | Jun 14 | 0.11 | Jul 14 | 0.37 | Aug 14 | 0.45 | Sep 14 | 0.65 | Oct 14 | 0.96 |
| Mar 15 | 0.33 | Apr 15 | 0.05 | May 15 | 0.33 | Jun 15 | 0.10 | Jul 15 | 0.40 | Aug 15 | 0.44 | Sep 15 | 0.67 | Oct 15 | 0.97 |
| Mar 16 | 0.31 | Apr 16 | 0.06 | May 16 | 0.34 | Jun 16 | 0.08 | Jul 16 | 0.41 | Aug 16 | 0.46 | Sep 16 | 0.68 | Oct 16 | 0.98 |
| Mar 17 | 0.30 | Apr 17 | 0.07 | May 17 | 0.31 | Jun 17 | 0.06 | Jul 17 | 0.42 | Aug 17 | 0.47 | Sep 17 | 0.69 | Oct 17 | 0.99 |
| Mar 18 | 0.28 | Apr 18 | 0.05 | May 18 | 0.32 | Jun 18 | 0.05 | Jul 18 | 0.43 | Aug 18 | 0.48 | Sep 18 | 0.70 | Oct 18 | 1.00 |
| Mar 19 | 0.26 | Apr 19 | 0.03 | May 19 | 0.32 | Jun 19 | 0.03 | Jul 19 | 0.45 | Aug 19 | 0.49 | Sep 19 | 0.71 | Oct 19 | 1.01 |
| Mar 20 | 0.24 | Apr 20 | 0.01 | May 20 | 0.33 | Jun 20 | 0.02 | Jul 20 | 0.45 | Aug 20 | 0.50 | Sep 20 | 0.73 | Oct 20 | 1.00 |
| Mar 21 | 0.22 | Apr 21 | 0.00 | May 21 | 0.35 | Jun 21 | 0.00 | Jul 21 | 0.47 | Aug 21 | 0.50 | Sep 21 | 0.75 | Oct 21 | 0.99 |
| Mar 22 | 0.20 | Apr 22 | 0.00 | May 22 | 0.33 | Jun 22 | 0.00 | Jul 22 | 0.43 | Aug 22 | 0.51 | Sep 22 | 0.76 | Oct 22 | 1.00 |
| Mar 23 | 0.15 | Apr 23 | 0.00 | May 23 | 0.31 | Jun 23 | 0.00 | Jul 23 | 0.45 | Aug 23 | 0.52 | Sep 23 | 0.77 | Oct 23 | 1.01 |
| Mar 24 | 0.13 | Apr 24 | 0.00 | May 24 | 0.30 | Jun 24 | 0.00 | Jul 24 | 0.47 | Aug 24 | 0.53 | Sep 24 | 0.78 | Oct 24 | 1.02 |
| Mar 25 | 0.11 | Apr 25 | 0.00 | May 25 | 0.28 | Jun 25 | 0.00 | Jul 25 | 0.45 | Aug 25 | 0.52 | Sep 25 | 0.79 | Oct 25 | 1.03 |
| Mar 26 | 0.10 | Apr 26 | 0.00 | May 26 | 0.26 | Jun 26 | 0.00 | Jul 26 | 0.43 | Aug 26 | 0.53 | Sep 26 | 0.80 | Oct 26 | 1.04 |
| Mar 27 | 0.05 | Apr 27 | 0.00 | May 27 | 0.28 | Jun 27 | 0.00 | Jul 27 | 0.42 | Aug 27 | 0.54 | Sep 27 | 0.81 | Oct 27 | 1.03 |
| Mar 28 | 0.03 | Apr 28 | 0.00 | May 28 | 0.25 | Jun 28 | 0.00 | Jul 28 | 0.43 | Aug 28 | 0.55 | Sep 28 | 0.82 | Oct 28 | 1.04 |
| Mar 29 | 0.01 | Apr 29 | 0.00 | May 29 | 0.20 | Jun 29 | 0.00 | Jul 29 | 0.42 | Aug 29 | 0.56 | Sep 29 | 0.81 | Oct 29 | 1.05 |
| Mar 30 | 0.02 | Apr 30 | 0.00 | May 30 | 0.18 | Jun 30 | 0.00 | Jul 30 | 0.42 | Aug 30 | 0.55 | Sep 30 | 0.81 | Oct 30 | 1.10 |
| Mar 31 | 0.03 | | | May 31 | 0.16 | | | Jul 31 | 0.40 | Aug 31 | 0.58 | | | Oct 31 | 1.10 |

**Table 19–17** Water level, in feet below land-surface datum, for October 1980 to September 1981

Washington County
350422095341901. local number, 08W-15E-254
Location—Lat 45 4’22" Long 122 34' 19"
