

Potable Water Sources for the Headquarters Area Bryce Canyon National Park

The purpose of this report is to compile all of the information regarding the potable water supplies at Bryce Canyon National Park. Information was found in files at the NPS Water Resources Division in Ft. Collins, in files at the park, in USGS databases, in Utah water rights databases, and in the administrative history of the park. Additionally, information from various geologic maps and reports is included and interpreted. This report is meant to serve as the archive for the historical information and to assess the reliability of the local aquifer at East Creek as a continuing and future source of water for the park.

Bryce Canyon National Monument was established in June 1923. It became a national park in September 1928. The Utah Parks Company (a subsidiary of Union Pacific Railroad) owned and operated restaurants, lodging, and bus tours in Bryce Canyon and other parks from the 1920s until 1972. Utah Parks Co. operated as a concessionaire of the National Park Service. Union Pacific donated its concession-related infrastructure to the National Park Service in 1972.

Public water supplies were initially obtained from springs. Later on, wells were constructed to provide a safer and more reliable source of water. Water supply sources are shown on Figure 1.

Public Water Supplies at Bryce Canyon

Starting in the 1920s, the Utah Parks Company operated a water catchment system for Bryce Canyon National Park. The system included collection of water from Shaker Spring, Trough Spring, and eventually included springs in the East Creek Valley (see Figure 1).

Trough and Shaker Springs (about 5 miles southeast of the Headquarters area) once provided a year-round water supply by gravity flow at a maximum rate of 14 gpm. Use of these sources was discontinued in 1980. The springs occur where the sandy, white beds of the Wasatch Formation overlie the dense, pink limestone beds. The springs are recharged by local precipitation on the adjacent plateau; Whiteman Bench. Flow from the springs fluctuates seasonally and is affected by the amount of precipitation on Whiteman Bench. Development at these two springs was simple, consisting of a fenced enclosure to protect the springs from contamination, and a pipe inserted to channel the flow of water from the spring. Water rights for these two springs were purchased from R.C. Syrett.

Trough Springs is located at; T37S, R4W, Sec 16dcb, at an elevation of about 8350 ft msl. Flow ranges from about 0.5-17 gpm. Water was collected in a concrete collection box, inside a fenced area, and then transmitted by gravity flow in a pipeline to the headquarters area.

Shaker Spring is located at; T37S, R4W, Sec 16dbb, at an elevation of about 8400 ft msl. Flow ranges from about 0.75-30 gpm. Water was collected in a concrete collection box, inside a fenced area, and then transmitted by gravity flow in a pipeline to the headquarters area.

The East Creek Valley spring collection system included several small concrete boxes that were constructed over natural springs. These concrete boxes pooled water from the springs which was

then fed by small pipes to larger sumps or reservoirs. Water was pumped from the reservoirs to storage tanks near the Lodge.

Water from the East Creek Springs was initially leased jointly from the Tropic and East Fork Irrigation Co. and W.J. Henderson, both of whom claimed title to the water. Later, the LA&SLC RR Co. purchased property and all interest to the water rights from the two parties in 1926 and then conveyed these rights to the Utah Parks Company. These rights were subsequently donated to the National Park Service.

The Headquarters Well was about 1000 feet west from the Bryce Canyon Lodge (T36S, R4W, Sec. 36acc). The well was originally a large diameter dug well, 30 feet deep, constructed in 1948. The well was deepened in 1955 by drilling to a total depth of 80 feet. After deepening, the well would produce 2000 gallons/day. Use of the well was discontinued in 1957 after the wells had been constructed at East Creek.

A deep test well (2000 feet) was drilled about 4500 feet west of Paria View overlook in 1959-60 (T37S, R4W, Sec. 11ddd). The well would yield more than 200 gallons/min. The water was very poor quality (high sulfide concentration) and the well was never put to use. Power lines to the well were removed in 1983.

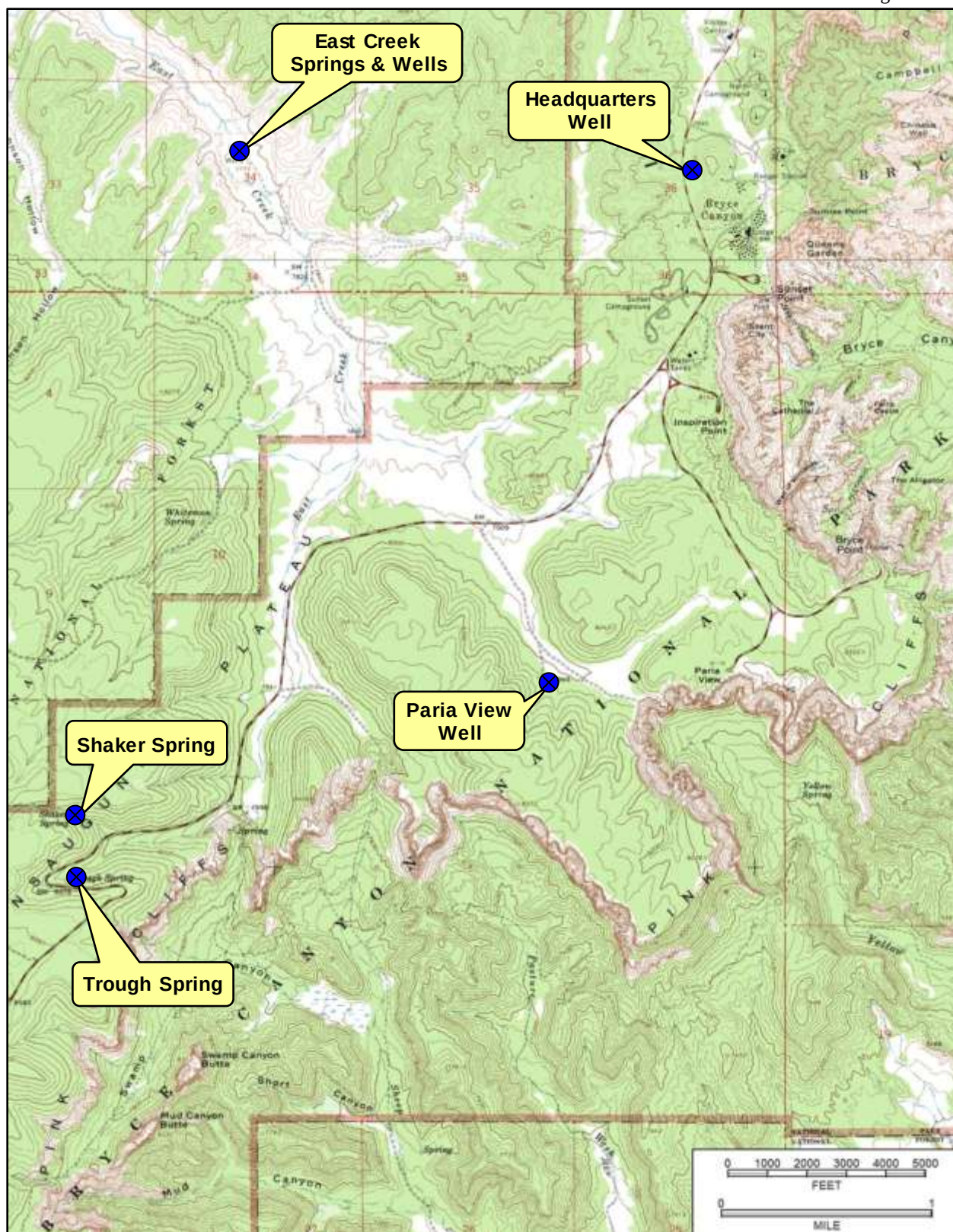


Figure 1. Locations of selected springs and wells at Bryce Canyon National Park. The East Creek wells have been the sole source of water for the park since the late 1950s.

Brief Chronology of Water Development

Utah Parks Co. developed tourist facilities at Bryce Canyon starting in 1923. Rights to water from Trough Spring and Shaker Spring, about 6 miles south of the developments, were purchased and the water was piped to the lodge and headquarters areas.

In the summer of 1924, the flow from the springs was so low that the water shortage at the Lodge was critical. By the summer of 1925, additional water from the springs on East Creek had been leased and a pumping station and pipeline to the lodge were constructed. Around 1926, the LA&SLC RR completed purchase of the water rights for the springs on East Creek and purchased 100 acres of land surrounding the springs from W.J. Henderson.

From 1925-29 these springs produced sufficient water to meet the needs of the lodge, headquarters, and the campground; estimated at 60-70,000 gallons/day. Water was generally only pumped during the 8-hour daytime shift.

Another dry period started in 1930. Flow from the springs at East Creek decreased such that the inflow of water to the 6,000 gallon collection sump would take some time to refill after pumping water to the Lodge area. Men operating the pumps had to remain on duty 24 hours a day to run the pumps as the sump refilled. Even with constant operation, the system would only provide 55,000 gallons per day. Water use at the lodge was curtailed. In 1931, a 50,000 gallon concrete reservoir was constructed next to the 6,000 gallon sump to provide additional storage for the collection system. With the additional storage, it was possible to collect water from the various springs and drain tiles over a 24-hour period and pump the water to the Lodge area during the day.

Flow from the springs increased in 1932 and the system would produce up to 90,000 gallons during an 8-hour shift. From 1932 onward, the flow of the springs continued to increase and plenty of water was available. The limited capacity of the power plant required operation of the pumps during the off-peak load periods at the lodge. Thus pumping generally occurred between midnight and 6:00 am and from 10:00 am to 6:00 pm.

