



**Ground-Water Discharge from the Navajo Sandstone
to the Streamflow of the Virgin River
in the Zion National Park Area**

Technical Report NPS/NRWRD/NRTR-2005/343

**Paul K. Christensen
Jeffrey C. Hughes
William R. Hansen**

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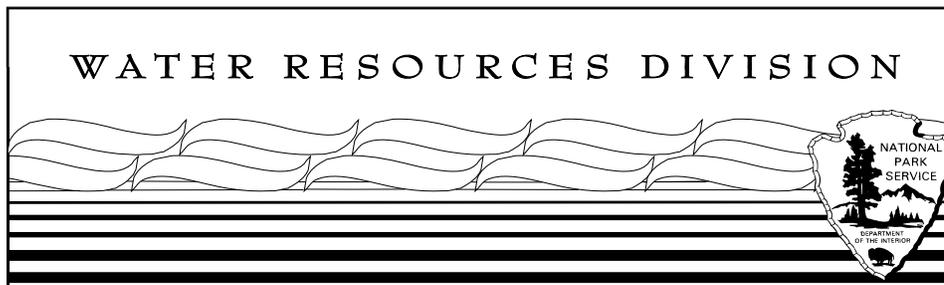
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**Paul K. Christensen, Jeffrey C. Hughes, and William R.
Hansen
Hydrologists**



**National Park Service - Department of the Interior
Fort Collins - Denver - Washington**

**1201 Oakridge, Drive, Suite 250
Fort Collins, Colorado 80525**

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EXECUTIVE SUMMARY

The North and East Forks of the Virgin River are the two major streams flowing through the Zion National Park. Water-related resources in the park depend on the ground-water discharge to the two streams. The purposes of this report are to (1) quantify ground-water discharge from the Navajo Sandstone to the East and North Forks and (2) publish streamflow measurements taken between 1986 and 1993.

The most extensive and thickest sandstone unit in the park area is the Navajo Sandstone which discharges water into the two forks. To quantify discharge from the sandstone to the forks, instantaneous streamflow measurements were taken at selected locations along the forks. From these measurements, sets of synoptic streamflow measurements were selected to determine increases or decreases in streamflow. These sets and daily mean streamflow records from gaging stations of U.S. Geological Survey and National Park Service were used to quantify discharge from the sandstone to the two forks.

Ground-water discharge from the Navajo Sandstone to the streamflow of the East Fork likely ranged from 26 to 36 ft³/s. This range comprised as much as 100 percent of the minimum streamflow (26 ft³/s) and 73 percent of the median streamflow (49 ft³/s) of the East Fork. Ground-water discharge from the Navajo Sandstone to the streamflow of the North Fork likely ranged from 24 to 55 ft³/s, a wider range than that of the East Fork. This estimated range comprised as much as 100 percent of the minimum (24 ft³/s) and 85 percent of the median streamflow (65 ft³/s) of the North Fork. In total, about 50 to 91 ft³/s of water discharge from the Navajo Sandstone to the two forks, likely making the sandstone the dominant source of water in the two forks during low-flow periods.

INTRODUCTION

Water-related resources in Zion National Park depend on the ground-water discharge to maintain low flow in streams. The North and East Forks of the Virgin River are the two major streams flowing through the park. Quantification of this discharge was necessary to support water-right claims of the National Park Service (NPS) and to preserve streamflow and associated biologic and aesthetic attributes for visitor enjoyment. The purposes of this report are to (1) quantify ground-water discharge from the Navajo Sandstone to the East and North Forks and (2) and publish streamflow measurements taken between 1986 and 1993.

All streamflow measurements in this report will appear with two significant figures. Any calculation made using streamflow measurements will also have two significant figures.

Physiographic, Geologic, and Hydrologic Settings

Zion National Park is located in southwestern Utah where the Virgin River cut deep into a plateau and formed several canyons, including Zion and Parunuweap Canyons (Figure 1). Regional dip of the sedimentary strata is about 2 degrees to the northeast (Gregory, 1950; Hamilton, 1987, 1992). Exposed geologic units in the area range from Triassic to Holocene in age and include both unconsolidated deposits and consolidated rocks. Mesozoic sedimentary rocks are the predominant rocks in the Zion National Park area. The Navajo Sandstone of Jurassic age is the most extensive sandstone formation and has a thickness of approximately 2,000 feet (Cordova, 1981). The sandstone contains water wherever the formation is present (Heilweil and Freethy, 1992). Where the Navajo Sandstone crops out, the aquifer is unconfined. In areas where the Navajo Sandstone is overlain by younger rocks, the aquifer may be confined, particularly outside of the park.

North and east of the park, a thick sequence (over 5,000 feet thick) of Jurassic-, Cretaceous-, and Tertiary-age rocks overlies the Navajo Sandstone and consists predominantly of sandstone, shale, coal, and limestone (Cordova, 1981). Most of this sequence has been eroded away within the park. The Navajo Sandstone is underlain by the Kayenta Formation, which has a thickness of about 200 feet and consists of siltstone and shale. Underlying the Kayenta Formation, are over 3,000 feet of Triassic age rocks that consist mostly of sandstone, siltstone, shale, and conglomerate.

Jointing in a north-northwest direction is common in the sandstone. Fracturing along bedding planes and conjugate joint systems at angles of about 60 degrees to the bedding planes is also common (Cordy and others, 1993). Ground water moves through the joints and fractures as well as through pore space in rock from plateaus to springs, seeps, and streams in the canyons. Recharge to aquifers, including the Navajo Sandstone, is from precipitation on the top of the plateaus and seepage from streams.

The East and North Forks of the Virgin River originate outside of the park and flow through the park to form the Virgin River, which runs in a general southwest direction and flows into Lake Mead in Nevada. The major tributaries of the East Fork near the park are Shunes and Meadow creeks. The major tributaries of the North Fork are Deep Creek and Kolob Creek. Lesser tributaries of the North Fork are Goose Creek and Orderville Canyon.

Water is diverted from the two streams upstream of the park. Inside the park, the town of Springdale diverts water from the North Fork year-round. Water is also stored and released from Kolob Reservoir into Kolob Creek upstream of the park boundary for use downstream of the park.

Seepage from the East and North Forks to the Navajo Sandstone occurs where the streams cross the upper unsaturated parts of the Navajo Sandstone (Heilweil and Freethey, 1992). Seepage of ground water to streams accounts for the largest quantity of known discharge from the Navajo Sandstone in the park area.

Previous Investigations

The geology of Zion National Park is described by Gregory (1950). A geologic map (Hamilton, 1987) and a geologic guidebook of the park (Hamilton, 1992) are available and show many important geologic features. Cordova (1981) described the ground-water conditions in the upper Virgin River area with emphasis on the Navajo Sandstone. Danielson and Hood (1984) studied recharge to the Navajo Sandstone in southern Utah, showing that recharge can result from precipitation on outcrops of the Navajo and other sandstones that are common throughout the Colorado Plateau. The hydrology of the Navajo Sandstone was studied by Heilweil and Freethey (1992), who simulated ground-water flow and potential water-level declines potentially caused from proposed ground-water withdrawals for coal mining. They describe the general geologic setting, hydrology of the area, and relationships between the Navajo Sandstone and the East and North Forks of the Virgin River (Freethey, 1988). Kimball and Christensen (1996) characterized the source of recharge to seeps and springs in Zion Canyon and estimated residence time of ground water moving from the Navajo Sandstone recharge area to seeps and springs.

Acknowledgments

Alice Johns (1988) of the NPS conceived this investigation. Several NPS staff and Colorado State University (CSU) graduate students measured streamflow, including Jeff Hughes, Nancy Granger, Karen Peterson, Linda Roos, Colleen Delaney, and Linda Butler. CSU research associates Nancy Stevens, Victoria Murt, and Christy Crandall prepared preliminary versions of this report.

AQUIFER-STREAM RELATIONS

Reaches where the two forks lie within the Navajo Sandstone are shown by a thick green line on Figure 2 for the East Fork and on Figure 3 for the North Fork. Accordingly, these reaches are referred to as “reaches within the Navajo Sandstone.” There, the streams are hydrologically connected with the Navajo, allowing water to seep from the stream into the aquifer and vice versa. Downstream of these reaches, ground water from the Navajo Sandstone flows from the base of the formation down slope to the forks through streams or unconsolidated sediments. These reaches are shown by a thick gray line on Figures 2 and 3 and are referred to as “reaches below the base of the Navajo Sandstone.” Similar reaches were not determined for

tributaries to the forks because of the lack of information.

RIVER-MILE DESIGNATIONS

Initially, river-mile designations were approximated using 1:24000 and 1:100000 U.S. Geological Survey (USGS) topographic maps, a map wheel, and river-mile designations of the Pacific Southwest Inter-Agency Committee (1974). Since the time that streamflow measurements were made for this investigation, the Institute for Natural Systems Engineering of the Utah Water Research Laboratory in Logan, Utah, re-determined river miles for the major streams in the Virgin River basin (Tyler, 2002). The river miles, in one tenth mile increments, were generated using ARCVIEW® and the 1:100000 National Hydrography Dataset. The river-mile shapefile is in UTM NAD83 format.

River-mile designations thus have been re-calculated using the shapefile, ARCVIEW®, and 1:24000 and 1:100000 USGS maps showing the location of pertinent sites or points. These river miles are much more accurate than those previously determined and are used in this report.

The Pacific Southwest Inter-Agency Committee designated river miles from the mouth of the Virgin River at Lake Mead, and the East Fork was the considered the main stem of the Virgin River. For the North Fork, the river miles began at the confluence of the two streams. In the new designation, the confluence of the two streams marks the 0.0 river mile for both streams. See Figures 2 and 3.

River miles were determined for (1) streamflow measuring sites, (2) the upper and lower ends of the reaches within the Navajo Sandstone, and (3) locations where the two streams pass into and out of the park. The initial and new river-mile designations for each streamflow measuring site are found in Appendix 1 for the East Fork and Appendix 2 for the North Fork. Appendix 3 contains the initial and new river-mile designations for reaches within Navajo Sandstone, and Appendix 4 contains the initial and new river-mile designations for park boundaries on the two streams.

STREAMFLOW CHARACTERISTICS

The USGS has operated several gaging stations on the North and East Forks (Table 1). All streamflow data for the gaging stations was obtained from the USGS (2005).

Streamflow originates ultimately from precipitation. Precipitation events in the winter are caused by large storms originating over the Pacific Ocean west of the park. Snowmelt occurs from March through May. From about July through September, tropical moisture from the south (monsoons) feeds thunderstorms in the area. See CLIMAS (2005) for an introduction to the climate of the Southwest.

The USGS operated Gaging Station 09404900 on the East Fork of the Virgin River near Springdale, Utah, from October 1, 1991, to present. Data are available through September 30, 2004. Figure 4 shows the maximum, median, and minimum daily mean streamflow values over the period of record. The station is located at river mile 3.8, downstream from the reach within Navajo Sandstone. The maximum daily mean streamflow for the period of record is 450 ft³/s, the median is 49 ft³/s, and the minimum is 26 ft³/s (Figure 4).

The USGS operated Gaging Station 09405500 on the North Fork of the Virgin River near Springdale, Utah, from July 6, 1923, to present. Data are available through September 30, 2004.

The station is located at river mile 4.7, downstream from the reach within the Navajo Sandstone. The maximum daily mean streamflow for the period of record is 5,000 ft³/s, the median is 53 ft³/s, and the minimum is 22 ft³/s. This station does not account for water diverted by the town of Springdale from the North Fork upstream of the gaging station.

The USGS operated Gaging Station 09405499, Springdale Canal near Springdale, Utah, from October 1, 1968, through September 30, 1989. The station is located at river mile 4.9, about 0.2 mi upstream of Station 09405500. The daily mean streamflow for Stations 09405500 and 09405499 were combined for the overlapping period of record, and the maximum, median, and minimum daily mean streamflow values over the period of record are shown on Figure 5. The maximum daily mean streamflow of the North Fork for this period of record was 3,000 ft³/s, the median was 65 ft³/s, and the minimum was 24 ft³/s.

The drainage areas for Stations 09404900 (East Fork Virgin River near Springdale) and 09405500 (North Fork Virgin River near Springdale) are 343 and 344 mi². Although the drainage areas are nearly equal, much more water flows down the North Fork (see Figure 6), because a larger part of the North Fork's drainage is located in higher elevations, where precipitation and snow pack are larger.

STREAMFLOW MEASUREMENTS

The NPS operated a gaging station on the North Fork in 1988 and 1989 at the same site as USGS Gaging Station 09405490 (North Fork Virgin River above Big Bend near Glendale, Utah). A staff plate, transducer, and recorder were installed. The NPS downloaded data from the recorder, verified the data, and created a stage-discharge rating curve. The daily mean streamflow values are contained in Appendix 5.

Instantaneous streamflow measurements were also taken at selected locations on the North and East Forks of the Virgin River. From these, sets of synoptic streamflow measurements were defined for estimating discharge from the Navajo Sandstone to the streams.

Instantaneous Streamflow Measurements

Instantaneous streamflow measurements were taken at selected locations on the North and East Forks of the Virgin River conditions from mid-May through early October, at 15 locations along the East Fork (Figure 2) and 22 locations along the North Fork (Figure 3) from 1986 through 1993. The measurements were taken during low flow conditions to reduce the effects of larger flows caused by snowmelt and convective storm events (thunderstorms) on streamflow and, thus, better represent ground-water discharge to the streams.

Selection of streamflow measurement sites was based on suitability, accessibility, and safety concerns associated with storm events. Some sites were selected between major tributaries or known points of inflow.

Streamflow measurements were taken using the USGS's mid-point method (Buchanan and Somers, 1969). Either pygmy or Price AA current meters were used, depending on water velocity and depth. Meters were spin-tested before each streamflow measurement to ensure the equipment was operating correctly.

At sites where no permanent staff gage existed, a temporary stage marker was installed at each measurement site to determine if surface-water elevations remained constant during streamflow measurements. Stage was recorded using either a pocket rod placed in the water or a scratch made on a rock. Stage levels were checked before and after each streamflow measurement and remained constant during all measurements.

Streamflow measurements were recorded in field notebooks along with water and air temperature, stage height, spin test time, weather conditions, and miscellaneous information. All streamflow measurements were later verified in the office.