Well characteristics—Observation well
Datum—Altitude of land-surface is unavailable

| Date | Water level | Date | Water level | Date | Water level | Date | Water level | Date | Water level | Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mar 1 | 0.50 | Apr 1 | 0.00 | May 1 | 0.10 | Jun 1 | 0.18 | Jul 1 | 0.10 | Aug 1 | 0.41 | Sep 1 | 0.60 | Oct 1 | 0.85 |
| Mar 2 | 0.50 | Apr 2 | 0.00 | May 2 | 0.11 | Jun 2 | 0.19 | Jul 2 | 0.15 | Aug 2 | 0.42 | Sep 2 | 0.61 | Oct 2 | 0.86 |
| Mar 3 | 0.49 | Apr 3 | 0.00 | May 3 | 0.12 | Jun 3 | 0.20 | Jul 3 | 0.20 | Aug 3 | 0.42 | Sep 3 | 0.62 | Oct 3 | 0.86 |
| Mar 4 | 0.48 | Apr 4 | 0.05 | May 4 | 0.13 | Jun 4 | 0.20 | Jul 4 | 0.22 | Aug 4 | 0.44 | Sep 4 | 0.63 | Oct 4 | 0.86 |
| Mar 5 | 0.47 | Apr 5 | 0.05 | May 5 | 0.15 | Jun 5 | 0.21 | Jul 5 | 0.25 | Aug 5 | 0.45 | Sep 5 | 0.61 | Oct 5 | 0.87 |
| Mar 6 | 0.47 | Apr 6 | 0.10 | May 6 | 0.18 | Jun 6 | 0.22 | Jul 6 | 0.26 | Aug 6 | 0.45 | Sep 6 | 0.60 | Oct 6 | 0.89 |
| Mar 7 | 0.44 | Apr 7 | 0.10 | May 7 | 0.29 | Jun 7 | 0.20 | Jul 7 | 0.27 | Aug 7 | 0.46 | Sep 7 | 0.61 | Oct 7 | 0.90 |
| Mar 8 | 0.43 | Apr 8 | 0.10 | May 8 | 0.25 | Jun 8 | 0.19 | Jul 8 | 0.30 | Aug 8 | 0.47 | Sep 8 | 0.62 | Oct 8 | 0.91 |
| Mar 9 | 0.42 | Apr 9 | 0.05 | May 9 | 0.28 | Jun 9 | 0.18 | Jul 9 | 0.35 | Aug 9 | 0.48 | Sep 9 | 0.63 | Oct 9 | 0.93 |
| Mar 10 | 0.40 | Apr 10 | 0.03 | May 10 | 0.25 | Jun 10 | 0.16 | Jul 10 | 0.33 | Aug 10 | 0.49 | Sep 10 | 0.65 | Oct 10 | 0.94 |
| Mar 11 | 0.38 | Apr 11 | 0.00 | May 11 | 0.28 | Jun 11 | 0.14 | Jul 11 | 0.35 | Aug 11 | 0.48 | Sep 11 | 0.66 | Oct 11 | 0.95 |
| Mar 12 | 0.37 | Apr 12 | 0.00 | May 12 | 0.37 | Jun 12 | 0.13 | Jul 12 | 0.37 | Aug 12 | 0.48 | Sep 12 | 0.65 | Oct 12 | 0.97 |
| Mar 13 | 0.35 | Apr 13 | 0.00 | May 13 | 0.33 | Jun 13 | 0.12 | Jul 13 | 0.38 | Aug 13 | 0.49 | Sep 13 | 0.67 | Oct 13 | 0.95 |
| Mar 14 | 0.32 | Apr 14 | 0.00 | May 14 | 0.35 | Jun 14 | 0.11 | Jul 14 | 0.37 | Aug 14 | 0.45 | Sep 14 | 0.65 | Oct 14 | 0.96 |
| Mar 15 | 0.33 | Apr 15 | 0.00 | May 15 | 0.33 | Jun 15 | 0.10 | Jul 15 | 0.40 | Aug 15 | 0.44 | Sep 15 | 0.67 | Oct 15 | 0.97 |
| Mar 16 | 0.31 | Apr 16 | 0.00 | May 16 | 0.34 | Jun 16 | 0.08 | Jul 16 | 0.41 | Aug 16 | 0.46 | Sep 16 | 0.68 | Oct 16 | 0.98 |
| Mar 17 | 0.30 | Apr 17 | 0.00 | May 17 | 0.31 | Jun 17 | 0.06 | Jul 17 | 0.42 | Aug 17 | 0.47 | Sep 17 | 0.69 | Oct 17 | 0.99 |
| Mar 18 | 0.28 | Apr 18 | 0.00 | May 18 | 0.32 | Jun 18 | 0.05 | Jul 18 | 0.43 | Aug 18 | 0.48 | Sep 18 | 0.70 | Oct 18 | 1.00 |