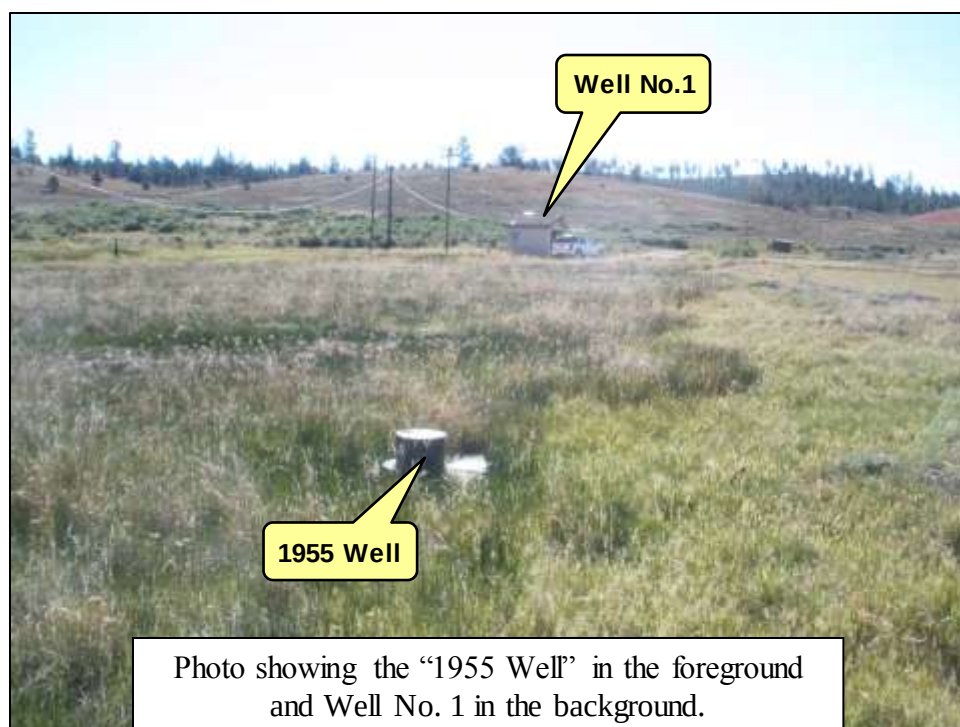
Another drought period began in 1951. Flow from the springs on East Creek gradually decreased from 1951 through 1957. By July 1955 the available water supply had again dropped to critically low levels and water use was curtailed. A well was drilled in the alluvium to provide a more reliable supply. The well produced 180 gpm during an 8-hour test. This well ("1955 Well") became the primary source of water. However, it was soon discovered that pumping from the well caused a large decrease of flow from the springs. A second well was constructed to provide additional water supplies ("1956 Well"). Increased precipitation during the fall and winter of 1957-58 restored water levels in the alluvial aquifer and the springs at East Creek were once again flowing and the wells could easily meet the demand for water at the Lodge.

Two wells were drilled in the East Creek area in 1980. One of these wells was a replacement for the "1956 Well". The other, Well No. 1, was at a new site, approximately 300 feet east of the "1955 Well". These wells remain in use today as the only active wells at Bryce Canyon.

East Creek Wells

The first well in the East Creek area was constructed in July 1955 (T36S, R4W, Sec. 34bda-1). Drilling was through surface peat and blue clay from 0-10 feet. Gravel was encountered at 10 feet. They placed 12-inch steel casing in the borehole and continued drilling and driving casing down to 26 feet. Another gravel layer was encountered at 22-23 feet below ground surface. There is no indication of the nature of the material encountered between the upper gravel layer at 10 feet and the lower gravel layer at 22-23 feet. Nor is there any record of the thickness of these two gravel layers. At 26 feet, a harder formation was encountered; probably soft limestone bedrock of the Wasatch Formation. Drilling continued with the 12-inch bit in an uncased hole to 52 feet and then with an 8-inch bit from 52-80 feet. No water-bearing formations were encountered in the bedrock, i.e. below 26 feet. The casing was perforated from 16-23 feet. The well was tested by pumping at 180 gpm for 8 hours resulting in drawdown from the static water level of 5 feet to a pumping level of 17½ feet below ground surface (BGS) .

The well was a good source of water for some time, but it has not been used for many years. The casing remains in place in the middle of the valley, about 300 feet west of the main water supply well for the park (called Well No. 1 by park staff). The location of the well is shown on Figure 2. There is a steel cap fitting tightly over the top of the 12-inch casing. There is a larger 16-inch casing surrounding the 12-inch casing. In June 2012, the depth of the well was measured at 28 feet from the top of the casing. The top of the casing rises about one foot above ground surface. Water level was observed to be a few feet below ground surface, but no exact measurement was made. The wellhead could be modified to facilitate monitoring of water levels in the alluvial aquifer, if there was a need for such data. The photo below shows the wellhead in the foreground, looking easterly toward Well No. 1 in the background. The remains of an old access road is evidenced by the change in vegetation on the right side of the photo.



Log of 1955 Well

Yield 180 gpm, Diameter 12 inches, Static water level 5 feet BGS

Alluvium:	<u>Thickness</u>	<u>Depth (feet)</u>
Clay.....	12.....	12
Gravel.....	3.....	15
Porous Formation.....	9.....	24
Tight Formation.....	6.....	30
Wasatch Formation.....	50.....	80
(dry chalky formation)		

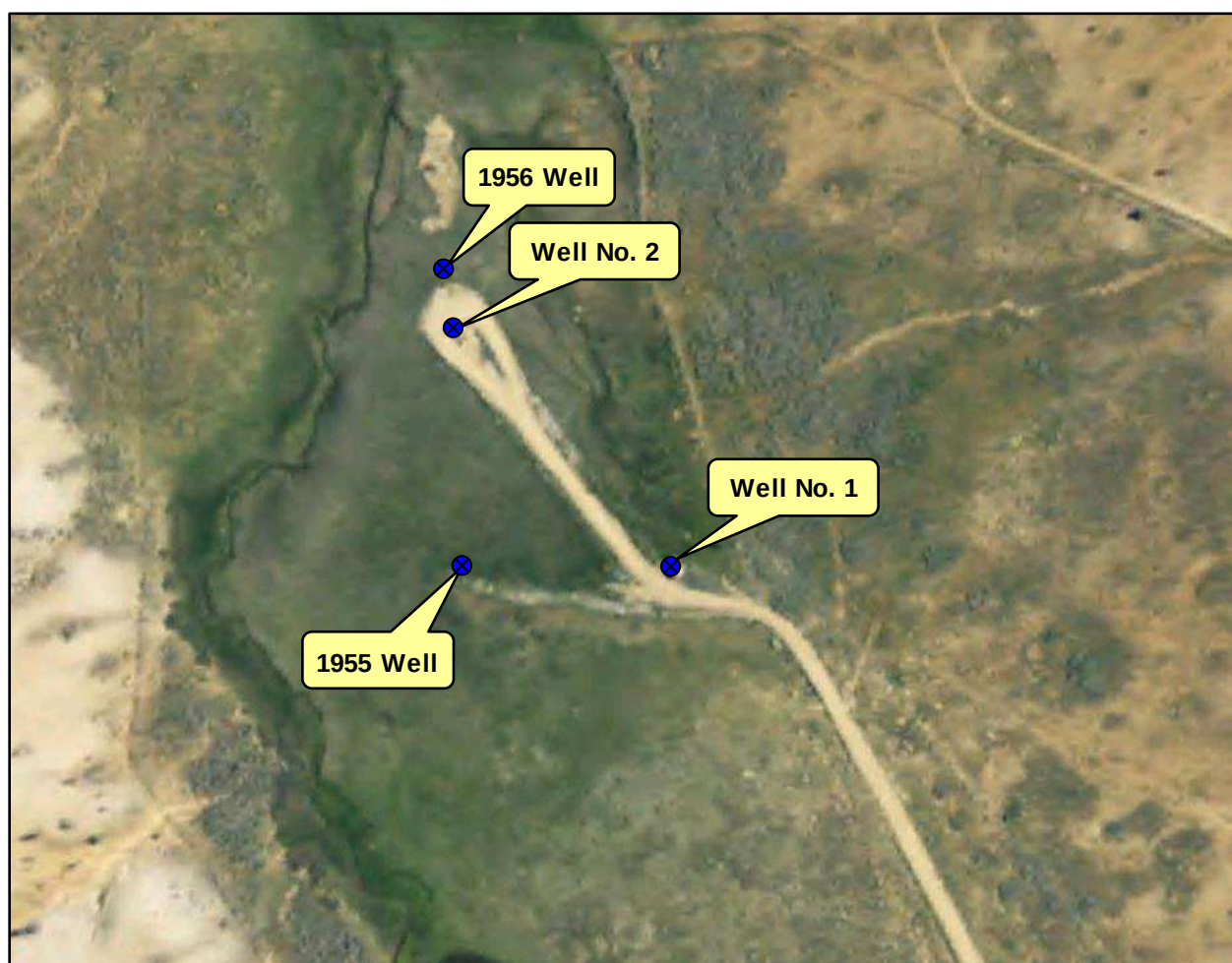


Figure 2. GoogleEarth view of the East Creek wellfield with locations of wells.

A second well was constructed at East Creek in August 1956 (see Figure 2). The well was drilled through the same geologic strata as the 1955 Well, but drilling was halted when the limestone bedrock was encountered at 30 feet. Casing was placed in the borehole and perforated.

Log of 1956 Well

Yield 90 gpm, Diameter 12 inches, Static water level 4 feet BGS

Alluvium:	<u>Thickness</u>	<u>Depth (feet)</u>
Clay.....	6.....	6
Sand and gravel.....	4.....	10
Clay.....	2.....	12
Gravel.....	2.....	14
Clay.....	4.....	18
Gravel and sand.....	8.....	26
Clay.....	4.....	30
Wasatch Formation	--.....	30+
(dry chalky formation)		

In 1979, NPS submitted a permit application to deepen the 1956 Well to 50-80 feet. However, in 1980 a new well was constructed about 25 feet south of the 1956 Well. This well is called Well No. 2 by park staff (see Figure 2). Well No. 2 was drilled to 52 feet. The sediments are described as; “muck, whitish-pink shaley lime with clay seams.” It doesn’t sound like it would be a productive aquifer, but the well was reportedly test pumped at 160 gpm with 12 feet of drawdown after 24 hours. The well was completed with 8-inch casing and screen. A concrete surface seal extends to a depth of 12 feet. A Johnson well screen was installed from 12-49½ feet. The screen has 0.080” openings, which seems large for the description of the geologic strata, but is consistent with a well that produces 160 gpm.

Well No. 2 was measured in June 2012 and found to be about 38 feet deep, but it seemed to have a soft bottom. That is, the weighted probe seemed to continue to slowly fall deeper into the well after initially seeming to hit the bottom. This is consistent with a well that has been partially filled with fine-grained sediments that have migrated through the well screen. The combination of factors, measuring the depth of the well, the large screen size, and the description of the geologic strata; leads me to believe that the well has partially filled with sediments and should be flushed out and the well redeveloped to restore productivity. This will be difficult and messy as a wellhouse has been constructed over the wellhead. The only reported use of Well No. 2 in recent years was for a few months during the summer of 1994.

Well No.1 was apparently also constructed in 1980 (see Figure 2). Information regarding the construction and testing of the well could not be located. Well No. 1 was measured in June 2012 and found to be about 50 feet deep. It also has 8-inch casing at the surface. Construction is probably similar to Well No. 2 as the wells were apparently both part of the same construction project. Well No. 1 has been the primary water source for the park for at least 20 years.