Several flow measurements were taken through some reaches over a period of several days because access required long, difficult hikes. During measurements taken one, two, or three days in a row, streamflow for the most part remained fairly constant as determined by staff gages, records from USGS stream-gaging stations, and precipitation records.

Streamflow measurement sites, river mile of measurement sites, and rock units underlying measurement sites are shown in Table 2 for the East Fork and Table 3 for the North Fork. Instantaneous streamflow measurements are shown in Appendix 6 for the East Fork and Appendix 7 for the North Fork.

Sets of Synoptic Streamflow Measurements

Sets of synoptic streamflow measurements were selected to estimate discharge from the Navajo Sandstone to the streamflow of the two streams, using the instantaneous streamflow measurements in Appendices 6 and 7. Each set consists of several streamflow measurements taken (1) in upper and lower reaches or in middle and lower reaches and (2) within a one-, two- or three-day period. Given these criteria, six sets were found for the East Fork (Table 4), and nine sets were found for North Fork (Table 5).

Streamflow measurements from these sets were compared with daily mean streamflow from Gaging Stations 09404900 and combined Stations 09405499 and 09405500 to determine how streamflow conditions may affect the interpretation of these sets. When possible, two comparisons were made for each set: (1) daily mean streamflow for each year with one or more sets of synoptic streamflow measurements plotted against the maximum, median, and minimum daily mean streamflow over the period of record and (2) streamflow measured at the site of gaging station plotted against daily mean streamflow from June through October.

For the East Fork, daily mean streamflow is available for only one of the three years when streamflow measurements were taken (1992). Streamflow conditions in 1992 were near median (Figure 7). The set of synoptic streamflow measurements taken September 8-10, 1992, occurred during a period of relatively constant streamflow (Figure 8).

For the North Fork, stream hydrographs are available for each year with one or more sets of synoptic streamflow measurements. Streamflow conditions in 1986, 1987, and 1989 were near median (Figures 9, 10, and 11). Except for two sets, the streamflow measurements were taken during gradual rises or declines in streamflow (Figures 12, 13, and 14). Two sets were taken when the limb of the storm-event hydrograph was rapidly falling or rising (August 10-11, and August 24-25, 1987).

For the other five sets for the East Fork, where daily mean streamflow is not available, the streamflow measurements taken at mile 3.8 (location of the gaging station) were plotted

against maximum, median, and minimum daily mean streamflow (Figure 15). The measurements lie below median streamflow and, except for one, above minimum streamflow over the period of record.

The sets indicate that the streamflow of the two streams increases three- to six-fold where the streams lie within the Navajo Sandstone and below the base of the Navajo Sandstone (see Figures 16 and 17). This increase is derived from the Navajo Sandstone, inflow from tributaries, or both.

GROUND-WATER DISCHARGE FROM THE NAVAJO SANDSTONE

Streamflow of the East and North Forks is influenced by several factors: precipitation, stream diversions, return flows from diversions, reservoir releases, inflow from tributaries, and seepage to and from aquifers.

Within the park, no diversions occur where the streams lie within the Navajo Sandstone, and one occurs on the North Fork where the stream lies below the base of the Navajo Sandstone (Springdale Canal diversion). Diversions, however, occur in both streams upstream of the reaches where the streams lie within the Navajo Sandstone. Return flows from diversions do not occur within the park.

Water is released from Kolob Reservoir down Kolob Creek to the North Fork (see Hansen, 1995; and Stevens and Hansen, 1997). The reservoir releases are not addressed in this report. Inflow from tributaries to the two streams is also not addressed because information is insufficient to quantify inflow from tributaries. This inflow during low-flow periods is small compared to total streamflow increase and likely includes an unquantified component of ground-water discharge from the Navajo Sandstone. Thus, ground-water discharge from the Navajo Sandstone to the two streams is assumed to range between minimum and median streamflow.

Streamflow data from continuously recording gages on the East Fork (Stations 094047000 and 09404900) indicate streamflow increases ranging from 26 to 36 ft³/s (the minimum to median values on Table 6) from 1992 to 2002 along the reach within the Navajo Sandstone and the reach below the base of the Navajo. The sets of synoptic streamflow measurements for the East Fork indicate streamflow increases ranging from 32 to 35 ft³/s in the reach within the Navajo Sandstone, -2.0 to 4 ft³/s in the reach below the base of the Navajo, and from 30 to 36 ft³/s along both reaches (Table 7). The range determined using streamflow data from gaging stations (26 to 36 ft³/s) is similar to the range determined using the sets of synoptic streamflow measurements (30 to 36 ft³/s).

In four of the six sets of synoptic streamflow measurements (see Table 7), the most upstream site selected to determine discharge from the Navajo Sandstone is located about 12 miles upstream of the reach within the Navajo Sandstone. Only two sets include measurements taken over the reach within the Navajo Sandstone.

Ground-water discharge from the Navajo Sandstone to the streamflow of the East Fork likely ranges from 26 to 36 ft³/s (minimum to median). This range comprises as much as 100 percent of the minimum streamflow (26 ft³/s) and 73 percent of the median streamflow (49 ft³/s) of the East Fork at Station 09404900 from 1992 to 2002.

Streamflow data from continuously recording gages on the North Fork (Stations 09405450, 09405499, and 09405500) indicate a streamflow increase ranging from 24 to 47 ft³/s (minimum to

median values on Table 8) along the reach within the Navajo Sandstone and the reach below the base of the Navajo Sandstone from 1978 to 1984. For the North Fork, the sets of synoptic streamflow measurements indicate streamflow increases of 27 to 59 ft³/s in the reach within the Navajo Sandstone, 2.0 to 37 ft³/s in the reach below the base of the Navajo (including the diversion to the Springdale Canal), and 35 to 81 ft³/s in both reaches (including the diversion to the Springdale Canal) (Table 9). The range determined using streamflow data from the gaging stations (24 to 47 ft³/s) differs considerably from the range determined using the sets of synoptic streamflow measurements (35 to 81 ft³/s). It is likely that the larger increases in streamflow determined using the sets of synoptic streamflow measurements (above 55 ft³/s, median in Table 9) include water from sources other than the Navajo Sandstone.

In seven of the nine sets of synoptic streamflow measurements (see Table 9), the most upstream site selected to determine discharge from the Navajo Sandstone is located about 5 miles upstream of the reach within the Navajo Sandstone. For another set, the most upstream site is about 8 miles upstream, and for the remaining set the most upstream site lies within the Navajo Sandstone. All but one set include measurements taken over the reach within the Navajo Sandstone.

Streamflow data from continuously recording gages on the North Fork (Stations 09405490, 09405499, and 09405500) indicate losses and gains ranging from -3.0 to 5.0 ft³/s (minimum to median in Table 10) along the reach below the base of the Navajo Sandstone in 1988 and 1989. This range is less than that determined using the sets of synoptic streamflow measurements (2.0 to 12 ft³/s, minimum to median in Table 9). Calendar years 1988 and 1989 were drier than usual (see Figure 6).

Ground-water discharge from the Navajo Sandstone to the streamflow of the North Fork likely ranges from 24 to 55 ft³/s (minimum to median), a range much wider than that of the East Fork. This range comprises as much as 100 percent of the minimum (24 ft³/s) and 85 percent of the median streamflow (65 ft³/s) of the North Fork for combined Stations 09405499 and 09405500. In total, about 50 to 91 ft³/s of water likely discharge from the Navajo Sandstone to the two streams, likely making the sandstone the dominant source of water in the two streams during low-flow periods.

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FIGURES

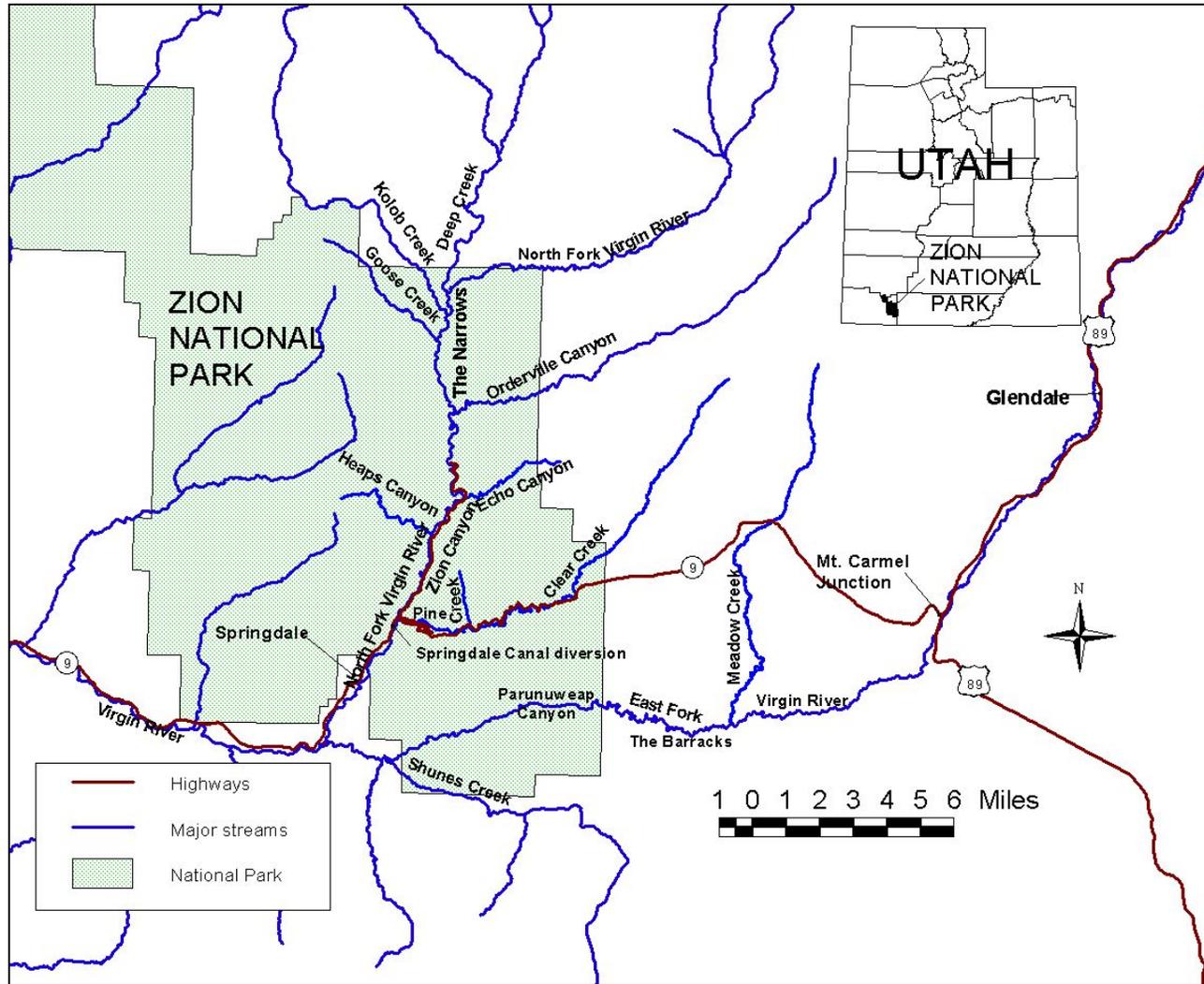


Figure 1. Location of study area and pertinent features.

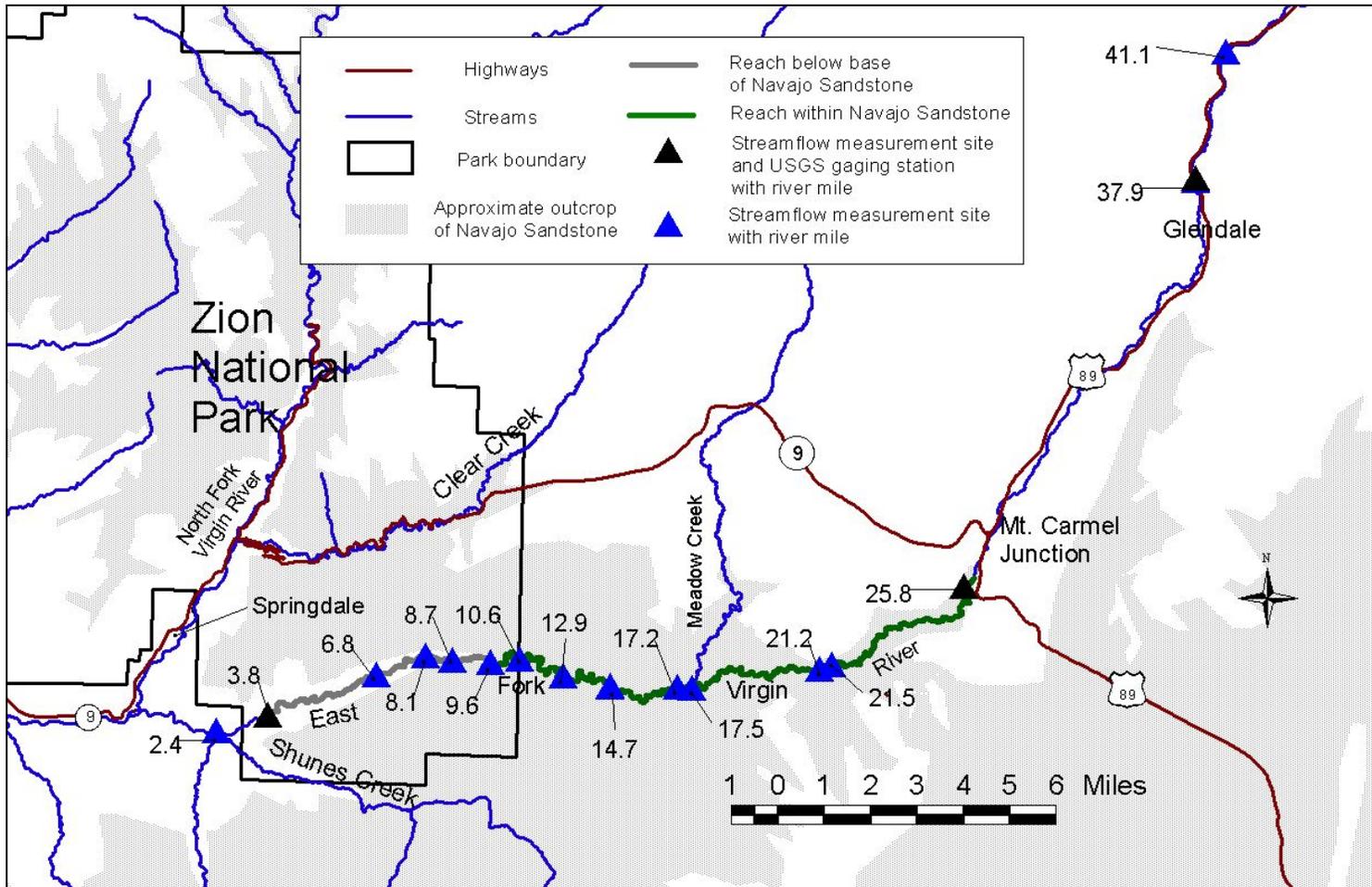


Figure 2. Stream reaches associated with the Navajo Sandstone and locations of streamflow measurement sites with river-mile designations, East Fork of the Virgin River, Zion National Park area.

