

July 2014 Hydrothermal Assessment of Proposed Old Faithful Inn Sewer Line Routes, Yellowstone National Park

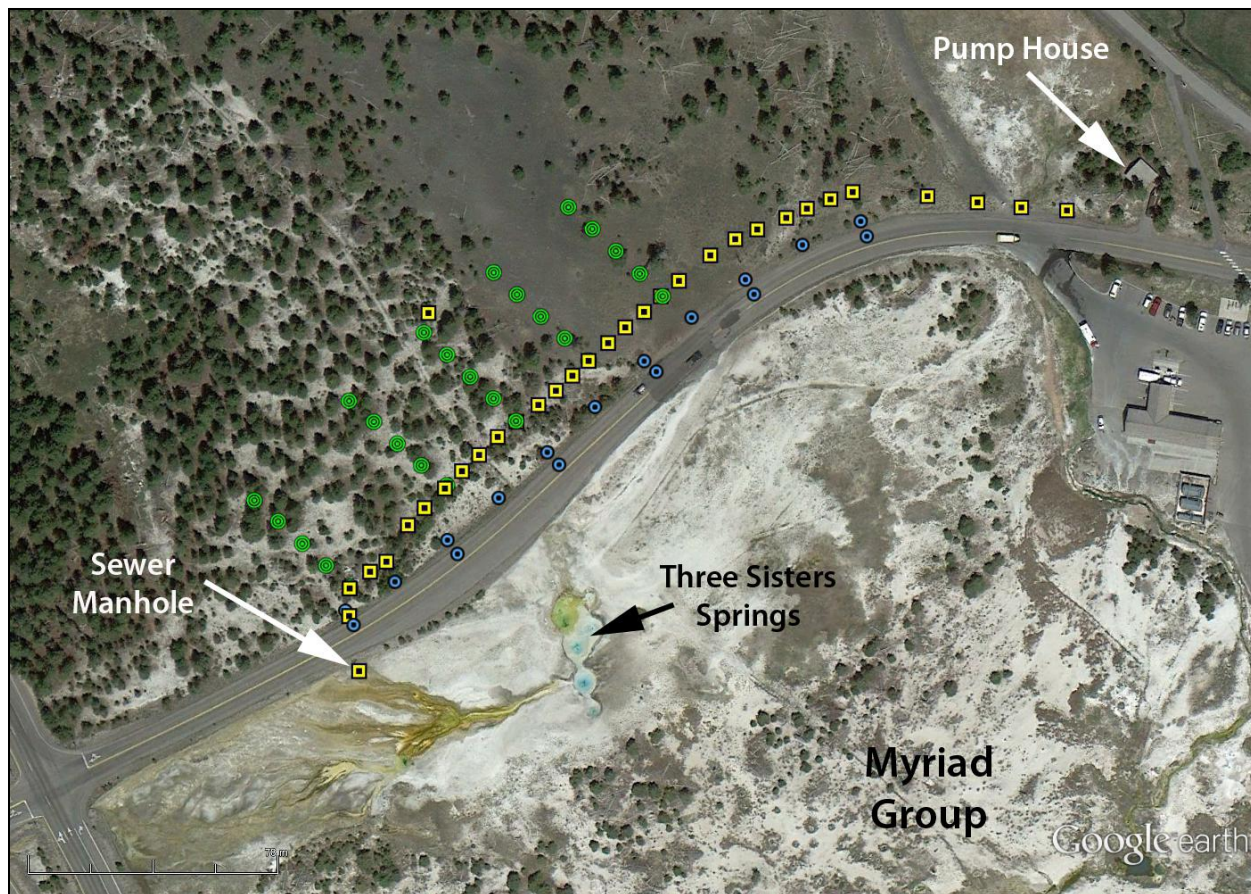


Figure 1. Google Earth image showing locations assessed for temperatures and gases along proposed routes of the Old Faithful Inn sewer line. The yellow squares along the lower service road represent data gathered 15 May 2014, the green concentric circles represent data gathered 24 June 2014, and the blue circles with center dots represent data gathered 24 July 2014. The Myriad Group, part of the Upper Geyser Basin hydrothermal system, extends south from the access road towards the Old Faithful Inn.