Water Use

Groundwater pumping from the East Creek wellfield is monitored by reading the master meter at the water treatment building at the water storage tanks. Pumping from the individual wells is not monitored as the meters at the wellheads are not in good operating condition. Almost all of the water pumped in recent years is from Well No. 1.

Monthly water use is reported to the Utah Division of Water Rights. These data are shown in Figure 3. Peak demand in 2010 and 2011 has been reduced to about two million gallons per month. The lower demand may be due to improvements to the water distribution system, reducing the amount of leakage. Continued monitoring during the next few years will show whether the reduced demand is a permanent condition.

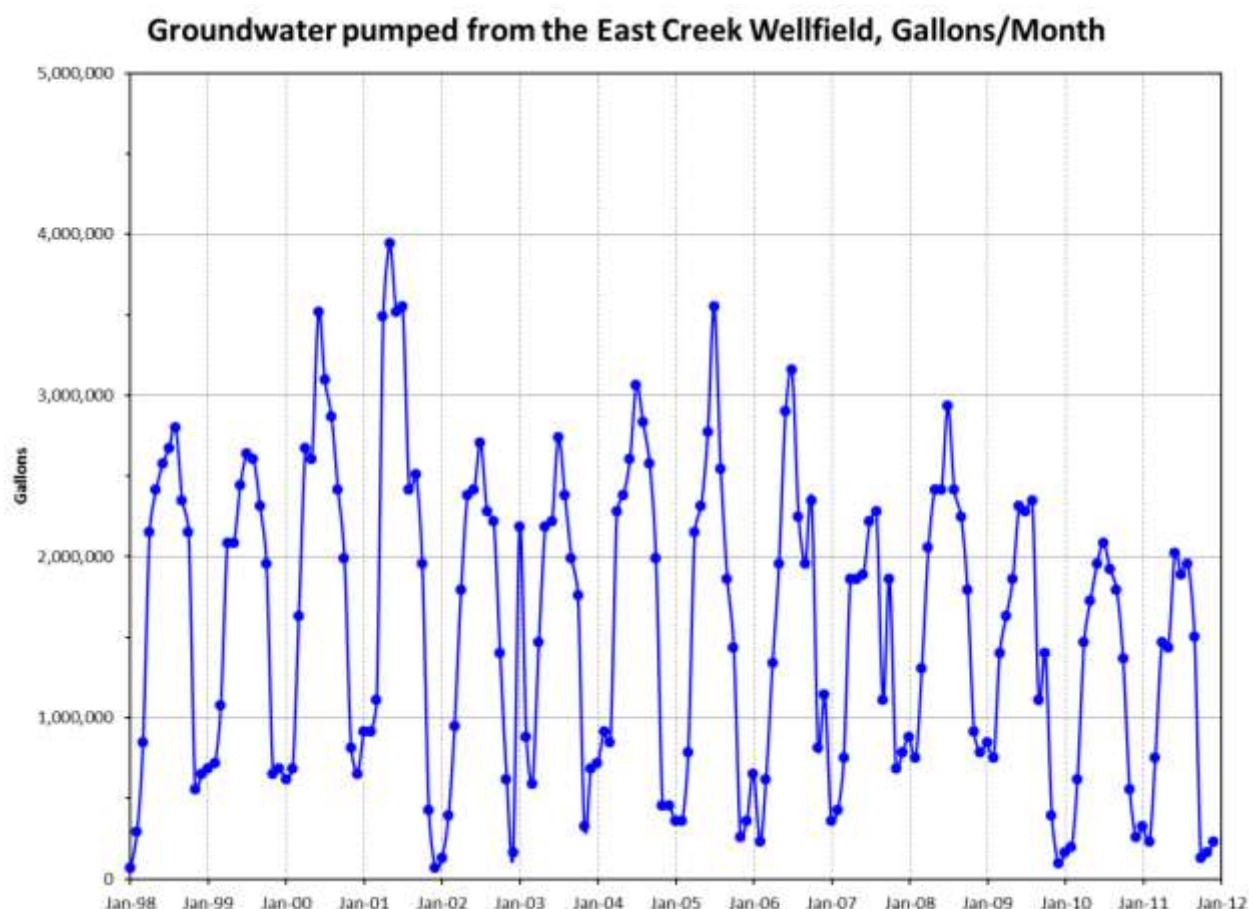


Figure 3. Groundwater pumping from the East Creek wellfield, gallons/month.

Groundwater Level Monitoring

Groundwater level monitoring at the East Creek wellfield has been conducted by both park staff and the USGS. Monitoring by USGS is discussed separately in the following section. Monitoring by NPS staff is presented in this section.

Water levels in Well No. 1 (the primary production well) are measured by park staff at irregular intervals. Measurements were made a couple of times a month in the winter and nearly daily in the summer. Data are available for the year 2000, and then more regularly from 2003 to present (Figure 4).

The short-term effect of groundwater pumping on depth to the water table does not show up on the chart. There does not seem to be a strong seasonal trend to the water level data. We don't see an obvious trend of rising water levels in winter and spring from recharge and declining levels through the summer. Water level is correlated with the local climate variations, i.e., wet years vs. dry years as discussed later in this report.

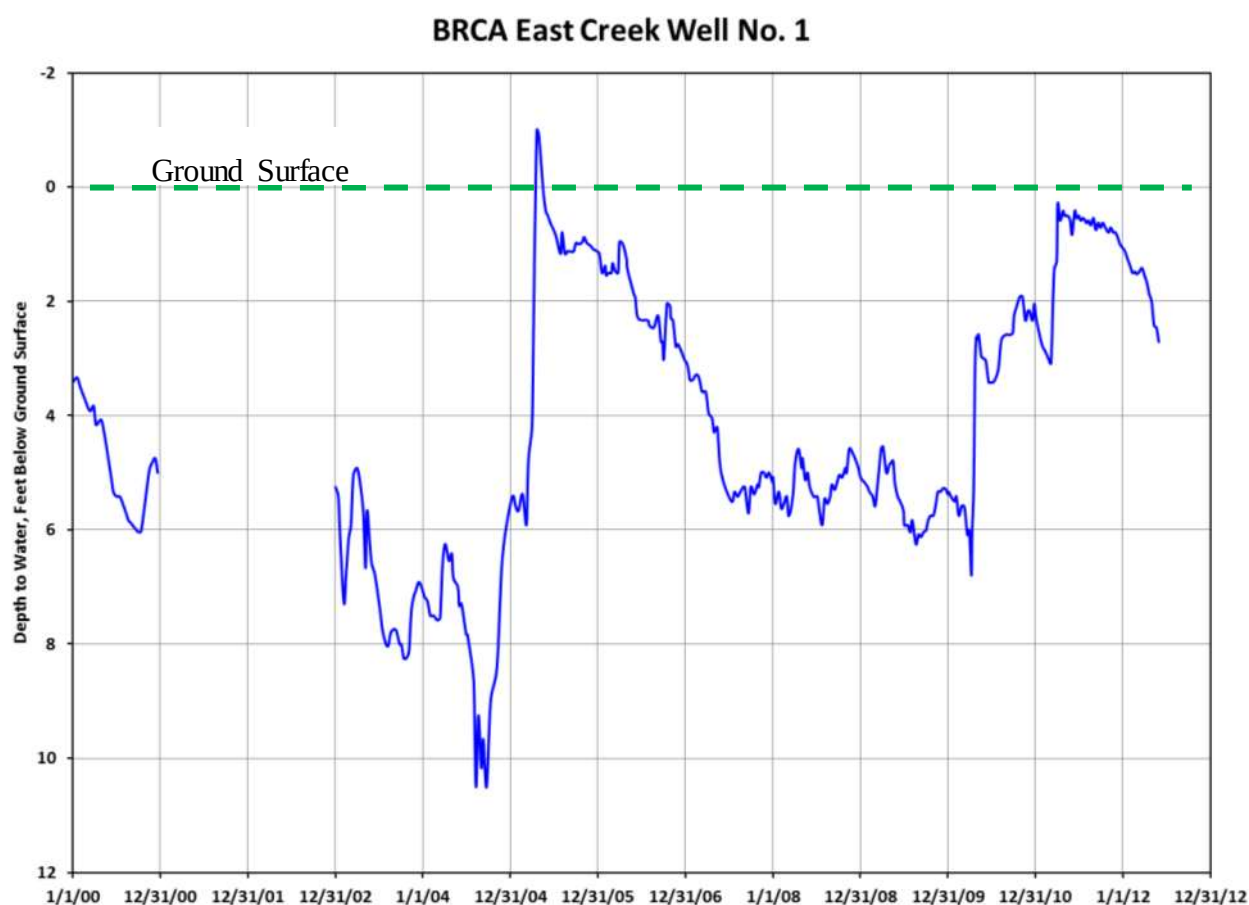


Figure 4. Water level data for 2000-present from manual measurements at Well No. 1 (the primary production well) by NPS staff.

A drawdown and recovery test was conducted at Well No.1 well in September 1997. The well was pumped at a constant rate of 145 gpm for 24 hours. The water level was monitored for three days prior to the test and one day after the pumping stopped. The water level was drawn down 3 feet during pumping, but quickly recovered to within 0.2 feet (2½") of the static water level after pumping stopped (Figure 5).