| Mar 19 | 0.26 | Apr 19 | 0.00 | May 19 | 0.32 | Jun 19 | 0.03 | Jul 19 | 0.45 | Aug 19 | 0.49 | Sep 19 | 0.71 | Oct 19 | 1.01 |
| Mar 20 | 0.24 | Apr 20 | 0.00 | May 20 | 0.33 | Jun 20 | 0.02 | Jul 20 | 0.45 | Aug 20 | 0.50 | Sep 20 | 0.73 | Oct 20 | 1.00 |
| Mar 21 | 0.22 | Apr 21 | 0.00 | May 21 | 0.35 | Jun 21 | 0.00 | Jul 21 | 0.47 | Aug 21 | 0.50 | Sep 21 | 0.75 | Oct 21 | 0.99 |
| Mar 22 | 0.20 | Apr 22 | 0.00 | May 22 | 0.33 | Jun 22 | 0.00 | Jul 22 | 0.43 | Aug 22 | 0.51 | Sep 22 | 0.76 | Oct 22 | 1.00 |
| Mar 23 | 0.15 | Apr 23 | 0.00 | May 23 | 0.31 | Jun 23 | 0.00 | Jul 23 | 0.45 | Aug 23 | 0.52 | Sep 23 | 0.77 | Oct 23 | 1.01 |
| Mar 24 | 0.13 | Apr 24 | 0.00 | May 24 | 0.30 | Jun 24 | 0.00 | Jul 24 | 0.47 | Aug 24 | 0.53 | Sep 24 | 0.78 | Oct 24 | 1.02 |
| Mar 25 | 0.11 | Apr 25 | 0.00 | May 25 | 0.28 | Jun 25 | 0.00 | Jul 25 | 0.45 | Aug 25 | 0.52 | Sep 25 | 0.79 | Oct 25 | 1.03 |
| Mar 26 | 0.10 | Apr 26 | 0.00 | May 26 | 0.26 | Jun 26 | 0.01 | Jul 26 | 0.43 | Aug 26 | 0.53 | Sep 26 | 0.80 | Oct 26 | 1.04 |
| Mar 27 | 0.05 | Apr 27 | 0.00 | May 27 | 0.28 | Jun 27 | 0.02 | Jul 27 | 0.42 | Aug 27 | 0.54 | Sep 27 | 0.81 | Oct 27 | 1.03 |
| Mar 28 | 0.03 | Apr 28 | 0.00 | May 28 | 0.25 | Jun 28 | 0.03 | Jul 28 | 0.43 | Aug 28 | 0.55 | Sep 28 | 0.82 | Oct 28 | 1.04 |
| Mar 29 | 0.01 | Apr 29 | 0.00 | May 29 | 0.20 | Jun 29 | 0.05 | Jul 29 | 0.42 | Aug 29 | 0.56 | Sep 29 | 0.81 | Oct 29 | 1.05 |
| Mar 30 | 0.00 | Apr 30 | 0.00 | May 30 | 0.18 | Jun 30 | 0.07 | Jul 30 | 0.42 | Aug 30 | 0.55 | Sep 30 | 0.81 | Oct 30 | 1.10 |
| Mar 31 | 0.00 | | | May 31 | 0.16 | | | Jul 31 | 0.40 | Aug 31 | 0.58 | | | Oct 31 | 1.10 |

**Table 19–18** Water level, in feet below land-surface datum, for October 1981 to September 1982

Washington County
350422095341901. local number, 08W-15E-254
Location—Lat 45 4'22" Long 122 34' 19"
Well characteristics—Observation well
Datum—Altitude of land-surface is unavailable

| Date | Water level | Date | Water level | Date | Water level | Date | Water level | Date | Water level | Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mar 1 | 0.50 | Apr 1 | 0.04 | May 1 | 0.10 | Jun 1 | 0.18 | Jul 1 | 0.10 | Aug 1 | 0.41 | Sep 1 | 0.60 | Oct 1 | 0.85 |
| Mar 2 | 0.50 | Apr 2 | 0.05 | May 2 | 0.11 | Jun 2 | 0.19 | Jul 2 | 0.15 | Aug 2 | 0.42 | Sep 2 | 0.61 | Oct 2 | 0.86 |
| Mar 3 | 0.49 | Apr 3 | 0.06 | May 3 | 0.12 | Jun 3 | 0.20 | Jul 3 | 0.20 | Aug 3 | 0.42 | Sep 3 | 0.62 | Oct 3 | 0.86 |