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EXECUTIVE SUMMARY

Park management plans to replace the existing Old Faithful Inn forced sewer line between the lift station and the existing gravity portion of the sewer line in the Myriad Group. This brief report summarizes hydrothermal and geologic conditions encountered on 24 July 2014.

All proposed sites are within an *active* hydrothermal system as defined by hydrothermally altered ground, hydrothermal deposits, and elevated subsurface temperatures. Fifteen additional subsurface temperatures measured within 4.6 m (15 feet) of the lower service road at 85 cm (33.5 in) depth ranged from 27.1 to 59.9 °C (80.8 to 139.8 °F). The maximum measured carbon dioxide concentration was 3.8%.

INTRODUCTION

A new sewer line is proposed to replace the failing sewer line for the Old Faithful Inn (Figure 1). Proposed routes begin at the lift station and follow the access road from the lower gas station towards the four-lane road (for a additional description and maps of the proposed routes, see Heasler et al., 2014).

This report summarizes subsurface temperature data and hydrothermal gas concentrations measured on 24 July 2014. Eleven sets of measurements were taken 4.6 m (15 feet) to the northwest of the lower service road. Five measurements were taken along the northwest asphalt edge of the lower service road.

A hydrothermal area (2-D) is a contiguous geologic unit that usually includes one or more hydrothermal features. Its boundary is the maximum spatial extent of hydrothermally altered ground, hydrothermal deposits, hydrothermal gas emissions, or heated ground. Thus, a hydrothermal area is more than individual hydrothermal features such as hot springs, geysers, steam vents, and mudpots. A hydrothermal system (3-D) integrates the subsurface geology (sediments, rock, fractures, porosity, permeability, etc.) and geologic processes (i.e. fluid flow, hydrothermal alteration, etc.). The geology of the area and its relationship to hydrothermal resources of the Upper Geyser Basin hydrothermal system is discussed in Heasler and Jaworowski, 2014.

LOCATION OF STUDY AREA

On the northwestern edge of the Old Faithful developed area, the existing Old Faithful sewer line is trenched into an *active* hydrothermal system. The proposed routes follow an access road to the lower gas station, the General Store and the Old Faithful Inn. The proposed sewer line is north of the Three Sisters hot springs. The Three Sisters hot springs are part of a spatially extensive, hydrothermal system and geochemically similar to other hydrothermal features within the Myriad Group (Figure 1).

METHODS

Previous hydrothermal assessments conducted during summer 2014 (Heasler et al., 2014) provide a description of the methods used in this study and for hydrothermal assessments generally. For the purpose of this study, temperatures and hydrothermal gas concentrations (carbon dioxide, hydrogen sulfide, and sulfur dioxide) were measured only at 85 cm (33.5 inch) depth.

A mobile mapping unit recorded accurate locations of the temperature sites. The mobile mapping system consists of a Trimble ProXH global positioning system (GPS) receiver with a Zephyr antenna and Allegro MX handheld field computer. After collecting data, geologists corrected the field locations using Trimble's GPS Pathfinder Office software and the Slough Creek Plate Boundary Observatory (PBO 720) precision GPS station. For lines R and S, the horizontal accuracy of the corrected points (~94 %) varied between ± 5 and 30 cm (± 2 inches to 12 inches).

RESULTS

Subsurface Temperatures

Figure 2 presents temperatures measured at 85 cm (33.5 inches) depth on 15 May 2014, 24 June 2014, and 24 July 2014 (see Figures 3 through 5 for hole locations and Appendix A for data values). On 15 May 2014, the maximum temperature was 39.7 °C (103.5 °F) in hole 22. On 24 June 2014, the maximum temperature was 72.5 °C, (162.5 °F) in hole B2. On 24 July 2014, the maximum temperature was 59.9 °C (139.8 °F) in hole S3. On 24 July 2014, the tip of the temperature probe was very hot when it was pulled from hole S3 at 14:30 Mountain Daylight Time (MDT). It is interesting to note that this high temperature in hole S3 coincides with the asphalt patch along the service road.