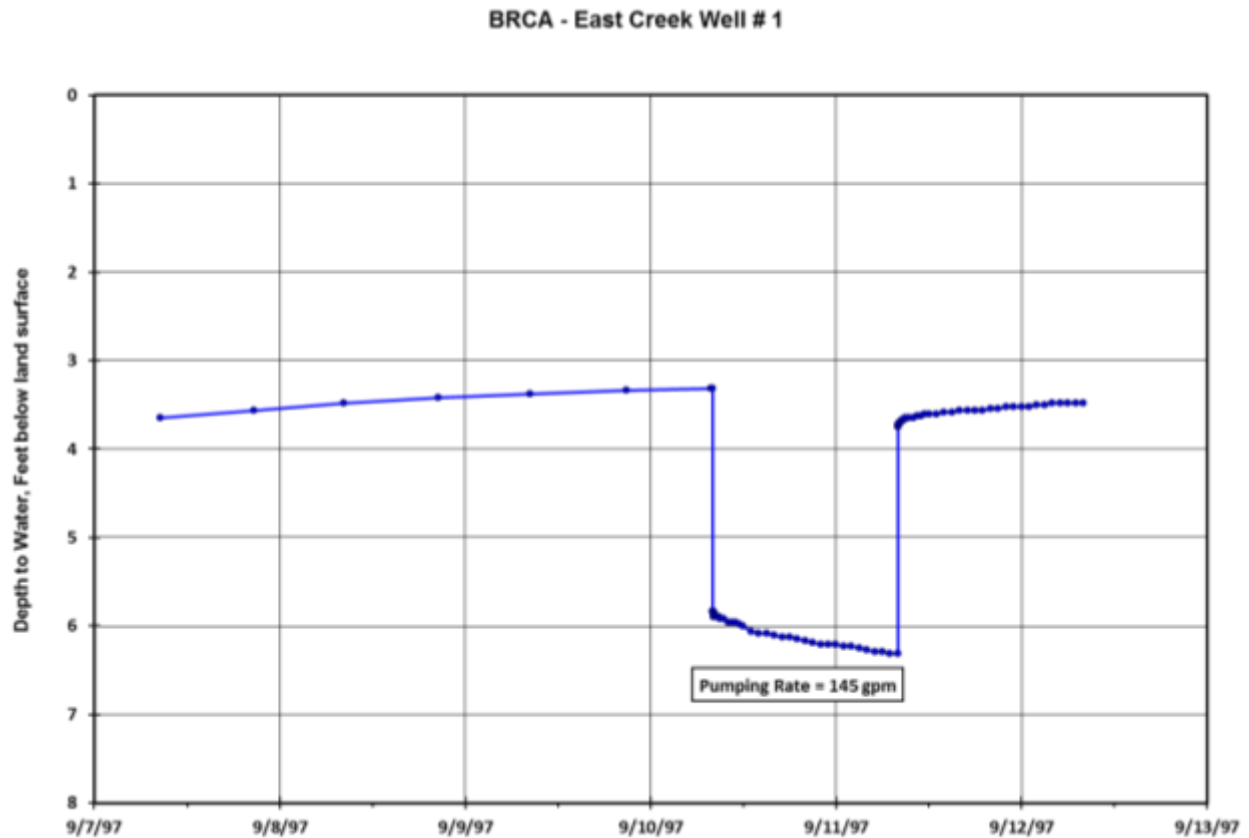


Figure 5. Water level drawdown and recovery at the East Creek Well No. 1 during a pumping test in 1997.

USGS Records and Monitoring at the East Creek Wellfield

The USGS database (NWIS) has four entries for wells in the East Creek area. The lat-long locations for each of the wells/records are plotted in Figure 6. It appears that each of the wells is plotted slightly south (ca. 100 feet) of its actual location. This may be an artifact of originally determining the location by interpolation from a 7.5' topographic map, or it might result from reporting the location to the nearest whole second.

Table 1. Summary of records from USGS NWIS database

#	Lat/Long	TRS	Depth	Begin Date	End Date	Records
1	3737541121239	T36S- R4W-34bda- 1	80ft	6/12/81	6/12/81	1 QW
2	3737581121243	T36S- R4W-34bda- 2	30 ft	9/4/56	9/4/56	1 WSL
3	3737541121242	T36S- R4W-34bda- 3	34 ft	3/2/57	6/26/89	500 WSL
4	3737561121243	T36S- R4W-34bda- 4	52 ft	5/31/80 6/12/81	1/17/90 6/12/81	70 WSL 1 QW

QW is water quality, WSL is water surface level.

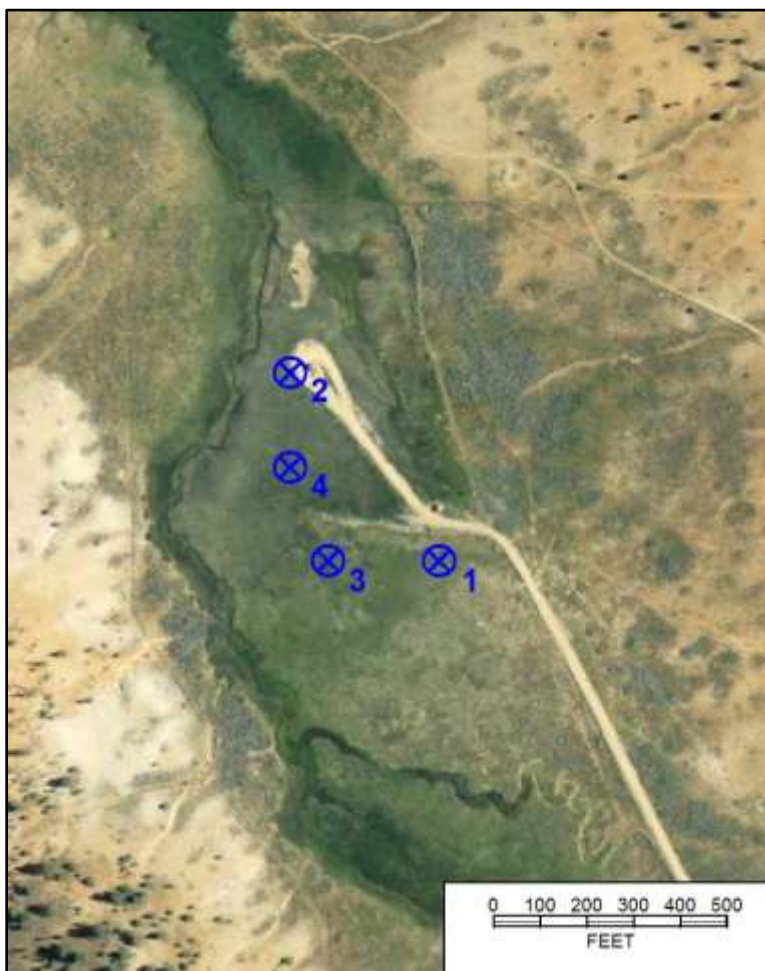


Figure 6. Locations of wells as plotted from the lat-long values in the USGS NWIS database.

Using the information for the location of each well, the depth, and the period of record, I surmise the following correlation for records in the USGS NWIS database.

1. #1 in the USGS NWIS database is the park's "Well No. 1". It is the primary water supply well for the park. This well was constructed in 1980 and it was common practice in that era to have USGS collect a water-quality sample from newly constructed NPS wells. Thus, it seems reasonable to assume that USGS sampled this well shortly after a pump had been installed. USGS records show one water quality sample from this well.
2. #2 in the USGS NWIS database is the "1956 Well". USGS probably visited the park to get data on the new well and made a water level measurement as was the custom at the time. USGS records show one water level measurement for this well.
3. #3 in the USGS NWIS database is the "1955 Well". The location and depth reported by USGS, along with the period of record provide evidence to match the records with the well. Water levels in this well were measured approximately every 5 days in the summer and less frequently in the winter from March 1957 to September 1963 (Figure 7). Monitoring resumed in June 1981 with infrequent measurements until April 1986 when they again resumed the pattern of frequent measurements in the summer and less frequent in the winter, through June 1989 (Figure 8).
4. #4 is likely the replacement well for the "1956 Well". This well is known to NPS park staff as Well No. 2. The location and depth reported by USGS and the period of record provide evidence to match the records with the well. The water level in this well was measured once when the well was constructed in May 1980 and then nearly daily from late-June 1989 to mid-January 1990 (Figure 9).

5.

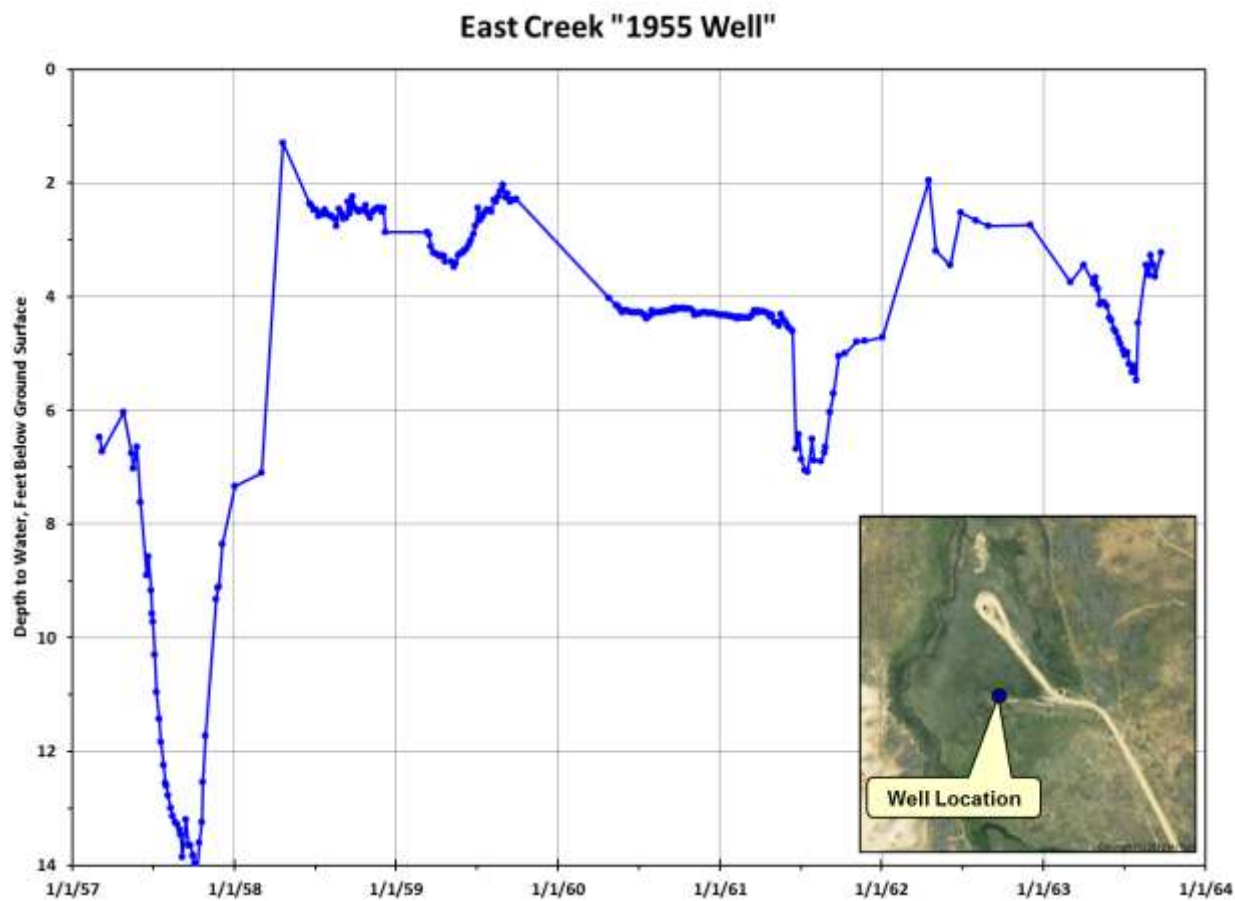


Figure 7. Water level data for 1957-63 from the USGS NWIS database for the well identified as #3 by the USGS. This is the first well that was constructed at East Creek in 1955.