| Mar 4 | 0.48 | Apr 4 | 0.05 | May 4 | 0.13 | Jun 4 | 0.20 | Jul 4 | 0.22 | Aug 4 | 0.44 | Sep 4 | 0.63 | Oct 4 | 0.86 |
| Mar 5 | 0.47 | Apr 5 | 0.05 | May 5 | 0.15 | Jun 5 | 0.21 | Jul 5 | 0.25 | Aug 5 | 0.45 | Sep 5 | 0.61 | Oct 5 | 0.87 |
| Mar 6 | 0.47 | Apr 6 | 0.10 | May 6 | 0.18 | Jun 6 | 0.22 | Jul 6 | 0.26 | Aug 6 | 0.45 | Sep 6 | 0.60 | Oct 6 | 0.89 |
| Mar 7 | 0.44 | Apr 7 | 0.10 | May 7 | 0.29 | Jun 7 | 0.20 | Jul 7 | 0.27 | Aug 7 | 0.46 | Sep 7 | 0.61 | Oct 7 | 0.90 |
| Mar 8 | 0.43 | Apr 8 | 0.10 | May 8 | 0.25 | Jun 8 | 0.19 | Jul 8 | 0.30 | Aug 8 | 0.47 | Sep 8 | 0.62 | Oct 8 | 0.91 |
| Mar 9 | 0.42 | Apr 9 | 0.05 | May 9 | 0.28 | Jun 9 | 0.18 | Jul 9 | 0.35 | Aug 9 | 0.48 | Sep 9 | 0.63 | Oct 9 | 0.93 |
| Mar 10 | 0.40 | Apr 10 | 0.03 | May 10 | 0.25 | Jun 10 | 0.16 | Jul 10 | 0.33 | Aug 10 | 0.49 | Sep 10 | 0.65 | Oct 10 | 0.94 |
| Mar 11 | 0.38 | Apr 11 | 0.05 | May 11 | 0.28 | Jun 11 | 0.14 | Jul 11 | 0.35 | Aug 11 | 0.48 | Sep 11 | 0.66 | Oct 11 | 0.95 |
| Mar 12 | 0.37 | Apr 12 | 0.03 | May 12 | 0.37 | Jun 12 | 0.13 | Jul 12 | 0.37 | Aug 12 | 0.48 | Sep 12 | 0.65 | Oct 12 | 0.97 |
| Mar 13 | 0.35 | Apr 13 | 0.05 | May 13 | 0.33 | Jun 13 | 0.12 | Jul 13 | 0.38 | Aug 13 | 0.49 | Sep 13 | 0.67 | Oct 13 | 0.95 |
| Mar 14 | 0.32 | Apr 14 | 0.06 | May 14 | 0.35 | Jun 14 | 0.11 | Jul 14 | 0.37 | Aug 14 | 0.45 | Sep 14 | 0.65 | Oct 14 | 0.96 |
| Mar 15 | 0.33 | Apr 15 | 0.05 | May 15 | 0.33 | Jun 15 | 0.10 | Jul 15 | 0.40 | Aug 15 | 0.44 | Sep 15 | 0.67 | Oct 15 | 0.97 |
| Mar 16 | 0.31 | Apr 16 | 0.06 | May 16 | 0.34 | Jun 16 | 0.08 | Jul 16 | 0.41 | Aug 16 | 0.46 | Sep 16 | 0.68 | Oct 16 | 0.98 |
| Mar 17 | 0.30 | Apr 17 | 0.07 | May 17 | 0.31 | Jun 17 | 0.06 | Jul 17 | 0.42 | Aug 17 | 0.47 | Sep 17 | 0.69 | Oct 17 | 0.99 |
| Mar 18 | 0.28 | Apr 18 | 0.05 | May 18 | 0.32 | Jun 18 | 0.05 | Jul 18 | 0.43 | Aug 18 | 0.48 | Sep 18 | 0.70 | Oct 18 | 1.00 |
| Mar 19 | 0.26 | Apr 19 | 0.03 | May 19 | 0.32 | Jun 19 | 0.03 | Jul 19 | 0.45 | Aug 19 | 0.49 | Sep 19 | 0.71 | Oct 19 | 1.01 |
| Mar 20 | 0.24 | Apr 20 | 0.01 | May 20 | 0.33 | Jun 20 | 0.02 | Jul 20 | 0.45 | Aug 20 | 0.50 | Sep 20 | 0.73 | Oct 20 | 1.00 |
| Mar 21 | 0.22 | Apr 21 | 0.00 | May 21 | 0.35 | Jun 21 | 0.00 | Jul 21 | 0.47 | Aug 21 | 0.50 | Sep 21 | 0.75 | Oct 21 | 0.99 |
| Mar 22 | 0.20 | Apr 22 | 0.00 | May 22 | 0.33 | Jun 22 | 0.00 | Jul 22 | 0.43 | Aug 22 | 0.51 | Sep 22 | 0.76 | Oct 22 | 1.00 |