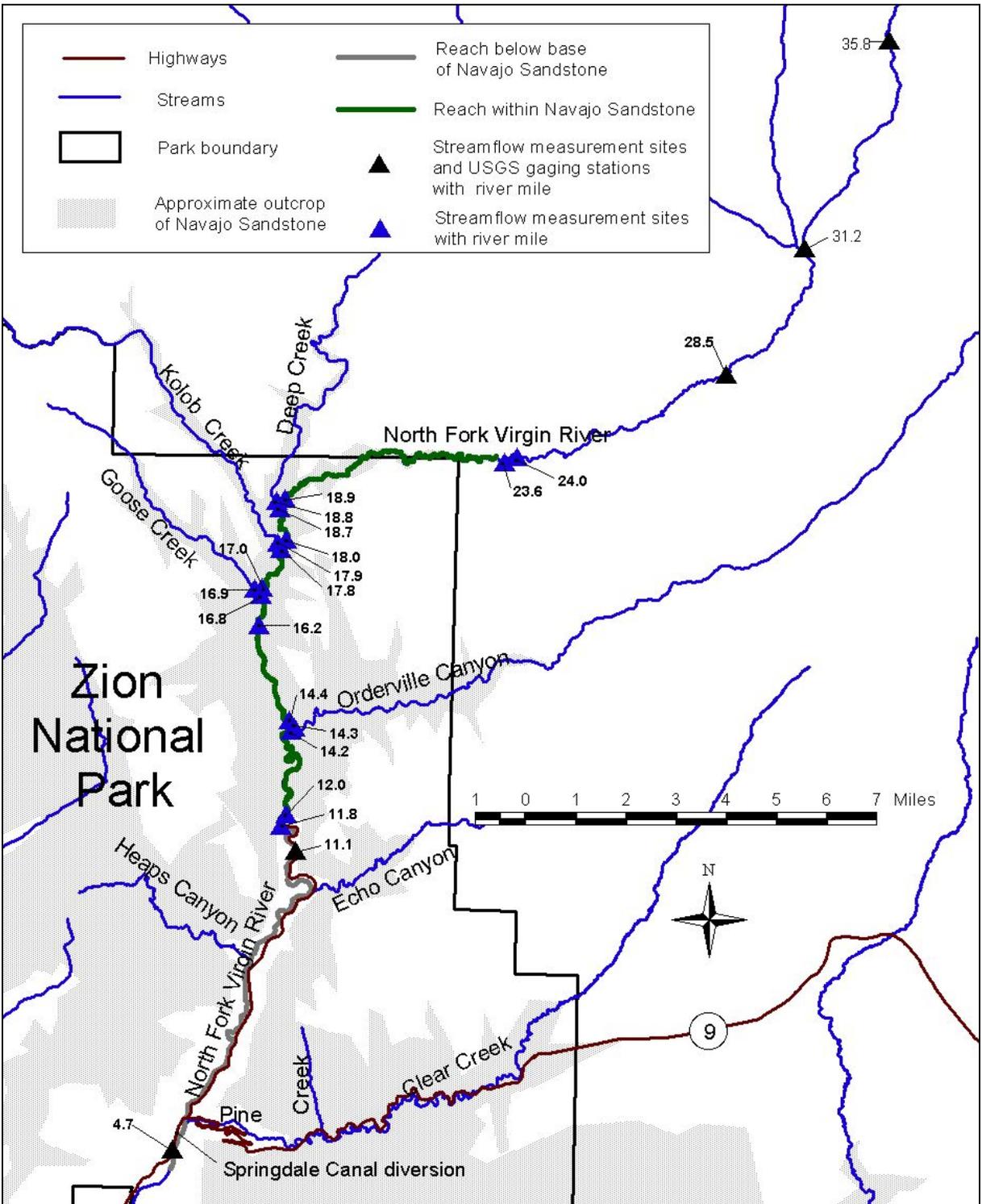


Figure 3. Stream reaches associated with the Navajo Sandstone and locations of streamflow measurement sites with river-mile designations, North Fork of the Virgin River, Zion National Park area.

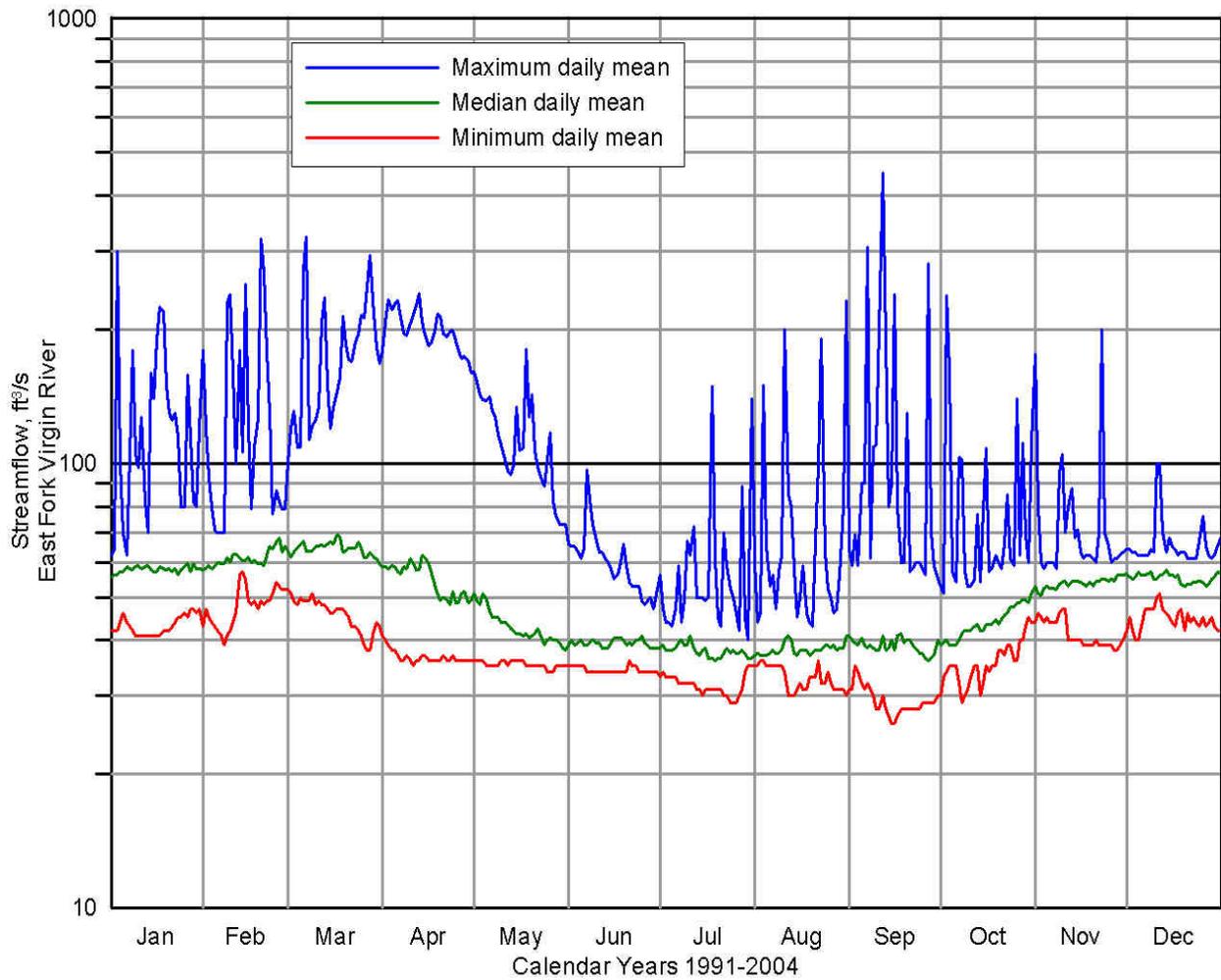


Figure 4. Streamflow characteristics of the East Fork of the Virgin River at Station 09404900 (East Fork near Springdale) and river mile 3.8.

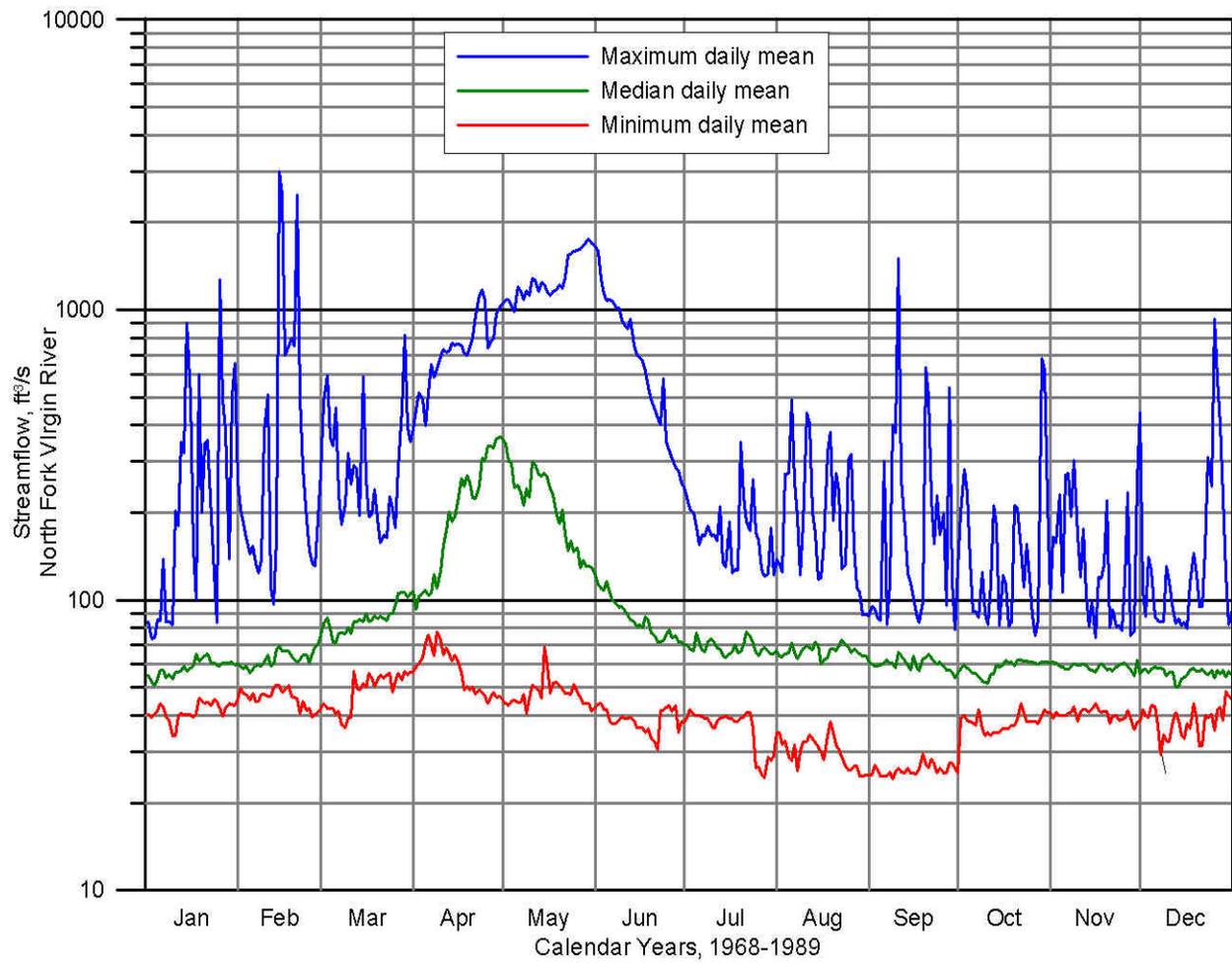


Figure 5. Streamflow characteristics of the North Fork of the Virgin River at combined Stations 09405499 (Springdale Canal) and 09405500 (North Fork near Springdale) and river mile 4.7.