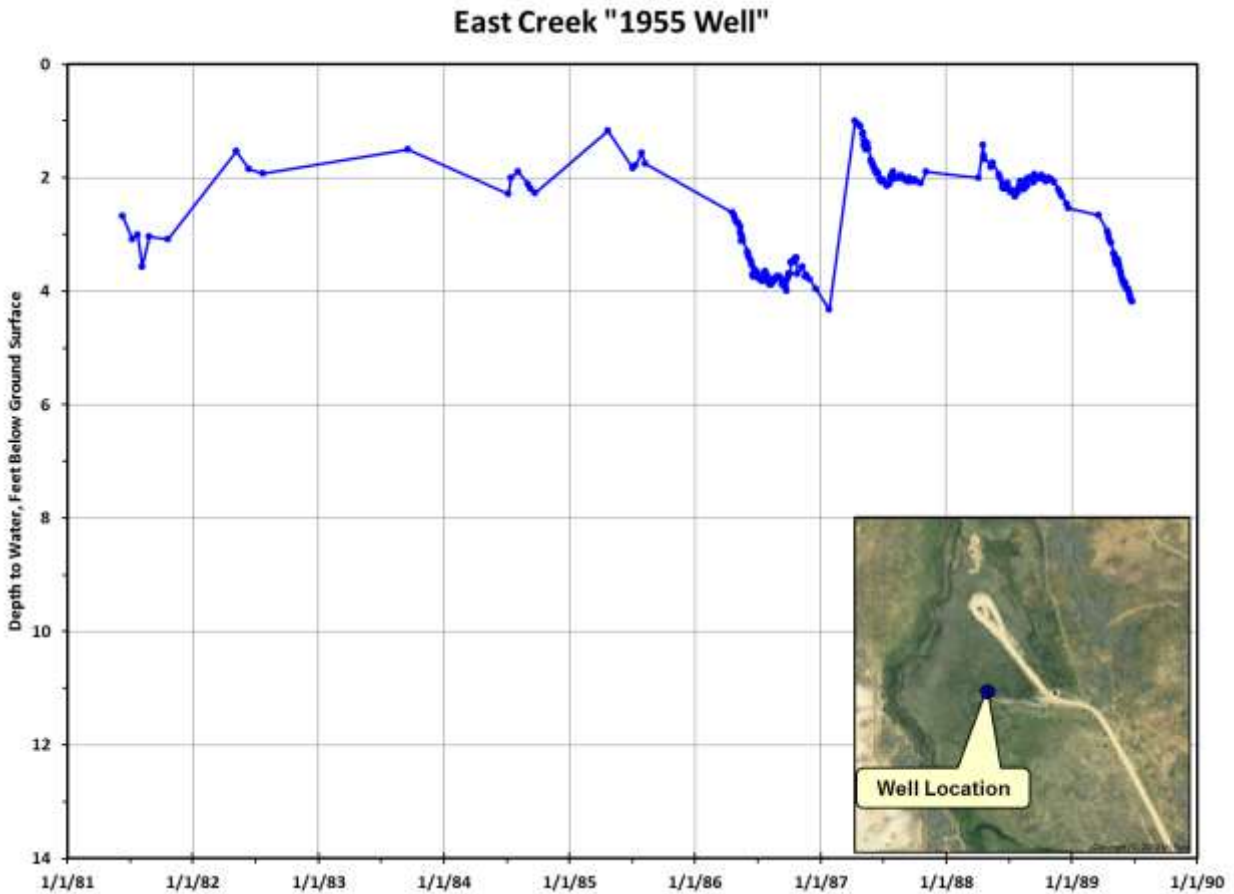


Figure 8. Water level data for 1981-890 from the USGS NWIS database for the well identified as #3 by the USGS. This is the first well that was constructed at East Creek in 1955.

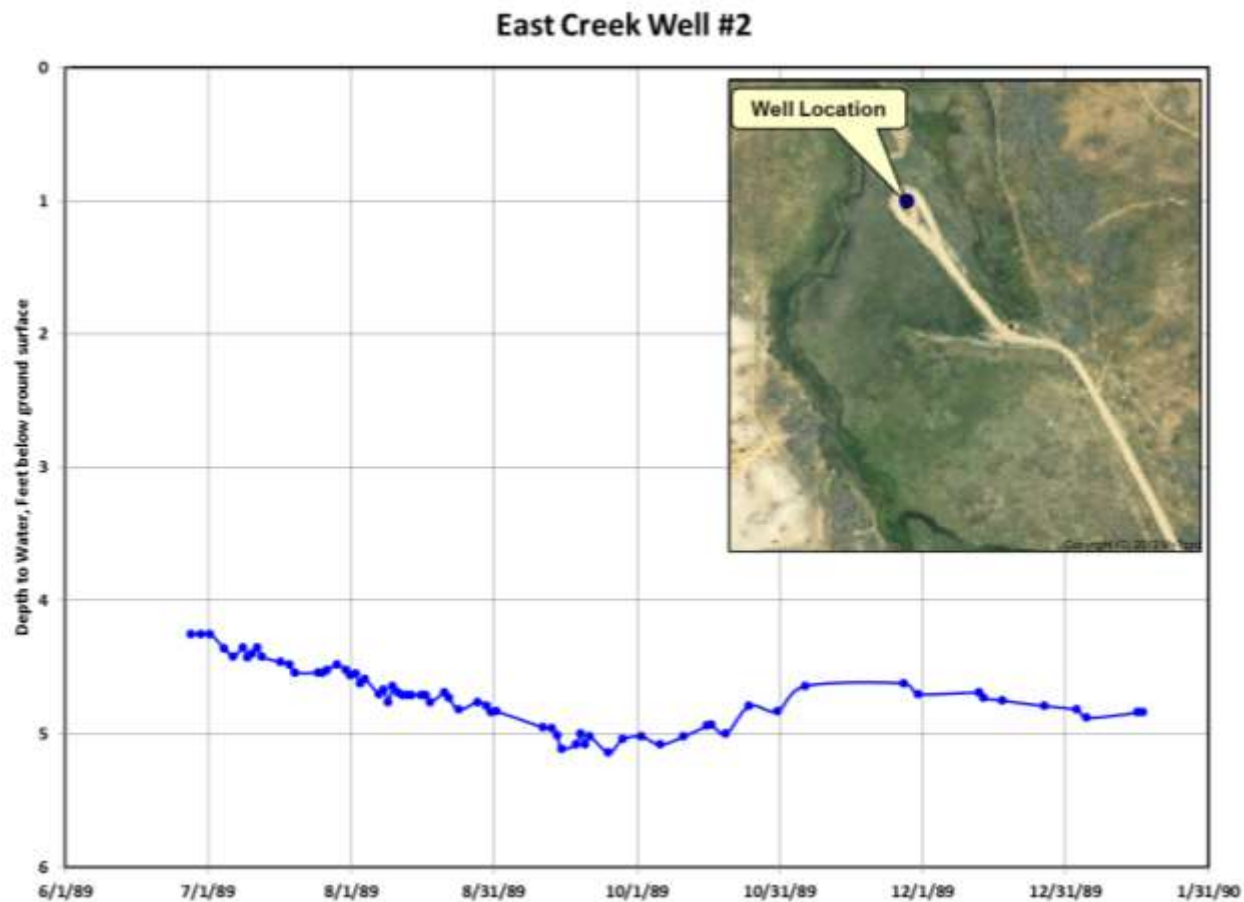


Figure 9. Water level data for June 1989 to January 1990 from the USGS NWIS database for the well identified as #4 by the USGS. This well is identified by park staff as the East Creek Well No. 2.

Groundwater levels affected by local climate

The Palmer Hydrological Drought Index (PHDI) is a long-term drought index. The PHDI uses data from the preceding 12 months to compute an index of the departure from normal conditions. Using data from this longer time period provides a better measure of the hydrological impacts of drought and wet conditions on groundwater levels. The longer time period is appropriate because it takes longer for drought conditions to affect groundwater levels and also longer for recovery after a return to more normal conditions.

An anonymous document (ca. 1958-59) in the files of the NPS Water Resources Division provides a summary of water use at the Bryce Canyon Lodge area and some history of the development of water sources for the lodge. The 10-page report identified several periods of drought that resulted in reduced water availability from Trough and Shaker Springs on the east side of Whiteman Bench and the springs in the East Creek Valley. The drought periods included; summer 1924, summer 1930 and 1931, and 1951-57. These drought periods coincide with negative values of the Palmer Hydrological Drought Index as shown on Figure 10. We would certainly expect springflow to be diminished during drought periods.

There are additional drought periods shown on Figure 10 that were not mentioned as being related to water shortages for the lodge. This may be because additional water supplies were developed with each drought. For example, additional supplies were developed from springs on East Creek in 1924-25 to supplement the reduced springflow from Shaker and Trough Springs. This supply was adequate during similar droughts in 1926 and 1928. However, a more severe drought in 1930-31 prompted further development of the water supply from the springs in East Creek. These sources were then sufficient to supply the demand of the Bryce Canyon Lodge area until the long drought period from 1950-57. Wells were constructed near the East Creek springs in 1956 and 1957 which then provided a more reliable source of water and enabled the park to pump groundwater from the alluvial aquifer. Groundwater pumping caused further reduction of flow from the springs as the water table was lowered, but a reliable source of water had been developed. The wells in the alluvial aquifer at East Creek continue to provide a reliable source of water for facilities at the park.