| Mar 23 | 0.15 | Apr 23 | 0.00 | May 23 | 0.31 | Jun 23 | 0.00 | Jul 23 | 0.45 | Aug 23 | 0.52 | Sep 23 | 0.77 | Oct 23 | 1.01 |
| Mar 24 | 0.13 | Apr 24 | 0.00 | May 24 | 0.30 | Jun 24 | 0.00 | Jul 24 | 0.47 | Aug 24 | 0.53 | Sep 24 | 0.78 | Oct 24 | 1.02 |
| Mar 25 | 0.11 | Apr 25 | 0.00 | May 25 | 0.28 | Jun 25 | 0.00 | Jul 25 | 0.45 | Aug 25 | 0.52 | Sep 25 | 0.79 | Oct 25 | 1.03 |
| Mar 26 | 0.10 | Apr 26 | 0.01 | May 26 | 0.26 | Jun 26 | 0.00 | Jul 26 | 0.43 | Aug 26 | 0.53 | Sep 26 | 0.80 | Oct 26 | 1.04 |
| Mar 27 | 0.05 | Apr 27 | 0.02 | May 27 | 0.28 | Jun 27 | 0.00 | Jul 27 | 0.42 | Aug 27 | 0.54 | Sep 27 | 0.81 | Oct 27 | 1.03 |
| Mar 28 | 0.03 | Apr 28 | 0.03 | May 28 | 0.25 | Jun 28 | 0.00 | Jul 28 | 0.43 | Aug 28 | 0.55 | Sep 28 | 0.82 | Oct 28 | 1.04 |
| Mar 29 | 0.01 | Apr 29 | 0.05 | May 29 | 0.20 | Jun 29 | 0.00 | Jul 29 | 0.42 | Aug 29 | 0.56 | Sep 29 | 0.81 | Oct 29 | 1.05 |
| Mar 30 | 0.02 | Apr 30 | 0.06 | May 30 | 0.18 | Jun 30 | 0.00 | Jul 30 | 0.42 | Aug 30 | 0.55 | Sep 30 | 0.81 | Oct 30 | 1.10 |
| Mar 31 | 0.03 | | | May 31 | 0.16 | | | Jul 31 | 0.40 | Aug 31 | 0.58 | | | Oct 31 | 1.10 |

**Table 19–19** Water level, in feet below land-surface datum, for October 1982 to September 1983

Washington County
350422095341901. local number, 08W-15E-254
Location—Lat 45 4'22" Long 122 34' 19"
Well characteristics—Observation well
Datum—Altitude of land-surface is unavailable

| Date | Water level | Date | Water level | Date | Water level | Date | Water level | Date | Water level | Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mar 1 | 0.50 | Apr 1 | 0.04 | May 1 | 0.10 | Jun 1 | 0.18 | Jul 1 | 0.10 | Aug 1 | 0.41 | Sep 1 | 0.60 | Oct 1 | 0.85 |
| Mar 2 | 0.50 | Apr 2 | 0.05 | May 2 | 0.11 | Jun 2 | 0.19 | Jul 2 | 0.15 | Aug 2 | 0.42 | Sep 2 | 0.61 | Oct 2 | 0.86 |
| Mar 3 | 0.49 | Apr 3 | 0.06 | May 3 | 0.12 | Jun 3 | 0.20 | Jul 3 | 0.20 | Aug 3 | 0.42 | Sep 3 | 0.62 | Oct 3 | 0.86 |
| Mar 4 | 0.48 | Apr 4 | 0.05 | May 4 | 0.13 | Jun 4 | 0.20 | Jul 4 | 0.22 | Aug 4 | 0.44 | Sep 4 | 0.63 | Oct 4 | 0.86 |
| Mar 5 | 0.47 | Apr 5 | 0.05 | May 5 | 0.15 | Jun 5 | 0.21 | Jul 5 | 0.25 | Aug 5 | 0.45 | Sep 5 | 0.61 | Oct 5 | 0.87 |
| Mar 6 | 0.47 | Apr 6 | 0.10 | May 6 | 0.18 | Jun 6 | 0.22 | Jul 6 | 0.26 | Aug 6 | 0.45 | Sep 6 | 0.60 | Oct 6 | 0.89 |
| Mar 7 | 0.44 | Apr 7 | 0.10 | May 7 | 0.29 | Jun 7 | 0.20 | Jul 7 | 0.27 | Aug 7 | 0.46 | Sep 7 | 0.61 | Oct 7 | 0.90 |
| Mar 8 | 0.43 | Apr 8 | 0.10 | May 8 | 0.25 | Jun 8 | 0.19 | Jul 8 | 0.30 | Aug 8 | 0.47 | Sep 8 | 0.62 | Oct 8 | 0.91 |