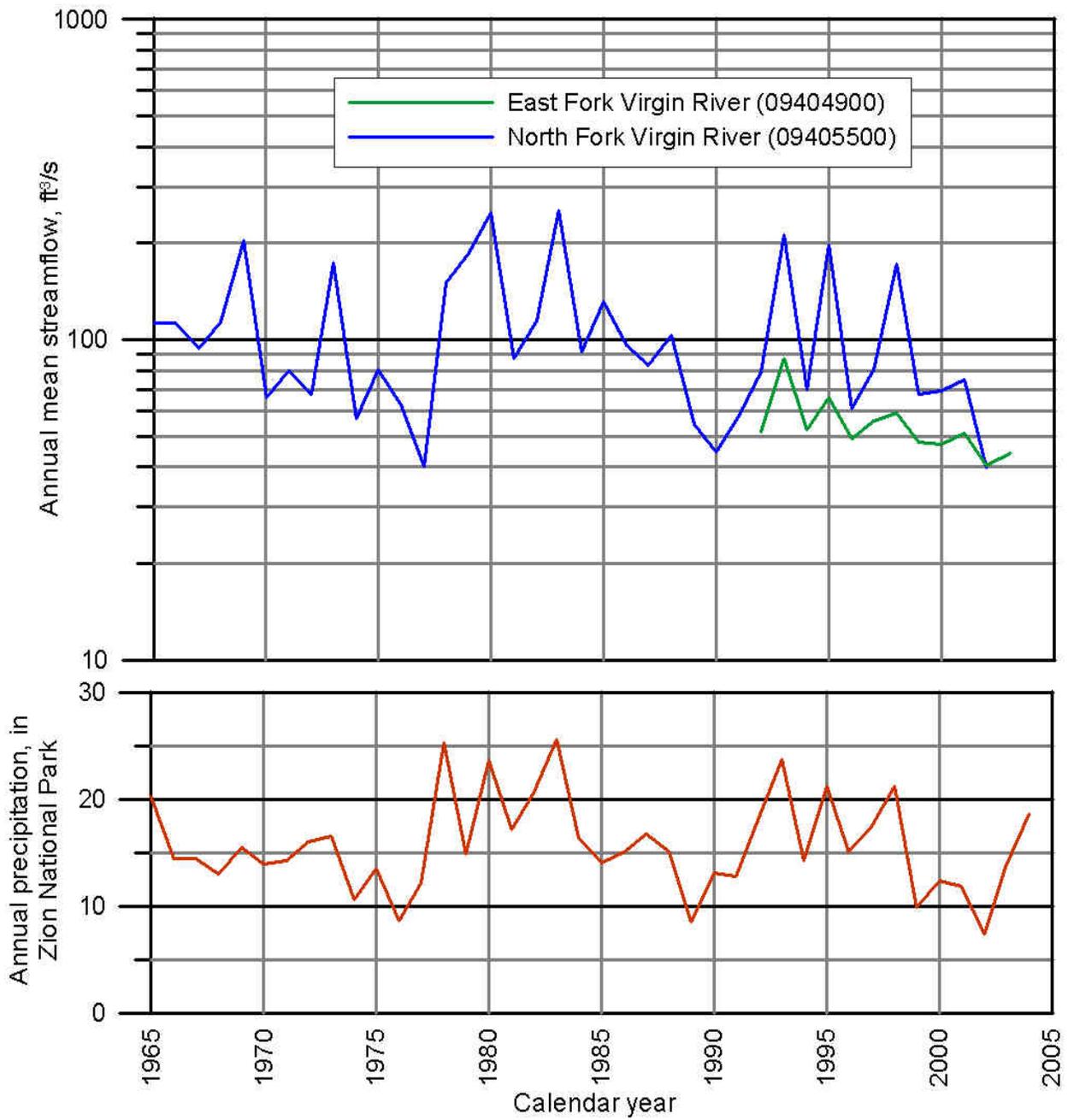


Figure 6. Annual precipitation at Zion National Park (Station 429717) with annual streamflow at Stations 09404900 (East Fork near Springdale) and 09405500 (North Fork near Springdale). Precipitation data are from the Western Regional Climate Center, 2005.

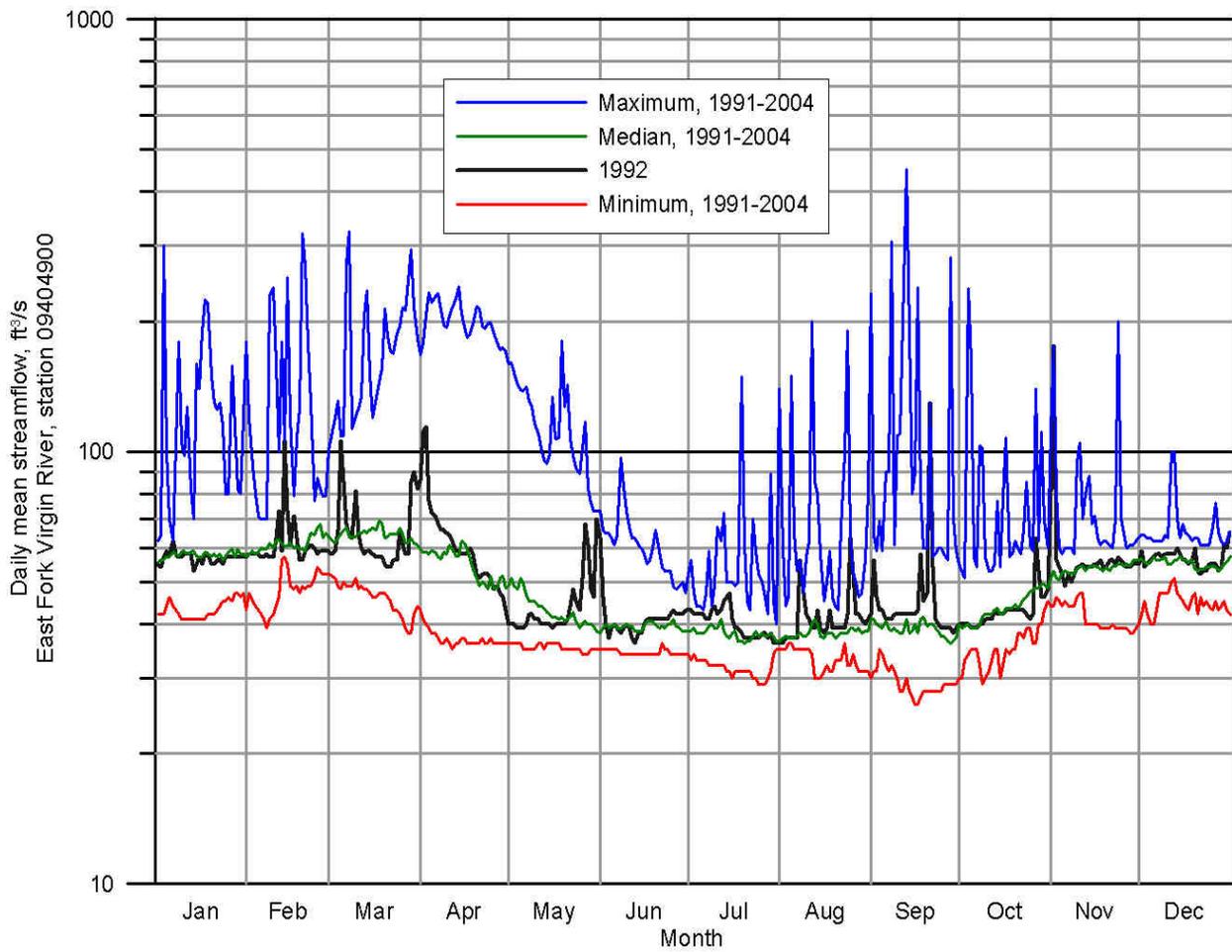


Figure 7. Daily mean streamflow at Station 09404900 (East Fork near Springdale), calendar year 1992 with maximum, median, and minimum daily mean streamflow for the 1991-2004 period of record.

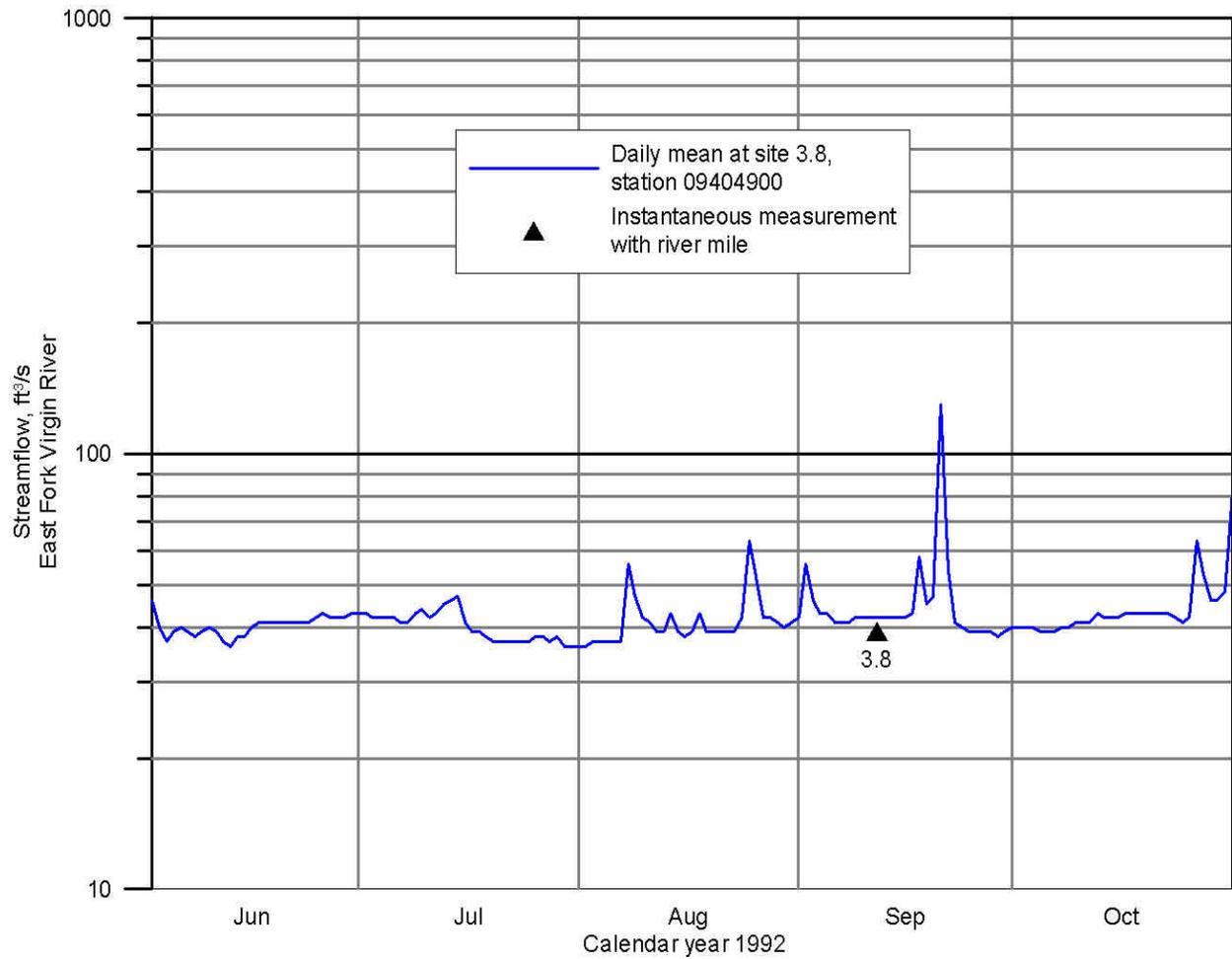


Figure 8. Daily mean streamflow at Station 09404900 (East Fork near Springdale) from June through October 1992 with instantaneous streamflow measurement.

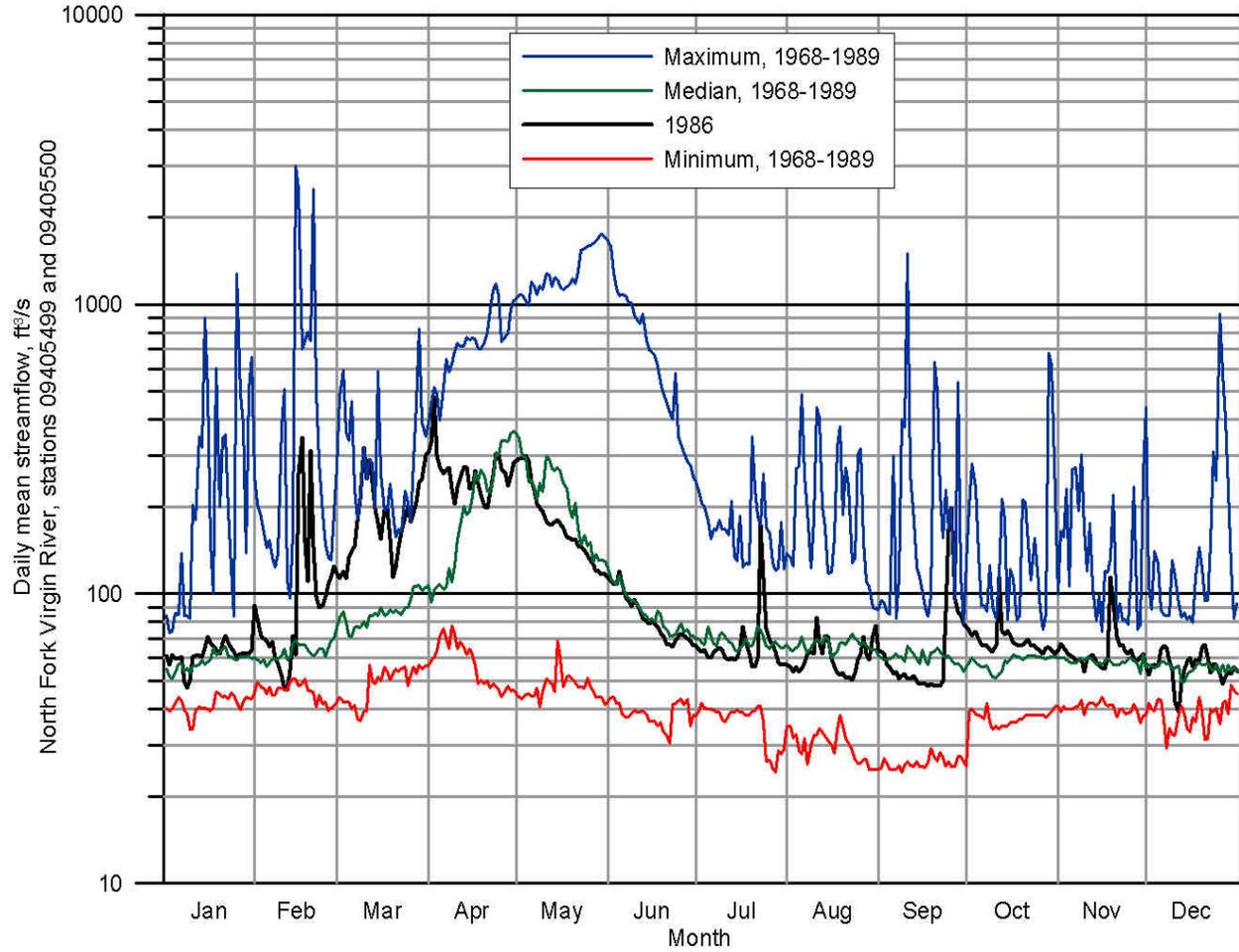


Figure 9. Daily mean streamflow at combined Stations 09405499 (Springdale Canal) and 09405500 (North Fork near Springdale) for calendar year 1986 with maximum, median, and minimum daily mean streamflow for 1968-1989 period of record.