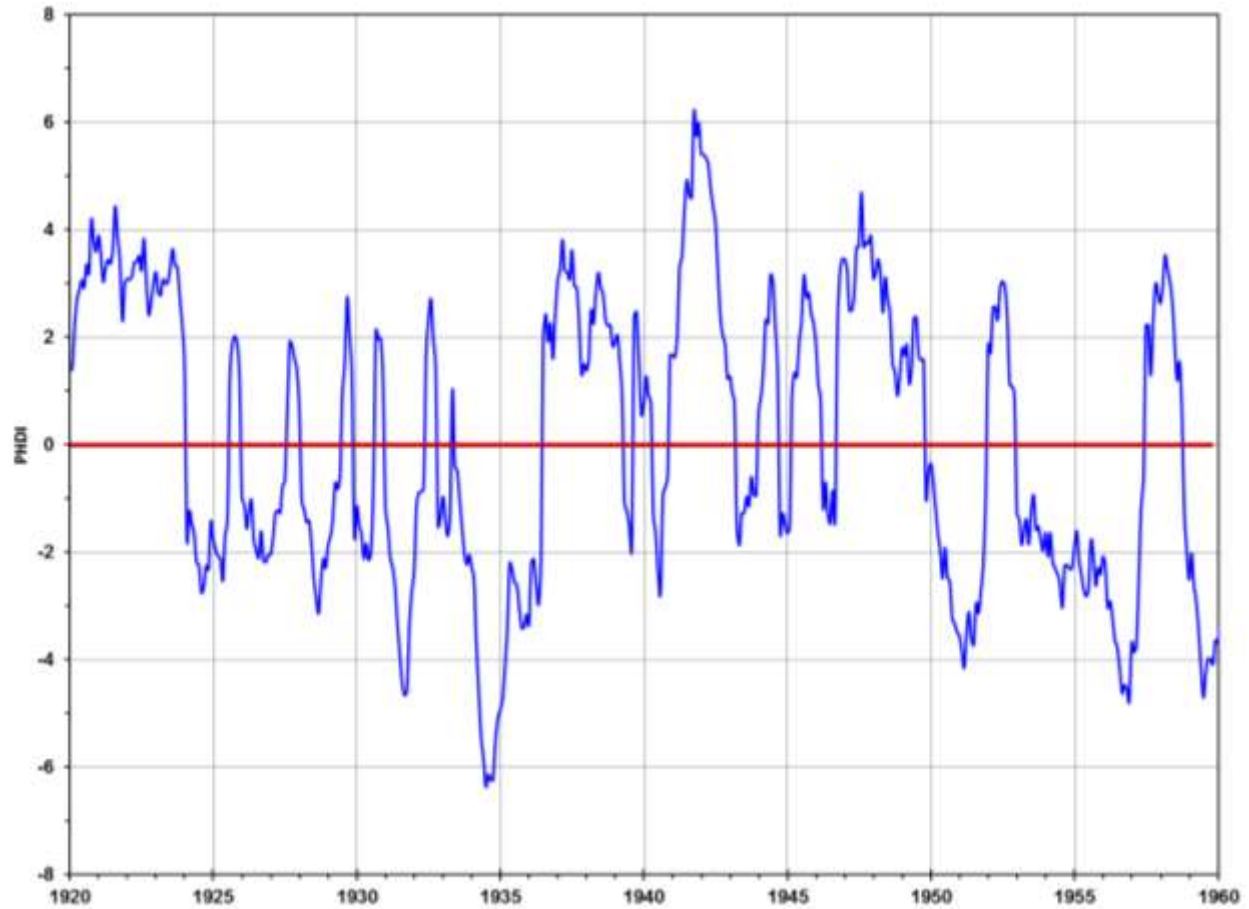


Figure 10. Graph of Palmer Hydrological Drought Index for south-central Utah, 1920-1960.
Negative values of PHDI indicate drought conditions, positive numbers show wetter than normal conditions.

We have two periods of record with sufficient groundwater level measurements at the East Creek wellfield to show correlation between the water table elevation and climate conditions. Figure 11 and 12 show graphs of depth to groundwater at Well No. 1 and the PHDI.

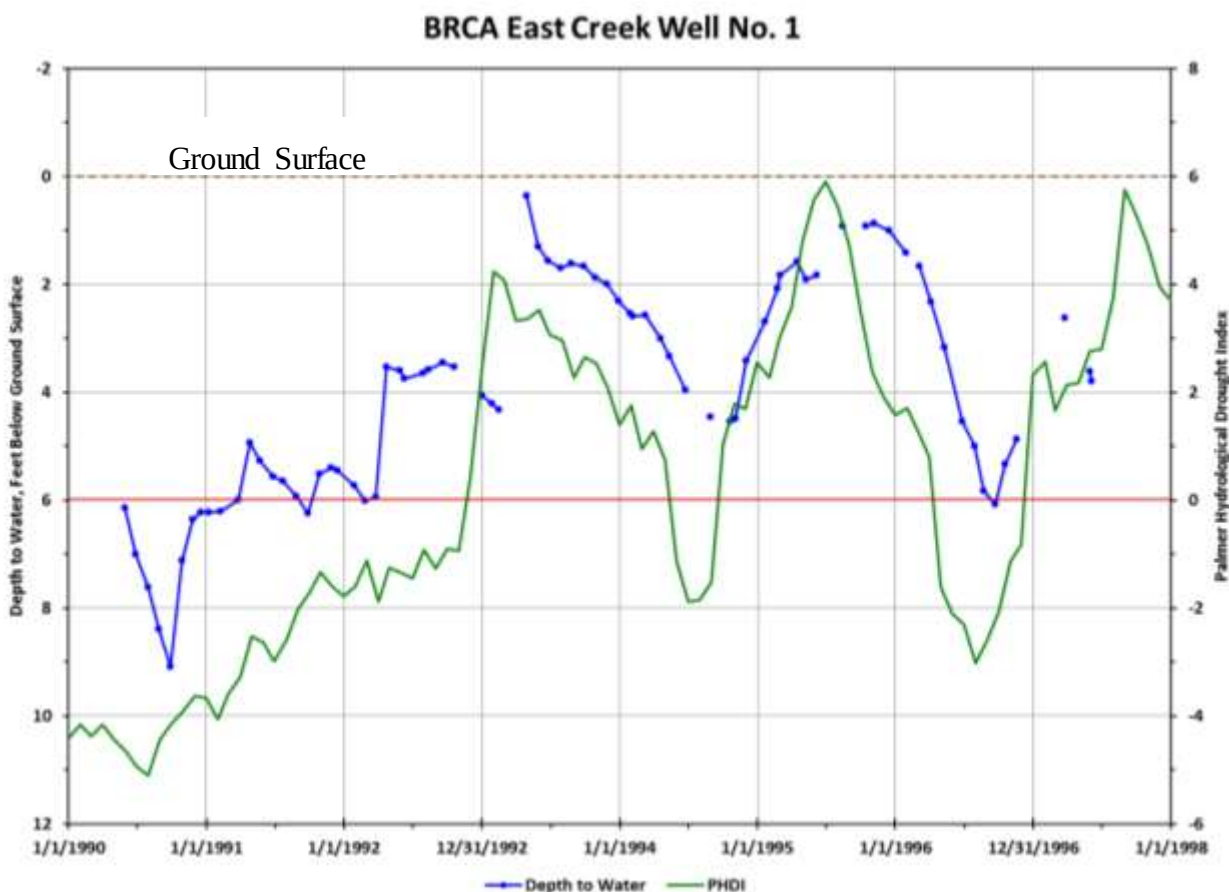


Figure 11. Graph showing correlation between regional Palmer Hydrological Drought Index and depth to water in the alluvial aquifer at the East Creek Wellfield; 1990-1998.

The data in Figure 12 show that even during an extended period of mostly drier than normal conditions from 2007 to 2010, the water level in Well No. 1 remained about 5-6 feet below ground surface. During this same time period, Well No. 1 was the sole source of water for the park, providing 2-2½ million gallons per month during the peak summer months (about 80,000 gallons per day). So it would appear that the East Creek alluvial aquifer will be a reliable source of water even during a prolonged, severe drought.

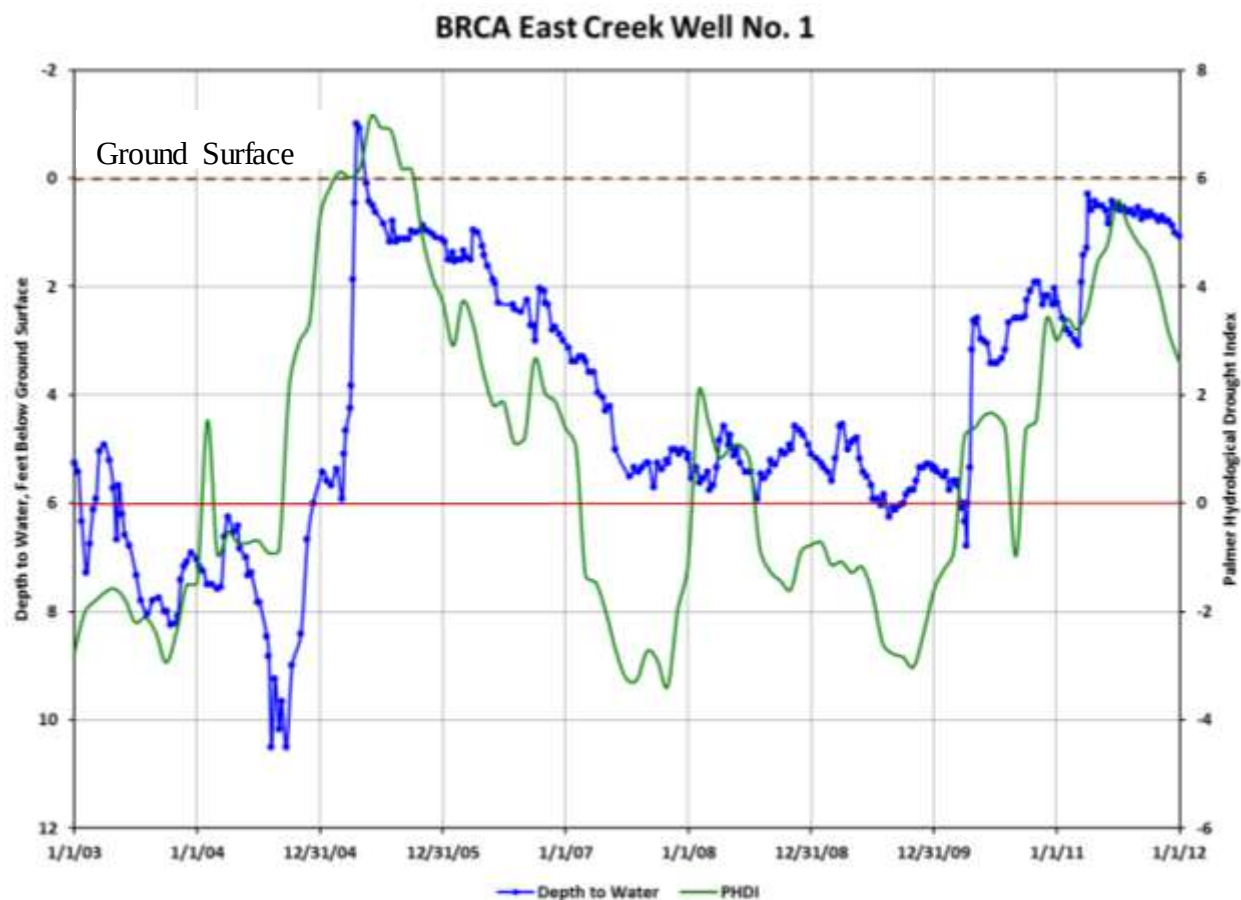


Figure 12. Graph showing correlation between regional Palmer Hydrological Drought Index and depth to water in the alluvial aquifer at the East Creek Wellfield; 2003-2012.