| Mar 9 | 0.42 | Apr 9 | 0.05 | May 9 | 0.28 | Jun 9 | 0.18 | Jul 9 | 0.35 | Aug 9 | 0.48 | Sep 9 | 0.63 | Oct 9 | 0.93 |
| Mar 10 | 0.40 | Apr 10 | 0.03 | May 10 | 0.25 | Jun 10 | 0.16 | Jul 10 | 0.33 | Aug 10 | 0.49 | Sep 10 | 0.65 | Oct 10 | 0.94 |
| Mar 11 | 0.38 | Apr 11 | 0.05 | May 11 | 0.28 | Jun 11 | 0.14 | Jul 11 | 0.35 | Aug 11 | 0.48 | Sep 11 | 0.66 | Oct 11 | 0.95 |
| Mar 12 | 0.37 | Apr 12 | 0.03 | May 12 | 0.37 | Jun 12 | 0.13 | Jul 12 | 0.37 | Aug 12 | 0.48 | Sep 12 | 0.65 | Oct 12 | 0.97 |
| Mar 13 | 0.35 | Apr 13 | 0.05 | May 13 | 0.33 | Jun 13 | 0.12 | Jul 13 | 0.38 | Aug 13 | 0.49 | Sep 13 | 0.67 | Oct 13 | 0.95 |
| Mar 14 | 0.32 | Apr 14 | 0.06 | May 14 | 0.35 | Jun 14 | 0.11 | Jul 14 | 0.37 | Aug 14 | 0.45 | Sep 14 | 0.65 | Oct 14 | 0.96 |
| Mar 15 | 0.33 | Apr 15 | 0.05 | May 15 | 0.33 | Jun 15 | 0.10 | Jul 15 | 0.40 | Aug 15 | 0.44 | Sep 15 | 0.67 | Oct 15 | 0.97 |
| Mar 16 | 0.31 | Apr 16 | 0.06 | May 16 | 0.34 | Jun 16 | 0.08 | Jul 16 | 0.41 | Aug 16 | 0.46 | Sep 16 | 0.68 | Oct 16 | 0.98 |
| Mar 17 | 0.30 | Apr 17 | 0.07 | May 17 | 0.31 | Jun 17 | 0.06 | Jul 17 | 0.42 | Aug 17 | 0.47 | Sep 17 | 0.69 | Oct 17 | 0.99 |
| Mar 18 | 0.28 | Apr 18 | 0.05 | May 18 | 0.32 | Jun 18 | 0.05 | Jul 18 | 0.43 | Aug 18 | 0.48 | Sep 18 | 0.70 | Oct 18 | 1.00 |
| Mar 19 | 0.26 | Apr 19 | 0.03 | May 19 | 0.32 | Jun 19 | 0.03 | Jul 19 | 0.45 | Aug 19 | 0.49 | Sep 19 | 0.71 | Oct 19 | 1.01 |
| Mar 20 | 0.24 | Apr 20 | 0.01 | May 20 | 0.33 | Jun 20 | 0.02 | Jul 20 | 0.45 | Aug 20 | 0.50 | Sep 20 | 0.73 | Oct 20 | 1.00 |
| Mar 21 | 0.22 | Apr 21 | 0.01 | May 21 | 0.35 | Jun 21 | 0.00 | Jul 21 | 0.47 | Aug 21 | 0.50 | Sep 21 | 0.75 | Oct 21 | 0.99 |
| Mar 22 | 0.20 | Apr 22 | 0.03 | May 22 | 0.33 | Jun 22 | 0.00 | Jul 22 | 0.43 | Aug 22 | 0.51 | Sep 22 | 0.76 | Oct 22 | 1.00 |
| Mar 23 | 0.15 | Apr 23 | 0.05 | May 23 | 0.31 | Jun 23 | 0.00 | Jul 23 | 0.45 | Aug 23 | 0.52 | Sep 23 | 0.77 | Oct 23 | 1.01 |
| Mar 24 | 0.13 | Apr 24 | 0.07 | May 24 | 0.30 | Jun 24 | 0.00 | Jul 24 | 0.47 | Aug 24 | 0.53 | Sep 24 | 0.78 | Oct 24 | 1.02 |
| Mar 25 | 0.11 | Apr 25 | 0.05 | May 25 | 0.28 | Jun 25 | 0.00 | Jul 25 | 0.45 | Aug 25 | 0.52 | Sep 25 | 0.79 | Oct 25 | 1.03 |
| Mar 26 | 0.10 | Apr 26 | 0.06 | May 26 | 0.26 | Jun 26 | 0.00 | Jul 26 | 0.43 | Aug 26 | 0.53 | Sep 26 | 0.80 | Oct 26 | 1.04 |
| Mar 27 | 0.05 | Apr 27 | 0.07 | May 27 | 0.28 | Jun 27 | 0.00 | Jul 27 | 0.42 | Aug 27 | 0.54 | Sep 27 | 0.81 | Oct 27 | 1.03 |