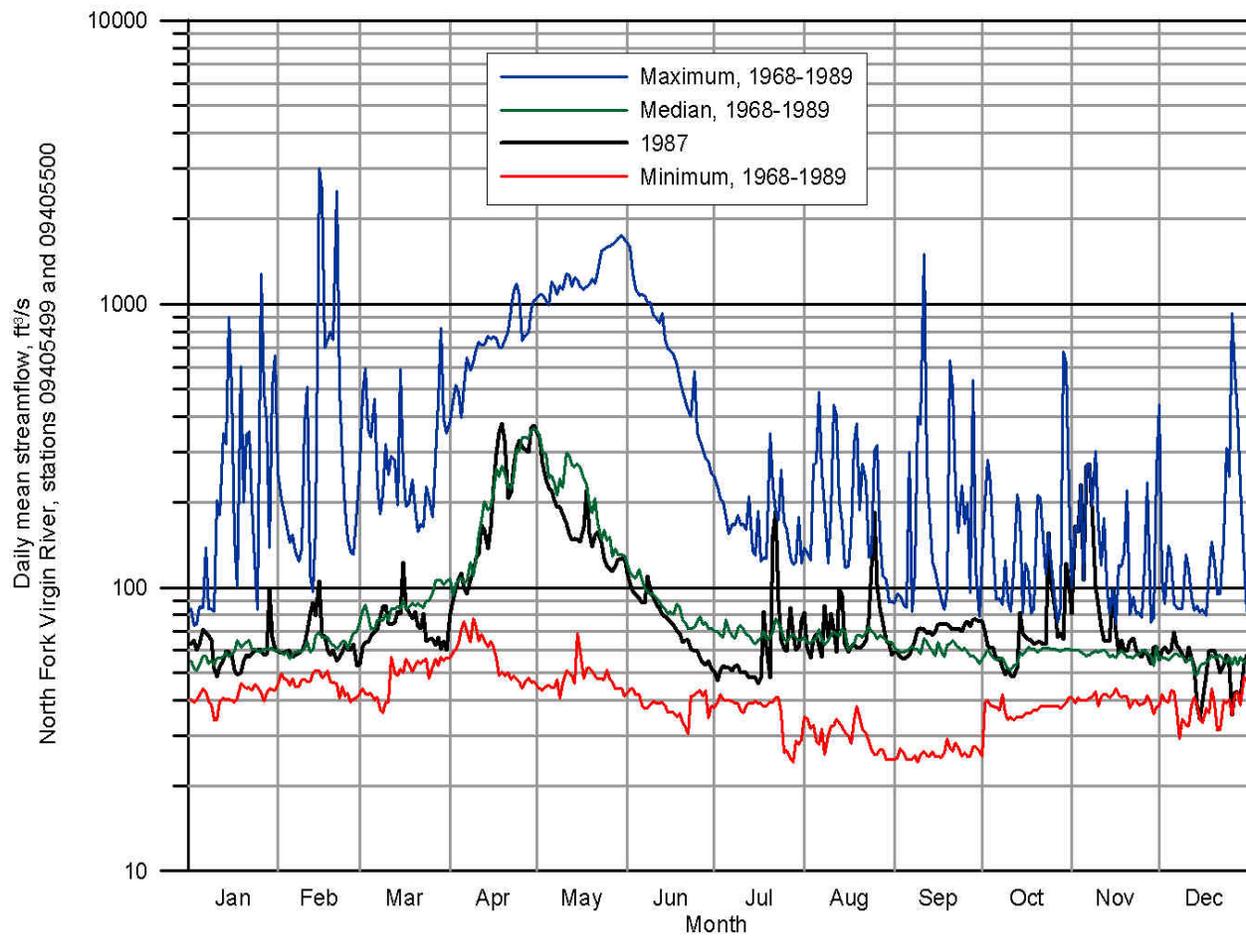


Figure 10. Daily mean streamflow at combined Stations 09405499 (Springdale Canal) and 09405500 (North Fork near Springdale) for calendar year 1987 with maximum, median, and minimum daily mean streamflow for 1968-1989 period of record.

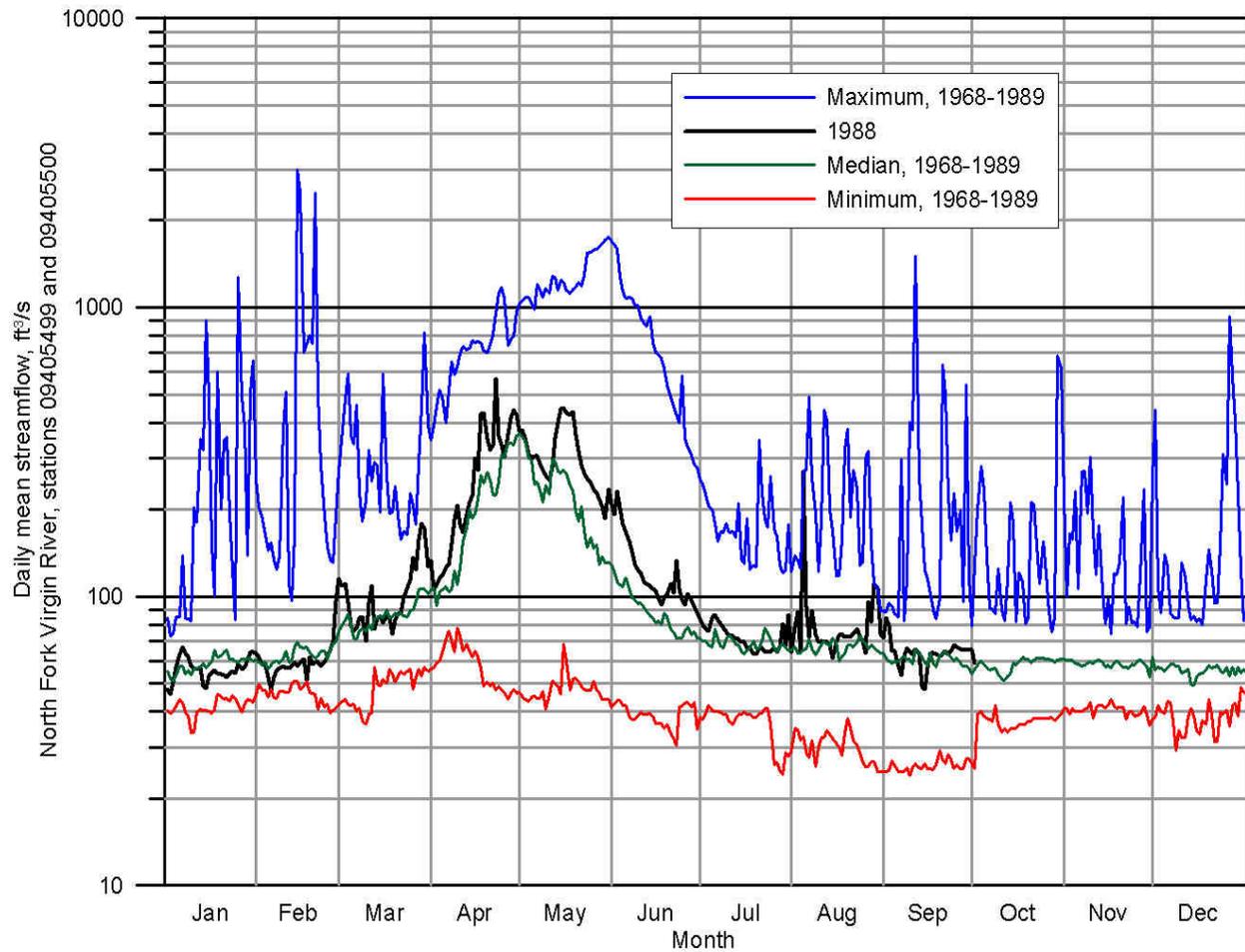


Figure 11. Daily mean streamflow at combined Stations 09405499 (Springdale Canal) and 09405500 (North Fork near Springdale) for calendar year 1988 with maximum, median, and minimum daily mean streamflow for 1968-1989 period of record.

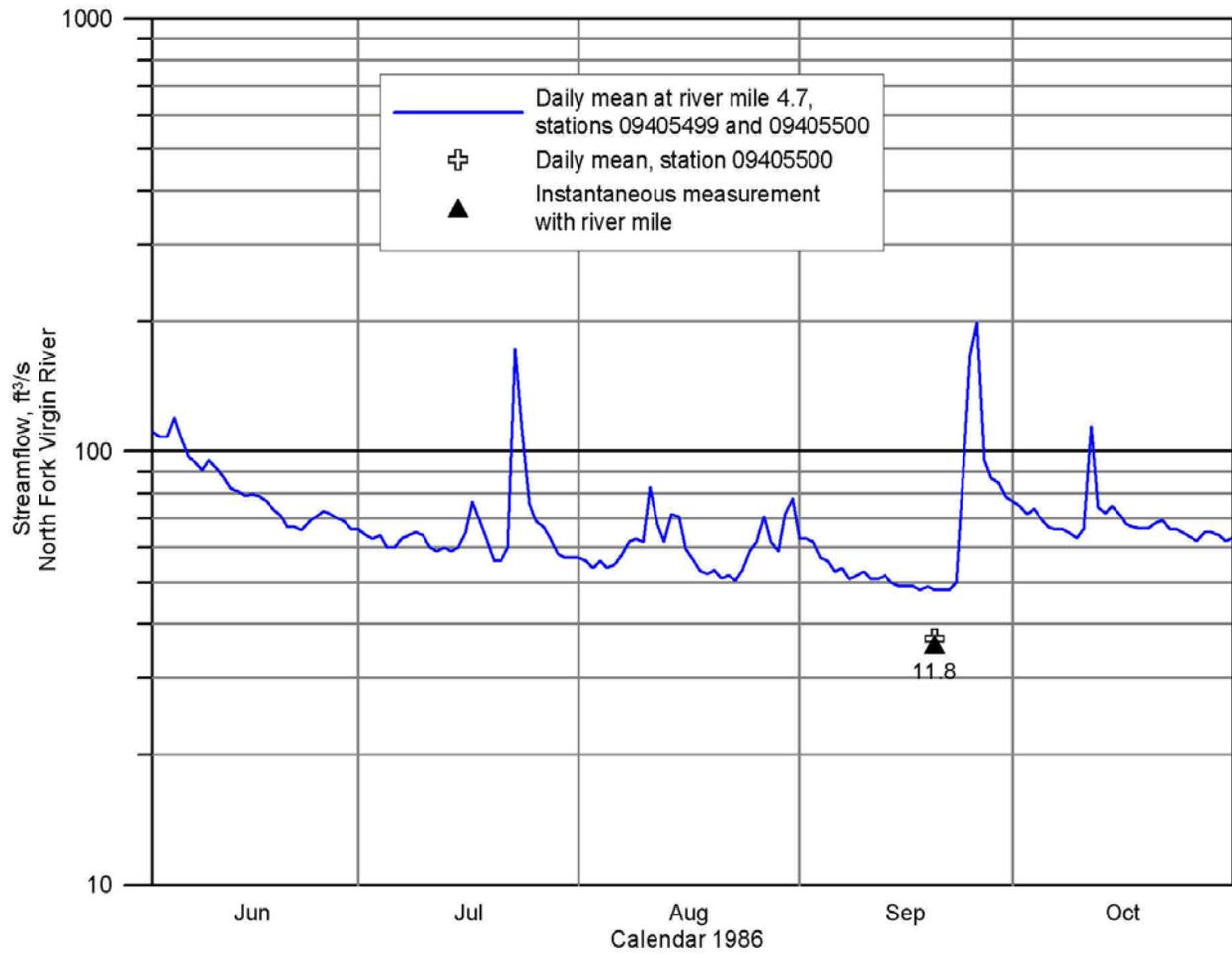


Figure 12. Daily mean streamflow at combined Stations 09405499 (Springdale Canal) and 09405500 (North Fork near Springdale) from June through October 1986 with instantaneous streamflow measurement.

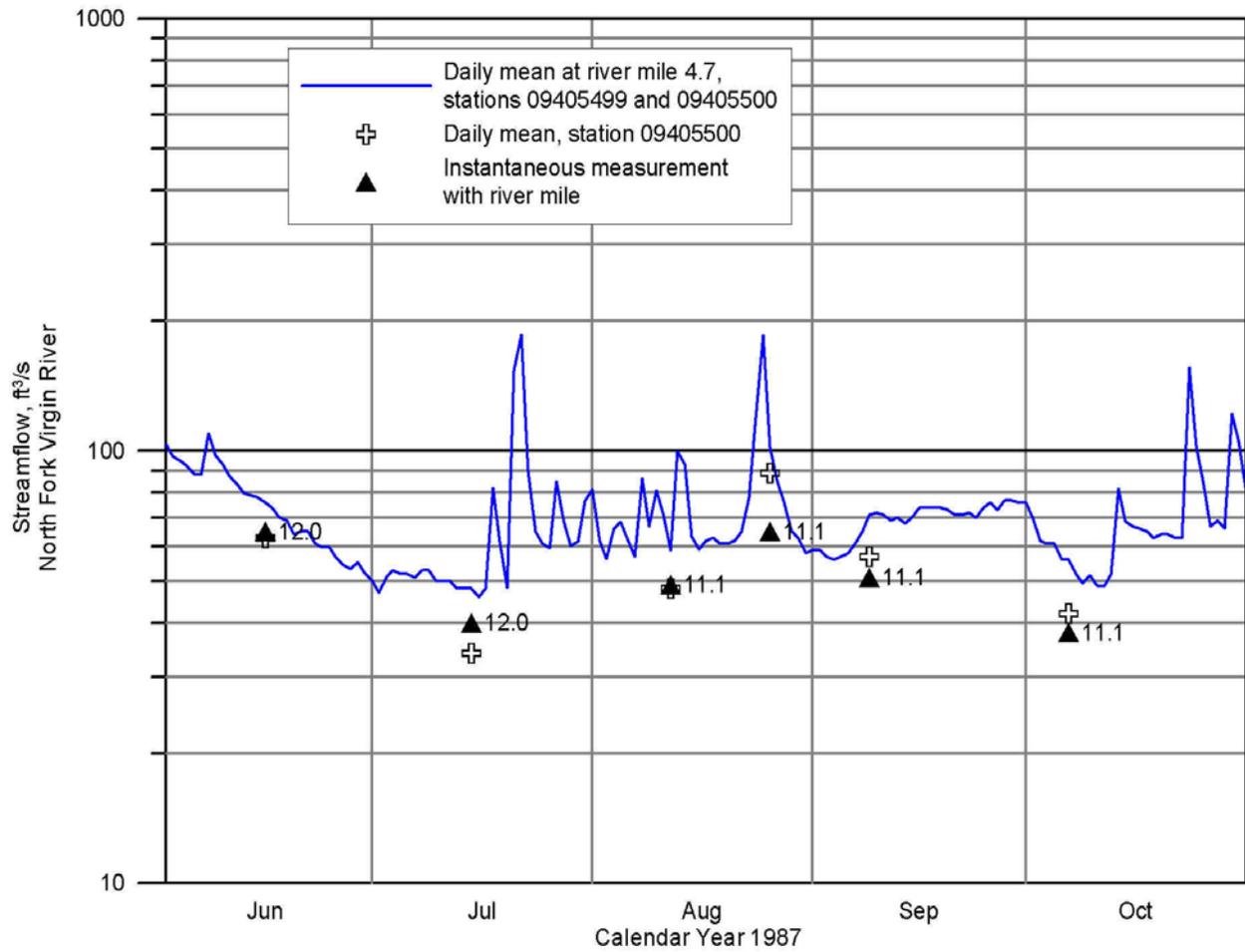


Figure 13. Daily mean streamflow at combined Stations 09405499 (Springdale Canal) and 09405500 (North Fork near Springdale) from June through October 1987 with instantaneous streamflow measurements.