Conceptual Model of Hydrogeology

The conceptual model for the groundwater system supplying water for the wells at East Creek is entirely of local origin. Rainfall and snowmelt infiltrates the white limestone bedrock capping Whiteman Bench. Groundwater percolates downward until it meets the low permeability layers of the pink limestone member. It then moves laterally until it discharges along the face of the bluff. The top of the pink limestone member dips to the north-northeast. Groundwater generally follows the dip of the geologic formations, resulting in more springs occurring along the east and north side of Whiteman Bench. These processes are illustrated in Figures 13a and 13b.

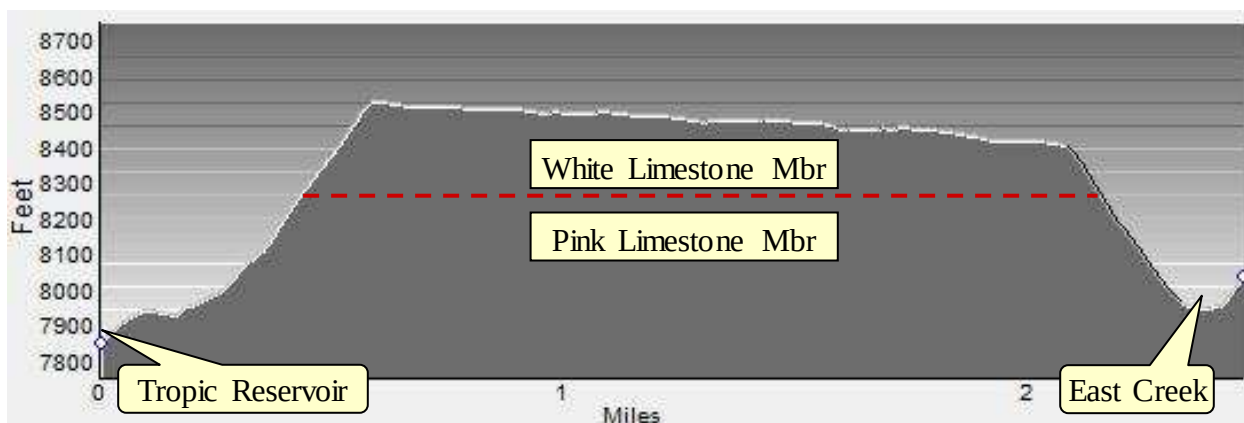


Figure 13a. West-East cross-section through Whiteman Bench in the vicinity of Trough and Shaker Springs, showing layers of the white and pink limestone members of the Claron Formation at this locale. The white limestone tends to be permeable and the pink limestone member has low permeability.

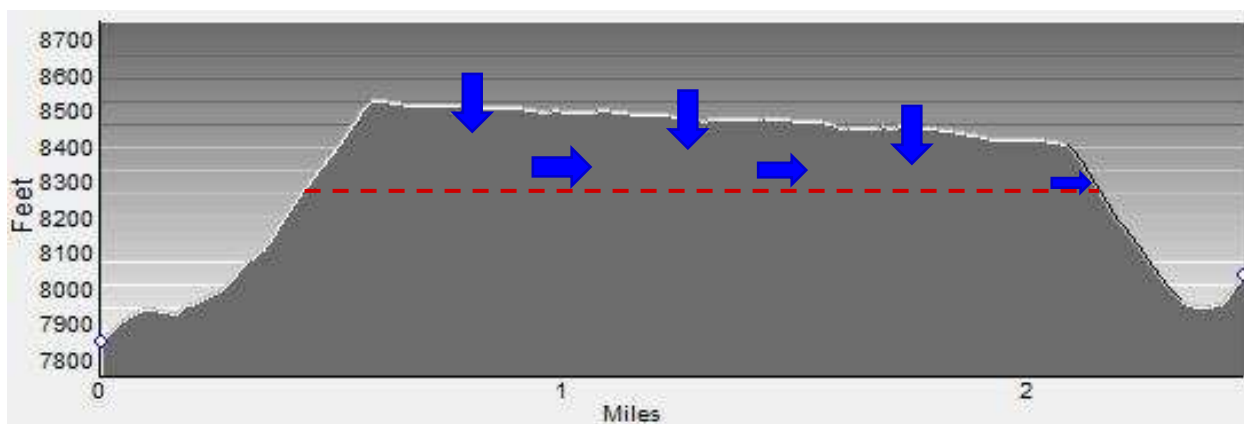


Figure 13b. West-East cross-section through Whiteman Bench in the vicinity of Trough and Shaker Springs. Blue arrows show groundwater flow patterns.

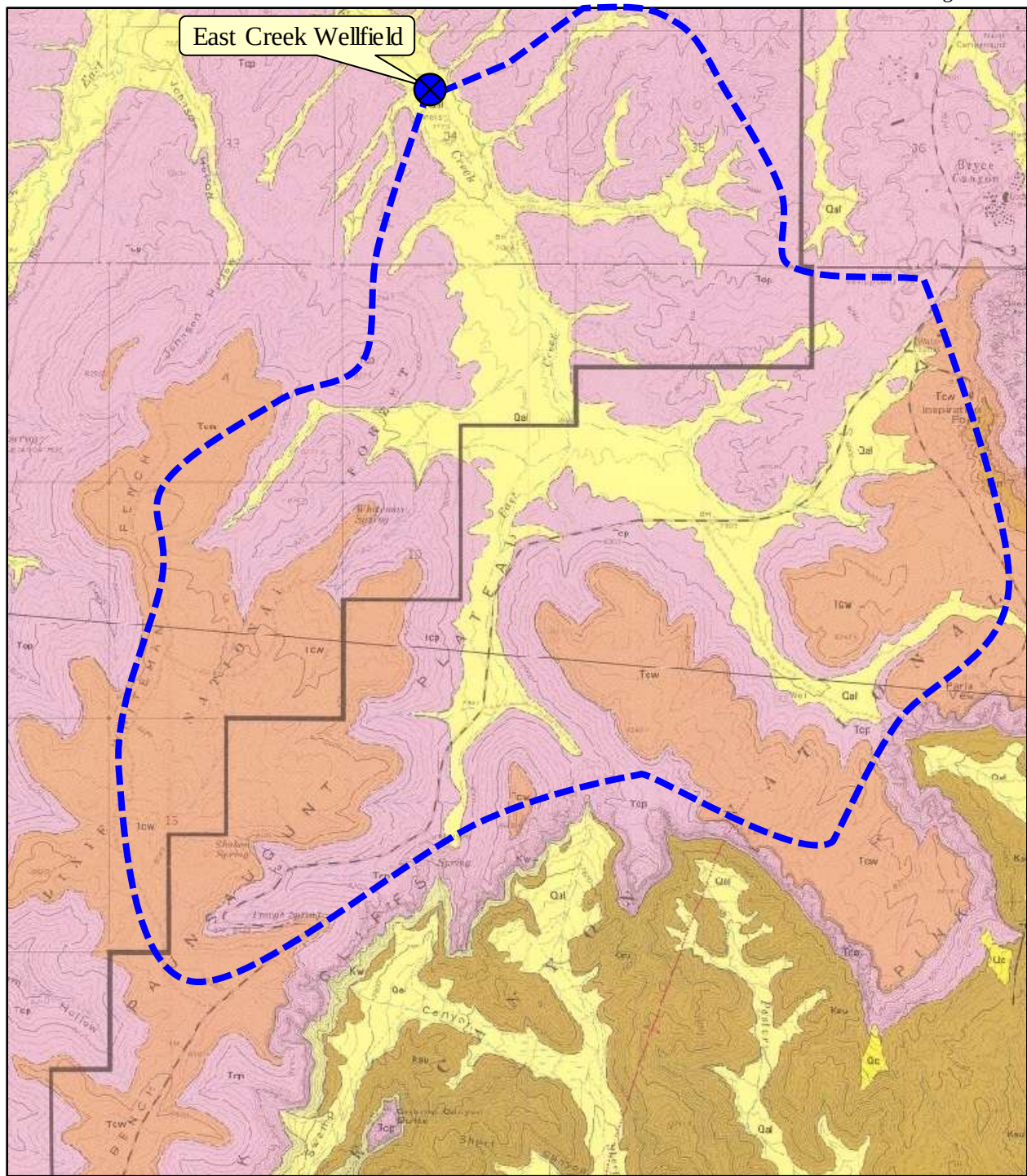
Additional recharge occurs as snowmelt and rainfall infiltration directly to the alluvial sediments in the upper reaches of the East Creek drainage basin. This groundwater flows downstream in the alluvium to the East Creek wellfield. The recharge area for groundwater at the East Creek wellfield includes the white limestone member capping the northern part of Whiteman Bench and the entire drainage basin upstream of the wellfield. The approximate recharge area is shown

as an overlay on the geologic map of the area in Figure 14. Since the recharge area is limited to a relatively small local area, the groundwater supply could be susceptible to long, severe droughts or climate change resulting in a permanent reduction of precipitation and recharge. Although, as discussed earlier in this report, groundwater level monitoring seems to show that the aquifer is a reliable source of water even during prolonged, severe droughts.

Future Reliability of the East Creek Alluvial Aquifer

When evaluating the future reliability of the East Creek alluvial aquifer, past performance is the best indicator of future results. Figure 15 shows the Palmer Hydrological Drought Index for the Dixie Division of Utah for the period from 1950-2012. The wells at East Creek were constructed toward the end of the drought that included most of the period from 1950 through 1957. There have been several drought periods since construction of wells at East Creek. There was a mild drought during much of the early 1960s, several short, moderate droughts in the 1970s, a longer, moderate drought from 1989-91, and a long, moderate-to-severe drought for most of the period from 1999-2008. During all of these drought periods, water levels remained within a few feet of ground surface (Figures 12) and the aquifer was able to meet the demand of pumping from the well.