| Mar 28 | 0.03 | Apr 28 | 0.08 | May 28 | 0.25 | Jun 28 | 0.00 | Jul 28 | 0.43 | Aug 28 | 0.55 | Sep 28 | 0.82 | Oct 28 | 1.04 |
| Mar 29 | 0.01 | Apr 29 | 0.08 | May 29 | 0.20 | Jun 29 | 0.00 | Jul 29 | 0.42 | Aug 29 | 0.56 | Sep 29 | 0.81 | Oct 29 | 1.05 |
| Mar 30 | 0.02 | Apr 30 | 0.09 | May 30 | 0.18 | Jun 30 | 0.00 | Jul 30 | 0.42 | Aug 30 | 0.55 | Sep 30 | 0.81 | Oct 30 | 1.10 |
| Mar 31 | 0.03 | | | May 31 | 0.16 | | | Jul 31 | 0.40 | Aug 31 | 0.58 | | | Oct 31 | 1.10 |

**Table 19–20** Water level, in feet below land-surface datum, for October 1983 to September 1984

Washington County
3504295341901. local number, 08W-15E-254
Location—Lat 45 4’22" Long 122 34' 19"
Well characteristics—Observation well
Datum—Altitude of land-surface is unavailable

| Date | Water level | Date | Water level | Date | Water level | Date | Water level | Date | Water level | Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mar 1 | 0.45 | Apr 1 | 0.14 | May 1 | 0.20 | Jun 1 | 0.28 | Jul 1 | 0.20 | Aug 1 | 0.41 | Sep 1 | 0.60 | Oct 1 | 0.85 |
| Mar 2 | 0.40 | Apr 2 | 0.15 | May 2 | 0.21 | Jun 2 | 0.19 | Jul 2 | 0.25 | Aug 2 | 0.42 | Sep 2 | 0.61 | Oct 2 | 0.86 |
| Mar 3 | 0.45 | Apr 3 | 0.16 | May 3 | 0.22 | Jun 3 | 0.20 | Jul 3 | 0.20 | Aug 3 | 0.42 | Sep 3 | 0.62 | Oct 3 | 0.86 |
| Mar 4 | 0.45 | Apr 4 | 0.15 | May 4 | 0.23 | Jun 4 | 0.20 | Jul 4 | 0.22 | Aug 4 | 0.44 | Sep 4 | 0.63 | Oct 4 | 0.86 |
| Mar 5 | 0.45 | Apr 5 | 0.15 | May 5 | 0.25 | Jun 5 | 0.21 | Jul 5 | 0.25 | Aug 5 | 0.45 | Sep 5 | 0.61 | Oct 5 | 0.87 |
| Mar 6 | 0.43 | Apr 6 | 0.20 | May 6 | 0.28 | Jun 6 | 0.25 | Jul 6 | 0.26 | Aug 6 | 0.45 | Sep 6 | 0.60 | Oct 6 | 0.89 |
| Mar 7 | 0.43 | Apr 7 | 0.20 | May 7 | 0.19 | Jun 7 | 0.25 | Jul 7 | 0.27 | Aug 7 | 0.46 | Sep 7 | 0.61 | Oct 7 | 0.90 |
| Mar 8 | 0.42 | Apr 8 | 0.20 | May 8 | 0.15 | Jun 8 | 0.29 | Jul 8 | 0.30 | Aug 8 | 0.47 | Sep 8 | 0.62 | Oct 8 | 0.91 |
| Mar 9 | 0.42 | Apr 9 | 0.15 | May 9 | 0.18 | Jun 9 | 0.38 | Jul 9 | 0.35 | Aug 9 | 0.48 | Sep 9 | 0.63 | Oct 9 | 0.93 |
| Mar 10 | 0.41 | Apr 10 | 0.23 | May 10 | 0.15 | Jun 10 | 0.26 | Jul 10 | 0.33 | Aug 10 | 0.49 | Sep 10 | 0.65 | Oct 10 | 0.94 |
| Mar 11 | 0.35 | Apr 11 | 0.25 | May 11 | 0.18 | Jun 11 | 0.24 | Jul 11 | 0.35 | Aug 11 | 0.48 | Sep 11 | 0.66 | Oct 11 | 0.95 |
| Mar 12 | 0.33 | Apr 12 | 0.13 | May 12 | 0.27 | Jun 12 | 0.23 | Jul 12 | 0.37 | Aug 12 | 0.48 | Sep 12 | 0.65 | Oct 12 | 0.97 |