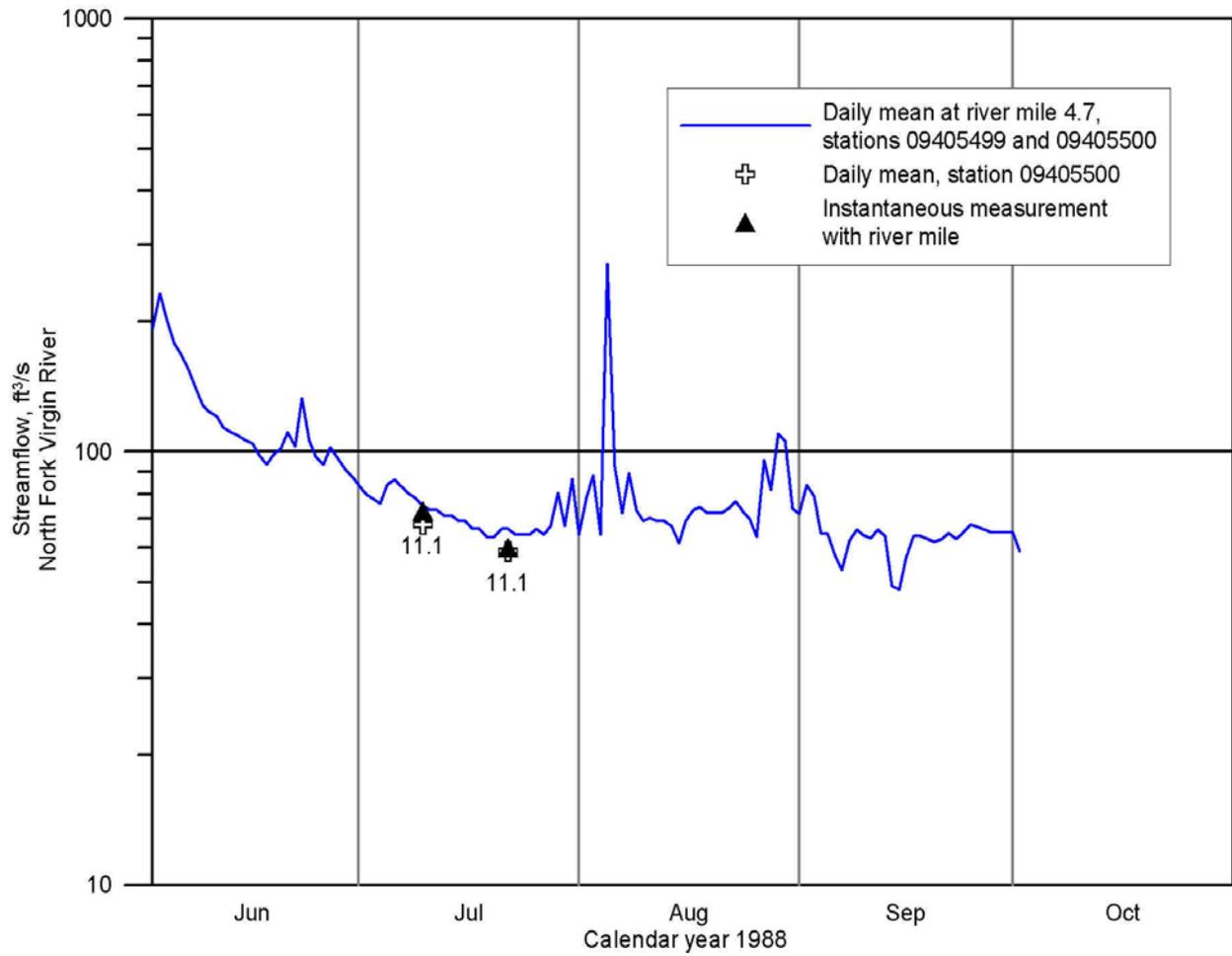


Figure 14. Daily mean streamflow at combined Stations 09405499 (Springdale Canal) and 09405500 (North Fork near Springdale) from June through October 1988 with instantaneous streamflow measurements.

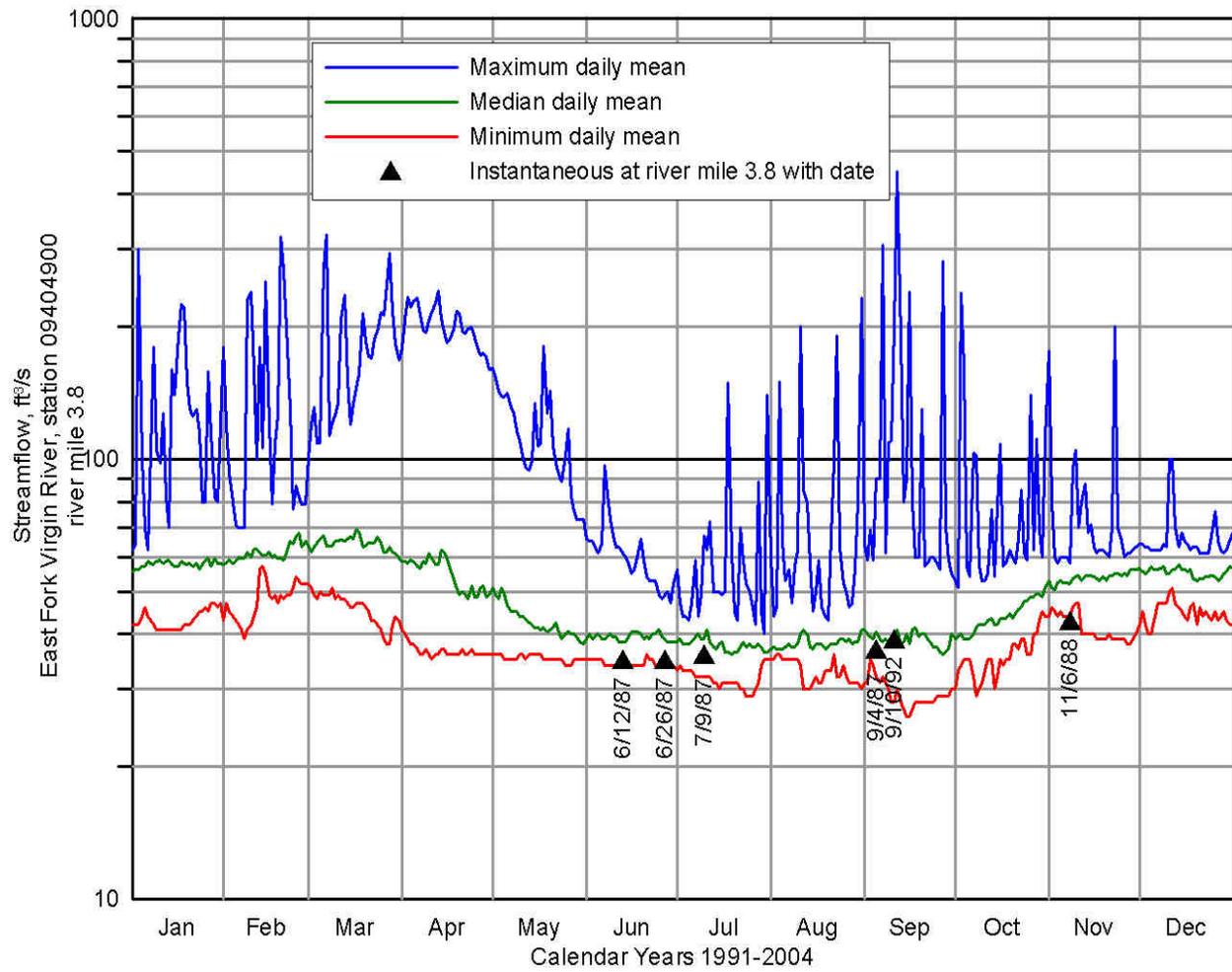


Figure 15. Daily mean streamflow at Station 09404900 (East Fork near Springdale) with instantaneous measurements for five sets of synoptic streamflow measurements.

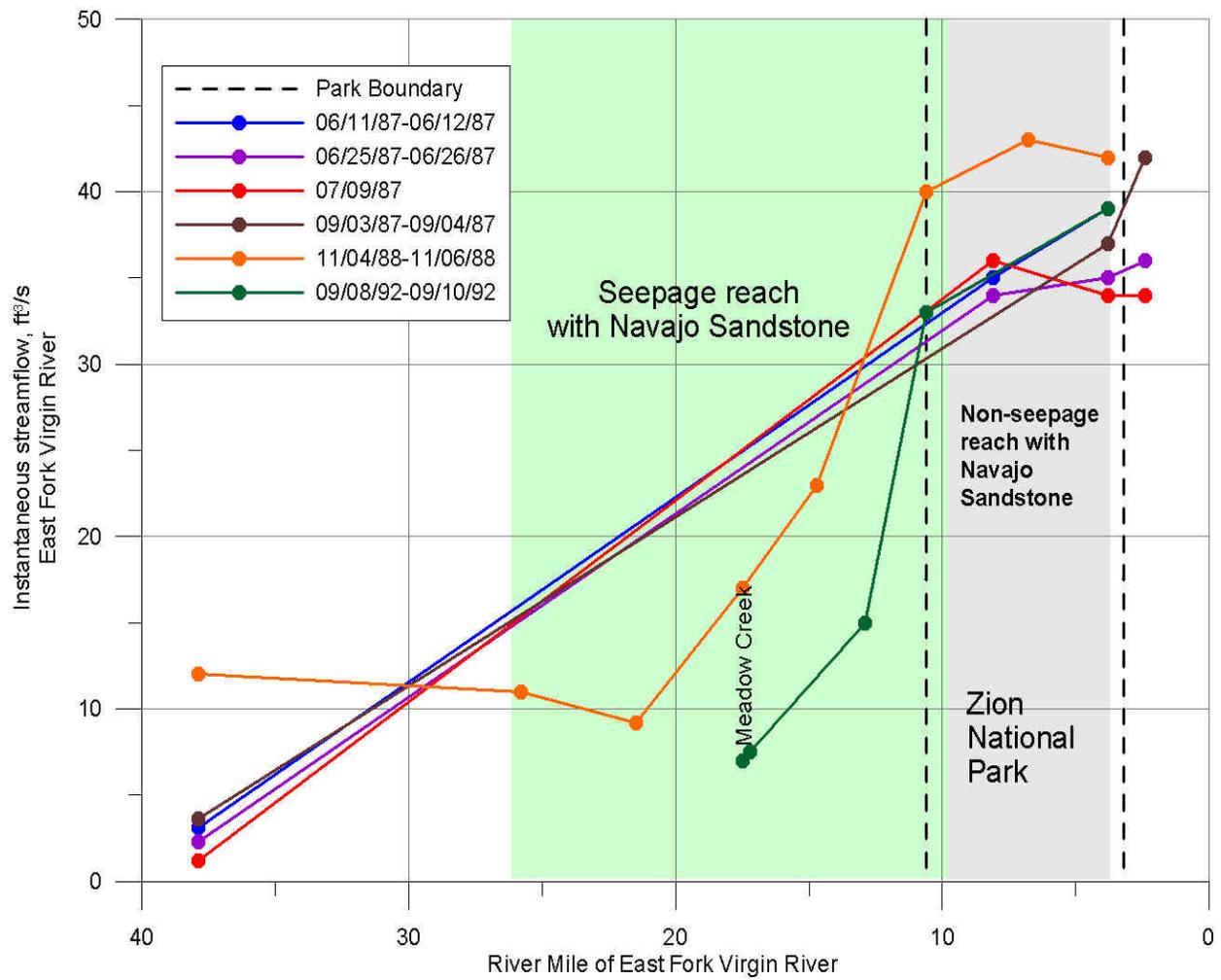


Figure 16. Six sets of synoptic streamflow measurements for the East Fork Virgin River, Zion National Park area. Area shaded light green is seepage reach with Navajo Sandstone; area shaded light gray is non-seepage reach with Navajo Sandstone.