While we cannot predict future climate conditions at the park, we can look at the drought period of 2007-09 (Figure 12) as an indicator of water availability during in a drier climate. During that period, the water level at Well No. 1 remained about 4-6 feet below ground surface, with no indication of a declining trend. At the same time, Well No. 1 was the sole source of water for the park, providing two million gallons per month during the peak summer season. Presumably future normal conditions would be no drier than drought conditions of 2007-09 when there was no shortage of water in the aquifer. The effect of future droughts added to permanently drier conditions might lead to water shortages, but the only way to evaluate that is to continue monitoring rainfall, drought, water levels, and groundwater pumping and then conduct periodic analyses of the data to provide advance warning of potential problems.



Geologic map from Bowers (1991)

Figure 14. Approximate extent of groundwater recharge area (blue dashed line) for the alluvial aquifer at the East Creek wellfield. Brown shading is the outcrop of the white limestone member, pink shading is the pink limestone member, and yellow is alluvium.

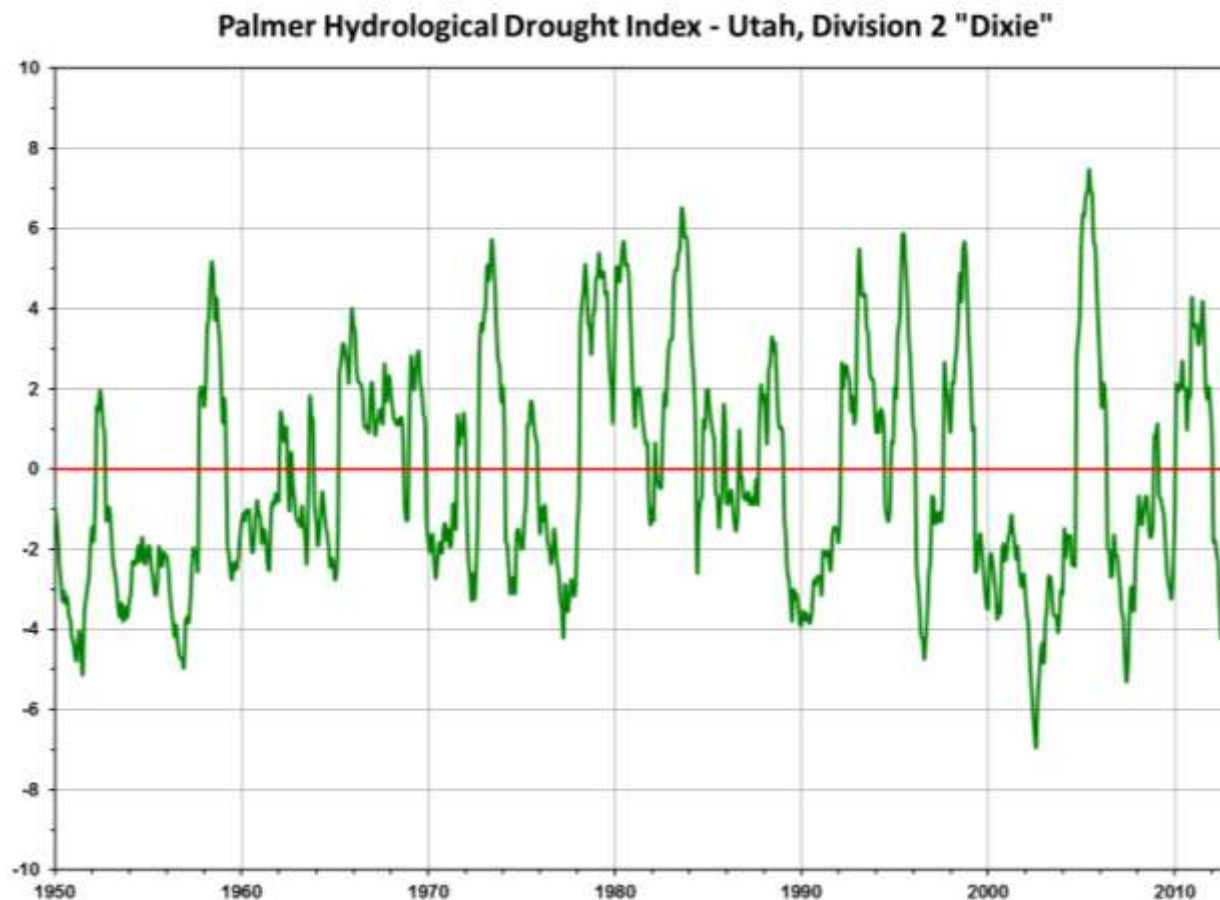


Figure 15. Palmer Hydrological Drought Index for the vicinity of Bryce Canyon; 1950-2012

Conclusions and Recommendations

The aquifer at the East Creek wellfield has proven to be a reliable source of water for the park. There is no indication that the aquifer is being over-pumped, even during extended drought periods. The water table is lowered a few feet during drought, but not to the point where it begins to affect the water supply to the wells.

Water level monitoring should continue along with recording the amount of water that is pumped. Along with climate data that is available from other sources, these data provide a basis for evaluating the effects of climate variability and groundwater pumping on the availability of groundwater in the alluvial aquifer of the East Creek valley. The “1955 Well” could be converted to a water level monitoring well, eliminating the need to monitor water levels in the water-supply wells. A datalogger could be installed in the 1955 Well to provide a continuous record of water levels in the aquifer.

The park has relied on one well (Well No. 1) for most of the past decade. This works for the park because the storage tanks have a capacity of 1.3 million gallons, or about 2½ weeks of water during the peak of the summer season. Spare pumps are on hand so a replacement could be made fairly quickly if needed. However, the park is primarily dependent on one well, as Well No. 2 suffers from a variety of mechanical or plumbing problems and operates at a lower pumping rate

(85 gpm?). It would be good to have a second well in good operating condition as a backup supply.

Well No. 2 might be redeveloped to increase the yield from the well. Also, when the well was measured in June 2012, it seemed that the total depth was 38 feet deep. Construction records show that it was constructed to a depth of 50 feet. The well screen has large openings (0.080") which might allow fine-grained sediments to enter and partially fill the well. The pump could be pulled and the well flushed or jetted using high volumes of either air or water under pressure to flush the accumulated sediment from the bottom of the well, restoring the full depth.

Redevelopment in this manner will also help to flush some of the fine-grained sediment from adjacent to the well screen, creating a natural gravel pack to filter fine-grained sediment from entering the well at normal pumping rates. Rehabbing the well by redevelopment will be difficult because the well is enclosed in a building. If the building cannot be easily removed, then electrical panels and other sensitive equipment will need to be covered or removed to protect them from being sprayed by water and sediment during the redevelopment process.

A new well might be constructed to replace Well No. 2. If a new well is constructed, it should include a well screen that is selected only after analyses of the sediment obtained during drilling to insure that the proper size screen is selected. Selecting the proper size screen will minimize movement of sediment into the well after the initial development of the well while maximizing the flow of groundwater into the well. Future wells should be constructed with pitless adaptors so the well and discharge piping do not need to be in a heated wellhouse. It is much easier to do repair/rehab work on a well if it is not in an enclosed structure.

References

- Bowers, W.E., 1991, *Geology of Bryce Canyon National Park and Vicinity*, Utah. U.S. Geological Survey Map I-2108, scale 1:24,000
- Czarnowski, Ken, 1991, *Hydrologic Characterization and Inventory of Water Rights, Uses, and Requirements at Bryce Canyon National Park*, unpublished report, NPS Water Resources Division, 25 pages.
- Davis, George H., and Gayle L. Pollock, 2000, *Geology of Bryce Canyon National Park, Utah*, in *Geology of Utah's Parks and Monuments*, Utah Geological Association Publication 28, D.A. Sprinkel, T.C. Chidsey, Jr., and P.B. Anderson, editors, pp. 37-60
- Doremus, Lyn, and Kreamer, David, 1999, *Bryce Canyon Water Resource Study Report*, unpublished report, 35 pp.
- Marine, I.Wendell, 1963, *Ground-Water Resources of the Bryce Canyon National Park Area, Utah*, USGS Water-Supply Paper 1475-M, pp. 441-486
- Ott, Amy, 1996, *Natural Spring Inventory Bryce Canyon national Park*, unpublished report Bryce Canyon Resource Management Division, 42 pages
- Scrattish, Nicholas, 1985, *Historic Resource Study Bryce Canyon National Park*, accessed at http://www.nps.gov/history/history/online_books/brca/hrs.htm

Appendix A

Summary of 1963 U.S. Geological Survey Water-Supply Paper

I. Wendell Marine, USGS hydrologist, conducted an investigation of the groundwater resources of Bryce Canyon National Park (Marine, 1963). The primary objective of the investigation was to provide sufficient information to allow the park service to develop an adequate and reliable water supply. This was after significant drought periods in the mid-1920s, early-1930s, and early-1950s. Marine considered the then existing water supply, the wells in the East Creek alluvium, to be unreliable to meet future demand, especially in dry years.

Marine's investigation included evaluating;

1. Surface water from the East Fork of the Sevier River.
2. Wells in the alluvium of East Fork of the Sevier River.
3. Springs below the canyon rim on the east side of the park.
4. A deep well (2000 feet) drilled to the top of the Tropic Shale.
5. The existing wells in the alluvium of East Creek.

Surface water in the East Fork of the Sevier River, and other surface water sources, are fully appropriated. NPS could purchase senior water rights from a willing seller. That would likely be very expensive and cause resentment among local residents of the area. Developing, treating, and transporting surface water to points of use within the park would add considerably to the long-term operations and maintenance of the system. Wells drilled in the alluvium of the East Fork drainage would probably be considered as intercepting tributary flow to the steams and might be subject to the claims of more senior surface water rights.

Yellow Creek Spring, and other springs on the east side of the park, below the canyon rim could provide sufficient water of good quality. These waters would likely need to be treated as a surface water source, adding to the expensive of developing the source. Also, the water would need to be pumped uphill from the base of the escarpment over very rugged terrain. Discharge from the springs might constitute a portion of the water right of downstream users and therefore might not be readily available for use in the park.

A deep test well was drilled near Paria Viewpoint in 1959-60. Testing determined that the well would yield 200 gpm, but the water quality was poor, having high concentrations of sulfate, probably from dissolution of gypsum in the bedrock formations. Any plans to treat the water from the well to drinking water standards vanished after repair/rehab of the shallow alluvial wells at East Creek in the early 1980s provided adequate supplies of good-quality water.

Repair/rehab of the East Creek wellfield and water system, including construction of a new well, in the early 1980s resulted in increasing the yield of the system. It has been a reliable supply of good quality water for the past 30 years. Marine's predictions have been incorrect, as the alluvial wells continue to meet the demand and show no signs of being overused. But to be fair, Marine based his predictions on a hypothetical future demand of 37 million gallons per year. Actual water use in past 30 years has been about 15-20 million gallons per year.