| Mar 13 | 0.33 | Apr 13 | 0.15 | May 13 | 0.23 | Jun 13 | 0.22 | Jul 13 | 0.38 | Aug 13 | 0.49 | Sep 13 | 0.67 | Oct 13 | 0.95 |
| Mar 14 | 0.31 | Apr 14 | 0.16 | May 14 | 0.25 | Jun 14 | 0.21 | Jul 14 | 0.37 | Aug 14 | 0.45 | Sep 14 | 0.65 | Oct 14 | 0.96 |
| Mar 15 | 0.33 | Apr 15 | 0.15 | May 15 | 0.23 | Jun 15 | 0.25 | Jul 15 | 0.40 | Aug 15 | 0.44 | Sep 15 | 0.67 | Oct 15 | 0.97 |
| Mar 16 | 0.34 | Apr 16 | 0.16 | May 16 | 0.34 | Jun 16 | 0.28 | Jul 16 | 0.41 | Aug 16 | 0.46 | Sep 16 | 0.68 | Oct 16 | 0.98 |
| Mar 17 | 0.32 | Apr 17 | 0.17 | May 17 | 0.33 | Jun 17 | 0.26 | Jul 17 | 0.42 | Aug 17 | 0.47 | Sep 17 | 0.69 | Oct 17 | 0.99 |
| Mar 18 | 0.28 | Apr 18 | 0.15 | May 18 | 0.33 | Jun 18 | 0.25 | Jul 18 | 0.43 | Aug 18 | 0.48 | Sep 18 | 0.70 | Oct 18 | 1.00 |
| Mar 19 | 0.28 | Apr 19 | 0.13 | May 19 | 0.33 | Jun 19 | 0.23 | Jul 19 | 0.45 | Aug 19 | 0.49 | Sep 19 | 0.71 | Oct 19 | 1.01 |
| Mar 20 | 0.26 | Apr 20 | 0.11 | May 20 | 0.35 | Jun 20 | 0.22 | Jul 20 | 0.45 | Aug 20 | 0.50 | Sep 20 | 0.73 | Oct 20 | 1.00 |
| Mar 21 | 0.21 | Apr 21 | 0.11 | May 21 | 0.35 | Jun 21 | 0.20 | Jul 21 | 0.47 | Aug 21 | 0.50 | Sep 21 | 0.75 | Oct 21 | 0.99 |
| Mar 22 | 0.22 | Apr 22 | 0.13 | May 22 | 0.35 | Jun 22 | 0.20 | Jul 22 | 0.43 | Aug 22 | 0.51 | Sep 22 | 0.76 | Oct 22 | 1.00 |
| Mar 23 | 0.18 | Apr 23 | 0.15 | May 23 | 0.32 | Jun 23 | 0.20 | Jul 23 | 0.45 | Aug 23 | 0.52 | Sep 23 | 0.77 | Oct 23 | 1.01 |
| Mar 24 | 0.16 | Apr 24 | 0.17 | May 24 | 0.36 | Jun 24 | 0.20 | Jul 24 | 0.47 | Aug 24 | 0.53 | Sep 24 | 0.78 | Oct 24 | 1.02 |
| Mar 25 | 0.16 | Apr 25 | 0.15 | May 25 | 0.38 | Jun 25 | 0.20 | Jul 25 | 0.45 | Aug 25 | 0.52 | Sep 25 | 0.79 | Oct 25 | 1.03 |
| Mar 26 | 0.11 | Apr 26 | 0.16 | May 26 | 0.36 | Jun 26 | 0.20 | Jul 26 | 0.43 | Aug 26 | 0.53 | Sep 26 | 0.80 | Oct 26 | 1.04 |
| Mar 27 | 0.11 | Apr 27 | 0.17 | May 27 | 0.38 | Jun 27 | 0.20 | Jul 27 | 0.42 | Aug 27 | 0.54 | Sep 27 | 0.81 | Oct 27 | 1.03 |
| Mar 28 | 0.13 | Apr 28 | 0.18 | May 28 | 0.35 | Jun 28 | 0.20 | Jul 28 | 0.43 | Aug 28 | 0.55 | Sep 28 | 0.82 | Oct 28 | 1.04 |
| Mar 29 | 0.11 | Apr 29 | 0.11 | May 29 | 0.30 | Jun 29 | 0.20 | Jul 29 | 0.42 | Aug 29 | 0.56 | Sep 29 | 0.81 | Oct 29 | 1.05 |
| Mar 30 | 0.12 | Apr 30 | 0.19 | May 30 | 0.28 | Jun 30 | 0.20 | Jul 30 | 0.42 | Aug 30 | 0.55 | Sep 30 | 0.81 | Oct 30 | 1.10 |
| Mar 31 | 0.13 | | | May 31 | 0.28 | | | Jul 31 | 0.41 | Aug 31 | 0.58 | | | Oct 31 | 1.10 |

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