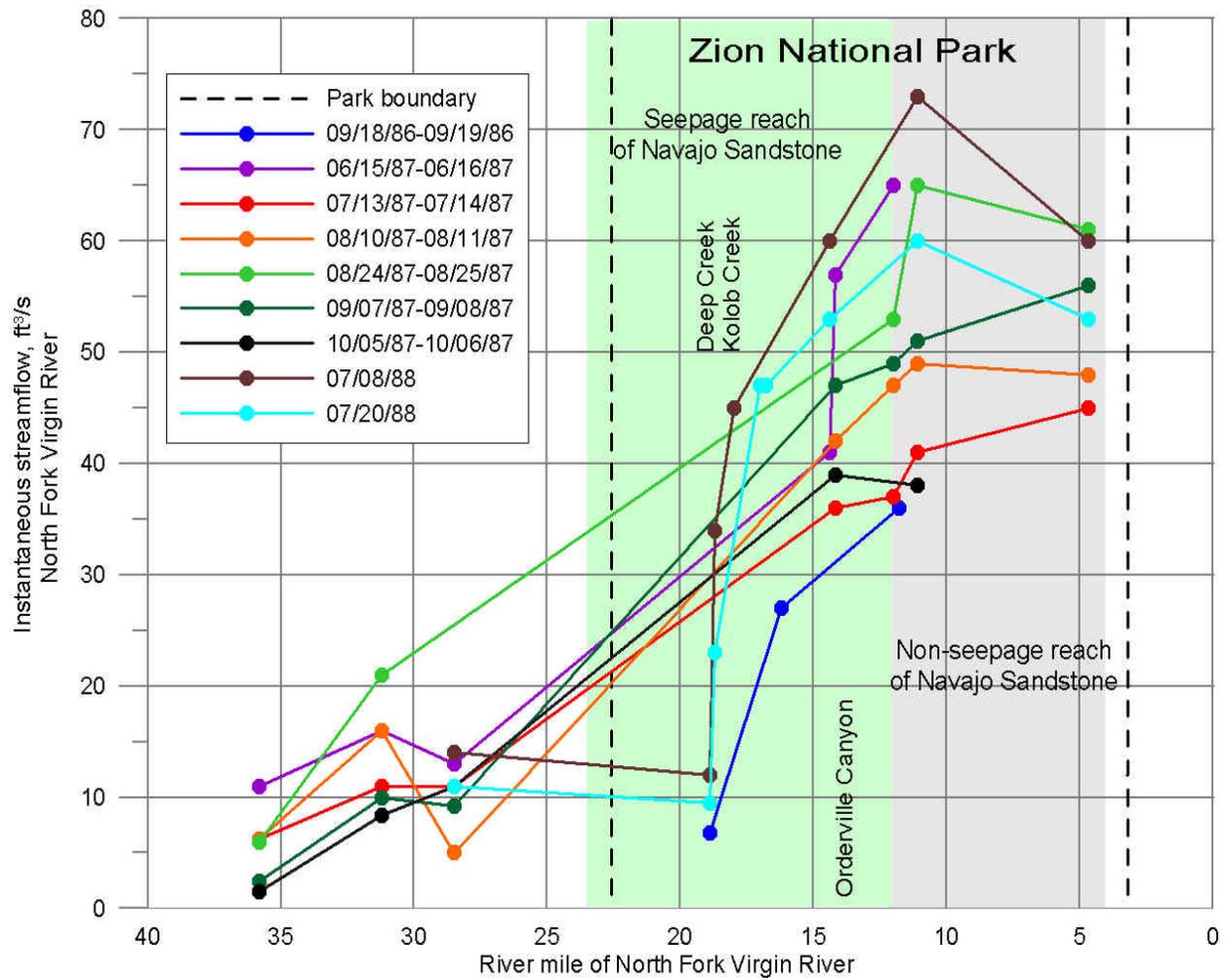


Figure 17. Nine sets of synoptic streamflow measurements for the North Fork of the Virgin River, Zion National Park area. Area shaded light green is seepage reach with Navajo Sandstone; area shaded light gray is non-seepage reach with Navajo Sandstone.

TABLES

Table 1. Selected U.S. Geological Survey gaging stations on the East and North Forks of the Virgin River in the Zion National Park area

Number	Name	Drainage area, mi ²	Elevation, ft above mean sea level, NGVD 1929	River mile	Period of record
09404450	East Fork Virgin River near Glendale, Utah	74.2	5,900	37.9	10/01/1966 to 09/30/2004
09404700	East Fork Virgin River near Mt. Carmel Junction, Utah	163	5,120	25.8	10/01/1992 to 10/20/2002
09404900	East Fork Virgin River near Springdale, Utah	343	3,940	3.8	10/01/1991 to 09/30/2004
09405400	North Fork Virgin River near Glendale, Utah	5.65	7,530	35.8	12/01/1972 to 10/18/1978
09405420	North Fork Virgin River below Bulloch Canyon near Glendale, Utah,	29.6	6,420	31.2	09/18/1974 to 09/30/1984
09405450	North Fork Virgin River above Zion Narrows, near Glendale, Utah	41.5	6,000	28.5	10/01/1978 to 09/30/1984
09405490	North Fork Virgin River above Big Bend near Glendale, Utah	---	4,400	11.1	06/10/1988 to 06/12/1989; 09/30/1991 to 09/30/1994
09405499	Springdale Canal near Springdale, Utah	---	3,970	4.9	10/01/1968 to 09/30/1989
09405500	North Fork Virgin River near Springdale, Utah:	344	3,970	4.7	06/06/1923 to 09/30/2004

Table 2. Streamflow measurement sites, river mile of measurement sites, and rock units underlying measurement sites, East Fork of the Virgin River, Zion National Park area.

Description of streamflow measurement site	Approximate river mile	Rock units underlying stream channel, excluding alluvium and colluvium
Stout Canyon	41.1	Undifferentiated sandstone, shale, coal, and limestone
Current USGS Gaging Station 09404450, East Fork Virgin River near Glendale, Utah	37.9	
Below Mt. Carmel Junction (Former USGS Gaging Station 09404700, East Fork Virgin River near Mt. Carmel Junction, Utah)	25.8	Navajo Sandstone
Above Bay Bill Canyon	21.5	
Below Bay Bill Canyon	21.2	
Below Meadow Creek	17.5	
Above unnamed wash	17.2	
At the Barracks	14.7	
Above Poverty Wash	12.9	
Park Boundary	10.6	
Below Labyrinth Falls	9.6	
Upper Parunuweap Canyon	8.7	Undifferentiated siltstone, shale, sandstone, and conglomerate
Lower Parunuweap Canyon	8.1	
Above Stevens Wash	6.8	
Current USGS Gaging Station 09404900, East Fork Virgin River near Springdale, Utah	3.8	
Below Shunes Creek	2.4	

Table 3. Streamflow measurement sites, river mile of measurement sites, and rock units underlying measurement sites, North Fork of the Virgin River, Zion National Park area.

Streamflow measurement site	Approximate river mile	Rock units underlying stream channel, excluding alluvium and colluvium
Ashdown Canyon (Former USGS Gaging Station 09405400, North Fork Virgin River near Glendale, Utah)	35.8	Undifferentiated sandstone, shale, coal, and limestone
Below Straight Canyon (Former USGS Gaging Station 09405420, North Fork Virgin River below Bulloch Canyon near Glendale, Utah)	31.2	
Below Willow Canyon (Former USGS Gaging Station 09405450, North Fork Virgin River above Zion Narrows, near Glendale, Utah)	28.5	
Below Bulloch Cabin	24.0	
Below Bulloch Cabin	23.6	
Above Deep Creek	18.9	
Deep Creek	18.8	
Below Deep Creek	18.7	
Above Kolob Creek	18.0	
Kolob Creek	17.9	
Below Kolob Creek	17.8	
Above Goose Creek	17.0	
Goose Creek	16.9	
Below Goose Creek	16.8	
Below Goose Creek	16.2	
Above Orderville Canyon	14.4	
Orderville Canyon	14.3	
Below Orderville Canyon	14.2	
Above Telephone Canyon	12.0	

Table 3. (continued) Streamflow measurement sites, river mile of measurement sites, and rock units underlying measurement sites, North Fork of the Virgin River, Zion National Park area.

Streamflow measurement site	Approximate river mile	Rock units underlying stream channel, excluding alluvium and colluvium
Temple of Sinawava	11.8	Undifferentiated siltstone, shale, sandstone, and conglomerate
Former USGS Gaging Station 09405490, North Fork Virgin River above Big Bend near Glendale, Utah	11.1	
Former USGS Gaging Station 09405499, Springdale Canal near Springdale, Utah	4.9	
Former USGS Gaging Station 09405501, Combined Flow North Fork Virgin River and Springdale Canal	4.7	
Current USGS Gaging Station 09405500, North Fork Virgin River near Springdale, Utah	4.7	

Table 4. Six sets of synoptic streamflow measurements for the East Fork of the Virgin River, Zion National Park area.

River mile	Instantaneous streamflow measurements, ft ³ /s					
	06/11/87-06/12/87	06/25/87-06/26/87	07/09/87	09/03/87-09/04/87	11/04/88-11/06/88	09/08/92-09/10/92
37.9	3.1	2.3	1.2	3.6	12	
25.8					11	
21.5					9.2	
17.5					17	7
17.2						7.5
14.7					23	
12.9						15
10.6					40	33
9.6						
8.7						
8.1	35	34	36			
6.8					43	
3.8	39	35	34	37	42	39
2.4		36	34	42		

Table 5. Nine sets of synoptic streamflow measurements for the North Fork of the Virgin River, Zion National Park area.

River mile	09/18/86-09/19/86	06/15/87-06/16/87	07/13/87-07/14/87	08/10/87-08/11/87	08/24/87-08/25/87	09/07/87-09/08/87	10/05/87-10/06/87	07/08/88	07/20/88
35.8		11	6.3	6.3	6.0	2.5	1.5		
31.2		16	11	16	21	10	8.4		
28.5		13	11	5.0		9.2	11	14	11
18.9	6.8							12	9.5
18.7								34	23
18.0								45	
17.0									47
16.8									47
16.2	27								
14.4		41						60	53
14.2		57	36	42		47	39		
12.0		65	37	47	53	49			
11.8	36								
11.1			41	49	65	51	38	73	60
4.7			45	48	61	56		60	53

Table 6. Streamflow increase between two gaging stations on the East Fork of the Virgin River over the reach within the Navajo Sandstone and the reach below the base of the Navajo Sandstone, Zion National Park area.

	Period of record October 1, 1992, to October 20, 2002		
	Daily mean discharge		
Item	East Fork Virgin River at Mt. Carmel Junction	East Fork Virgin River near Springdale	Difference
Station No.	09404700	09404900	---
Maximum	190	450	260
Median	15	51	36
Minimum	0.0	26	26

Table 7. Streamflow increase associated with the Navajo Sandstone, East Fork of the Virgin River, Zion National Park area.

Upstream site of reach within Navajo Sandstone ¹			Downstream site of reach within Navajo Sandstone ²				Downstream site of reach below base of Navajo Sandstone ³				Total stream-flow increase ft ³ /s (c-a)
Date	River mile	Measured stream-flow ft ³ /s (a)	Date	River mile	Measured stream-flow ft ³ /s (b)	Stream-flow increase ft ³ /s (b-a)	Date	River mile	Measured stream-flow ft ³ /s (c)	Stream-flow increase ft ³ /s (c-b)	
06/11/87	37.9	3.1	06/12/87	8.1	35	32	06/12/87	3.8	39	4	36
06/25/87	37.9	2.3	06/26/87	8.1	34	32	06/26/87	3.8	35	1	33
07/09/87	37.9	1.2	07/09/87	8.1	36	35	07/09/87	3.8	34	-2	34
09/03/87	37.9	3.6	---	---	---	---	09/04/87	3.8	37	---	34
11/04/88	37.9	12	---	---	---	---	11/06/88	3.8	42	---	30
09/08/92	17.5	7.0	09/10/92	10.6	39	32	09/10/92	3.8	39	0	32
					Median	32					
					Maximum	35					
					Minimum	32					
							Median	0.5			34
							Maximum	4			36
							Minimum	-2			30

¹ For five of the East Fork sets, the “upstream site” is located at the USGS Gaging Station 09404450 near Glendale, Utah, at river mile 37.9. This station is about 12 miles upstream of the reach within the Navajo Sandstone. The other set starts at river mile 17.5 in the reach within the Navajo Sandstone.

² Sites selected as closest to and either downstream or upstream of the reach within the Navajo Sandstone. Such sites were not available for two sets.

³ Sites selected as representative of channel outflow near the downstream end of the reach below the base of the Navajo Sandstone.

Table 8. Streamflow increase between two gaging stations on the North Fork of the Virgin River over the reach within the Navajo Sandstone and the reach below the base of the Navajo Sandstone, Zion National Park area.

	Period of record October 1, 1978, to September 20, 1984		
	Daily mean discharge		
Item	North Fork Virgin River above Zion Narrows near Glendale	Springdale Canal near Springdale and North Fork Virgin River near Springdale	Difference
Station No.	0945450	9045499 9405500	---
Maximum	200	3,000	2,800
Median	19	66	47
Minimum	2.2	26	24

Table 9. Streamflow increase associated with the Navajo Sandstone, North Fork of the Virgin River, Zion National Park area.
 (Numbers in italics are river mile and mean daily streamflow for Stations 09405499 and 09405500; * denotes that measurements and calculations do not include the diversion to Springdale Canal.)

Upstream site of reach within the Navajo Sandstone ¹			Downstream site of reach within the Navajo Sandstone ²				Downstream site of reach below base of Navajo Sandstone ³				Total stream-flow increase ft ³ /s (c-a)
Date	River mile	Measured stream-flow ft ³ /s (a)	Date	River mile	Measured stream-flow ft ³ /s (b)	Stream-flow increase ft ³ /s (b-a)	Date	River mile	Measured stream-flow ft ³ /s (c)	Stream-flow increase ft ³ /s (c-b)	
09/18/86	18.9	6.8	09/19/86	11.8	36	29	09/19/86	4.7	48	12	41
06/15/87	28.5	13	06/16/87	12.0	65	52	06/16/87	4.7	74	12	64
07/13/87	28.5	11	07/14/87	12.0	41	30	07/15/87	4.7	45*	4*	34*
								4.7	46	5	35
08/10/87	28.5	5.0	08/11/87	11.1	49	44	08/11/87	4.7	48*	-1*	43* ⁴
								4.7	59	10	54 ⁴
08/24/87	31.2	21	08/25/87	11.1	65	44	08/25/87	4.7	61*	-4*	40* ⁴
								4.7	102	37	81 ⁴
09/07/87	28.5	9.2	09/08/87	11.1	51	42	09/08/87	4.7	56*	5*	47*
								4.7	71	20	62
10/05/87	28.5	11	10/06/87	11.1	38	27	10/06/87	4.7	56	18	45
07/08/88	28.5	14	07/08/88	11.1	73	59	07/08/88	4.7	60*	-13*	46*
								4.7	75	2	61
07/20/88	28.5	11	07/20/88	11.1	60	49	07/20/88	4.7	53*	-7*	42*
								4.7	66	6	55
					Median	44			Median	-2.5*	42.5*
					Maximum	59			Maximum	12	55
					Minimum	27			Minimum	5*	47*
										37	81
										-13*	34*
										2	35

Table 9 (continued). Streamflow increase associated with the Navajo Sandstone, North Fork of the Virgin River, Zion National Park area.

¹ Sites selected as nearest to and upstream of the reach within the Navajo Sandstone. An exception is Site 18.9 which lies in the reach within the Navajo Sandstone.

² Sites selected as closest to and downstream of the reach within the Navajo Sandstone.

³ Sites selected as representative of channel outflow near the downstream end of reach below the base of the Navajo Sandstone.

⁴ Streamflow increases reflect rapidly rising or falling limbs of the hydrograph.

Table 10. Streamflow increase between two gaging stations on the North Fork of the Virgin River over the reach below the base of the Navajo Sandstone, Zion National Park area.

	Period of record June 10, 1988 to June 12, 1989		
	Daily mean discharge		
Item	North Fork Virgin River above Big Bend near Glendale	Springdale Canal near Springdale and North Fork Virgin River near Springdale	Difference
Station No.	0945490	9045499 9405500	---
Maximum	160	270	110
Median	62	67	5
Minimum	41	38	-3

APPENDICES

Appendix 1. Initial and new river-mile designations for stream-discharge measurement sites on the East Fork of the Virgin River, Zion National Park area.

Description of stream-discharge measurement Site	Approximate initial river mile	Approximate new river mile
Stout Canyon (not shown on maps)	193.6	41.1
USGS Gaging Station 09404450 near Glendale (not shown on maps)	186.6	37.9
Below Mt. Carmel Junction	175.7	25.8
Above Bay Bill Canyon	172.2	21.5
Below Bay Bill Canyon	171.6	21.2
Below Meadow Creek	168.5	17.5
Above unnamed wash	168.3	17.2
At the Barracks	166.9	14.7
Above Poverty Wash	166.2	12.9
Park Boundary	163.9	10.6
Below Labyrinth Falls	163.1	9.6
Upper Parunuweap Canyon	162.2	8.7
Lower Parunuweap Canyon	161.5	8.1
Above Stevens Wash	160.2	6.8
USGS Gaging Station 09404900 near Springdale	157.4	3.8
Below Shunes Creek	155.6	2.4

Appendix 2. Initial and new river-mile designations for stream-discharge measurement sites on the North Fork of the Virgin River, Zion National Park area.

Description of stream-discharge measurement site	Approximate initial river mile	Approximate new river mile
Ashdown Canyon	33.9	35.8
Below Straight Canyon	29.5	31.2
Below Willow Canyon	26.5	28.5
Below Bulloch Cabin	25.4	24.0
Below Bulloch Cabin	25.0	23.6
Above Deep Creek	19.9	18.9
Deep Creek	19.8	18.8
Below Deep Creek	19.7	18.7
Above Kolob Creek	19.1	18.0
Kolob Creek	19.0	17.9
Below Kolob Creek	18.7	17.8
Above Goose Creek	18.0	17.0
Goose Creek	17.9	16.9
Below Goose Creek	17.8	16.8
Below Goose Creek	17.1	16.2
Above Orderville Canyon	14.4	14.4
Orderville Canyon	14.3	14.3
Below Orderville Canyon	14.2	14.2
Above Telephone Canyon	13.2	12.0
Temple of Sinawava	12.7	11.8
USGS Gaging Station 094054900 about Big Bend near Springdale	11.8	11.1
Gaging Station 09405500 near Springdale	5.0	4.7

Appendix 3. Initial and new river-mile designations for reaches within the Navajo Sandstone, East and North Forks of the Virgin River, Zion National Park area.

Description of river mile for hydraulic connection with the Navajo Sandstone	Approximate initial river mile	Approximate new river mile
Uppermost river mile, East Fork	176.0	26.1
Lowermost river mile, East Fork	164.5	9.7
Uppermost river mile, North Fork	26.0	23.5
Lowermost river mile, North Fork	12.0	12.0

Appendix 4. Initial and new river-mile designations for park boundaries on the East and North Forks of the Virgin River, Zion National Park area.

Description of river mile for park boundary	Approximate initial river mile	Approximate new river mile
Uppermost river mile, East Fork	164.8	10.6
Lowermost river mile, East Fork	157.4	3.2
Uppermost river mile, North Fork	22.7	22.6
Lowermost river mile, North Fork	4.0	3.1

Appendix 5. Daily mean streamflow (ft³/s) at Station 09405490, river mile 11.1, June 1988 to June 1989, Zion National Park area.

Day	1988							1989					
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
1		66	65	63	55	47	41	57	60	57	149	60	43
2		67	67	52	55	47	44	52	58	167	165	54	43
3		70	155	51	55	47	40	50	56	138	151	54	43
4		72	66	52	56	47	42	61	68	61	143	55	44
5		74	63	52	56	47	41	65	43	78	141	55	44
6		73	66	60	57	46	41	65	46	78	153	56	44
7		71	68	63	57	46	45	55	51	93	155	56	45
8		70	66	58	59	46	40	50	51	114	162	57	45
9		68	68	62	54	46	39	49	63	132	164	57	45
10	94	67	62	63	52	46	44	55	64	151	161	58	45
11	94	64	56	56	53	46	43	55	64	139	145	58	45
12	95	63	59	52	53	45	42	55	64	148	137	63	44
13	96	63	55	54	51	45	47	54	57	155	122	61	
14	91	63	64	63	49	49	48	54	57	125	114	66	
15	81	62	61	61	48	47	47	51	57	107	115	72	
16	78	62	58	56	47	42	44	54	59	108	107	74	
17	83	61	56	60	46	48	46	54	58	129	98	74	
18	91	61	51	58	40	42	47	54	63	116	94	61	
19	92	60	53	57	35	40	54	54	63	113	91	61	
20	91	60	54	58	39	42	51	54	62	107	89	62	
21	114	60	66	59	42	43	57	54	57	101	89	62	
22	90	60	70	60	41	43	39	54	57	109	87	61	
23	91	60	70	61	39	46	59	55	55	125	72	56	
24	88	60	70	62	38	45	47	55	55	126	73	55	
25	84	61	105	57	41	41	58	55	60	133	73	53	
26	81	61	70	59	39	43	49	47	68	178	74	49	
27	77	69	112	58	42	46	43	57	68	121	70	41	
28	73	61	103	54	45	44	50	57	63	140	68	42	
29	68	62	64	54	46	43	46	55	---	157	68	42	
30	67	62	63	54	46	41	50	58	---	131	68	42	
31	---	86	71	---	46	---	57	60	---	135	---	43	---

Appendix 6. Instantaneous streamflow measurements, East Fork of the Virgin River, Zion National Park area, 1987-1992 (in ft³/s; SC = Stout Canyon; values in parentheses and italics in column for Measurement Site 3.8 are the daily mean flow for USGS Station 09404900).

Date	Approximate river mile														
	41.1 SC	37.9	25.8	21.5	17.5	17.2	14.7	12.9	10.6	9.6	8.7	8.1	6.8	3.8	2.4
05/18/87	5.1	10	---	---	---	---	---	---	---	---	---	---	---	---	---
05/28/87	5.5	8.7	---	---	---	---	---	---	---	---	---	---	---	---	---
06/05/87	---	---	---	---	---	---	---	---	---	---	---	39	---	38	---
06/08/87	---	---	---	---	---	---	---	---	---	---	---	36	---	41	---
06/11/87	4.7	3.1	---	---	---	---	---	---	---	---	---	---	---	---	---
06/12/87	---	---	---	---	---	---	---	---	---	---	---	35	---	39	---
06/18/87	---	---	---	---	---	---	---	---	---	---	---	37	---	36	---
06/25/87	3.9	2.3	---	---	---	---	---	---	---	---	---	---	---	---	---
06/26/87	---	---	---	---	---	---	---	---	---	---	---	34	---	35	36
07/01/87	---	---	---	---	---	---	---	---	---	---	---	36	---	35	36
07/09/87	3.9	1.2	---	---	---	---	---	---	---	---	---	36	---	34	34
07/16/87	---	---	---	---	---	---	---	---	---	---	---	35	---	39	35
07/24/87	---	---	---	---	---	---	---	---	---	---	---	39	---	42	35
07/28/87	---	---	---	---	---	---	---	---	---	---	---	---	---	45	39
08/06/87	3.9	4.0	---	---	---	---	---	---	---	---	---	---	---	---	---
08/18/87	---	---	---	---	---	---	---	---	---	---	---	---	---	38	40
08/19/87	---	---	---	---	---	---	---	---	---	---	---	35	---	39	---
08/27/87	---	---	---	---	---	---	---	---	---	---	---	42	---	43	---
09/03/87	3.7	3.6	---	---	---	---	---	---	---	---	---	---	---	---	---
09/04/87	---	---	---	---	---	---	---	---	---	---	---	---	---	37	42
09/10/87	---	---	---	---	---	---	---	---	---	---	---	---	---	42	48
09/17/87	4.1	4.1	---	---	---	---	---	---	---	---	---	---	---	---	---
10/01/87	4.3	3.0	---	---	---	---	---	---	---	---	---	---	---	---	---
05/27/88	---	---	---	---	---	---	---	---	34	34	---	37	---	42	---
06/03/88	---	---	---	---	---	---	---	---	---	---	---	43	---	44	---
06/24/88	---	---	---	---	---	---	---	---	---	38	---	40	---	45	---
06/30/88	---	---	---	---	---	---	---	---	---	34	---	39	---	---	---
07/15/88	---	---	---	---	---	---	---	---	---	33	35	37	---	39	---
11/04/88	---	12	11	9.2	17	---	---	---	---	---	---	---	---	---	---
11/05/88	---	---	---	---	---	---	23	---	40	---	---	---	---	---	---
11/06/88	---	---	---	---	---	---	---	---	---	---	---	---	43	42	---
09/08/92	---	---	---	---	7.0	---	---	---	---	---	---	---	---	(42)	---

Appendix 6 (continued). Instantaneous streamflow measurements, East Fork of the Virgin River, Zion National Park area, 1987-1992 (in ft³/s; SC = Stout Canyon; values in parentheses and italics in column for Measurement Site 3.8 are the daily mean flow for USGS Station 09404900).

Date	Approximate river mile														
	41.1	37.9	25.8	21.5	17.5	17.2	14.7	12.9	10.6	9.6	8.7	8.1	6.8	3.8	2.4
09/09/92	---	---	---	---	---	7.5	---	15	---	---	---	---	---	(42)	---
09/10/92	---	---	---	---	---	---	---	---	33	---	---	---	---	39 (42)	---

Appendix 7. Instantaneous streamflow measurements, North Fork of the Virgin River, Zion National Park area, 1987-1993
 (in ft³/s; DC = Deep Creek; KC = Kolob Creek; GC = Goose Creek; OC = Orderville Canyon; values in parentheses and italics in column
 for Measurement Site 4.7 are the daily mean flow for combined USGS Stations 09405500 and 09405499).

Date	Approximate river mile																						
	35.8	31.2	28.5	24.0	23.6	18.9	18.8 DC	18.7	18.0	17.9 KC	17.8	17.0	16.9 GC	16.8	16.2	14.4	14.3 OC	14.2	12.0	11.8	11.1	4.7	
09/16/86	---	---	---	6.8	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	(49)
09/18/86	---	---	---	---	---	6.8	9.1	---	---	---	---	---	0.2	---	27	---	---	---	---	---	---	---	(49)
09/19/86	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1.6	---	---	---	36	---	(48)
06/03/87	---	21	16	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	(95)
06/09/87	---	---	---	---	---	---	---	---	---	---	55	---	0.3	---	---	---	---	---	---	---	---	---	(93)
06/10/87	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	66	---	---	---	---	---	---	(87)
06/15/87	11	16	13	---	---	---	---	---	---	---	---	---	---	---	---	41	---	---	---	---	---	---	(76)
06/16/87	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	57	65	---	---	---	(74)
06/29/87	9.3	14	8.5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	(52)
07/07/87	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	43	---	48	47 (53)
07/13/87	6.3	11	11	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	(48)
07/14/87	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	36	37	---	41	---	(48)
07/15/87	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	40	---	---	45 (46)
07/30/87	8.0	17	12	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	(77)
08/10/87	6.3	16	5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	(71)
08/11/87	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	42	47	---	49	---	48 (59)
08/17/87	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	35	---	---	46 (63)
08/24/87	6.0	21	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	(185)
08/25/87	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	53	---	65	61 (102)
08/28/87	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	43	---	---	56 (65)
09/07/87	2.5	10	9.2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	(65)
09/08/87	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	47	49	---	51	---	56 (71)

Appendix 7 (continued). Instantaneous streamflow measurements, North Fork of the Virgin River, Zion National Park area, 1987-1993 (in ft³/s; DC = Deep Creek; KC = Kolob Creek; GC = Goose Creek; OC = Orderville Canyon; values in parentheses and italics in column for Measurement Site 4.7 are the daily mean flow for combined USGS Stations 09405500 and 09405499).

Date	Approximate river mile																						
	35.8	31.2	28.5	24.0	23.6	18.9	18.8	18.7	18.0	17.9	17.8	17.0	16.9	16.8	16.2	14.4	14.3	14.2	12.0	11.8	11.1	4.7	
09/21/87	1.4	8.3	9.1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<i>(71)</i>
09/22/87	---	---	---	---	---	---	---	---	---	---	28	---	0.3	---	---	---	---	---	---	---	---	---	<i>(72)</i>
09/23/87	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	41	---	---	---	---	---	<i>(70)</i>
10/05/87	1.5	8.4	11	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<i>(56)</i>
10/06/87	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	39	---	---	38	<i>(56)</i>
07/08/88	---	---	14	---	---	12	---	34	45	0.3	---	---	---	---	---	60	1.5	---	---	---	73	60 <i>(75)</i>	
07/20/88	---	---	11	---	---	9.5	---	23	---	---	---	47	0.2	47	---	53	1.5	---	---	---	60	53 <i>(66)</i>	
07/06/93	---	---	---	---	26	24	---	64	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
07/07/93	---	---	---	---	---	---	---	---	---	30	---	---	---	---	---	---	---	---	---	---	---	---	---
07/27/93	---	---	---	---	18	16	---	36	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

As the nation's principal conservation agency, the Department of the Interior has



responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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