For this study, all measured temperatures were less than the boiling temperature of water at the Old Faithful area. At the elevation of Old Faithful (about 2,225 m or 7,300 feet), water boils at approximately 92 °C (198 °F).

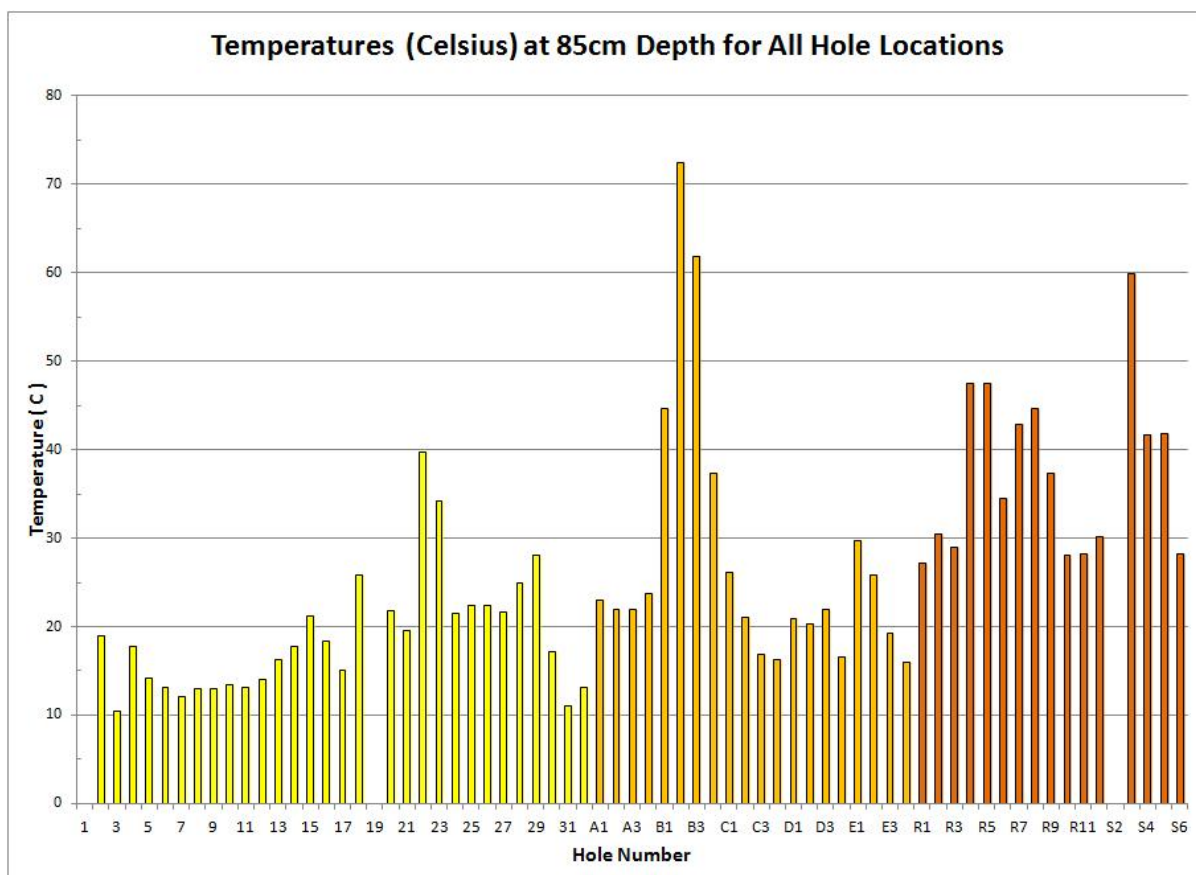


Figure 2. Graph showing temperatures at 85 cm (33.5 inches) depth for all holes. See Figures 3–5 for locations. Holes 1–32 (yellow color) were drilled 15 May 2014. Holes A1–E4 (orange color) were drilled 24 June 2014. Holes R1–S6 (red color) were drilled 24 July 2014. Some holes could not be drilled to 85 cm due to a hard substrate (holes 1, 19, and S2).

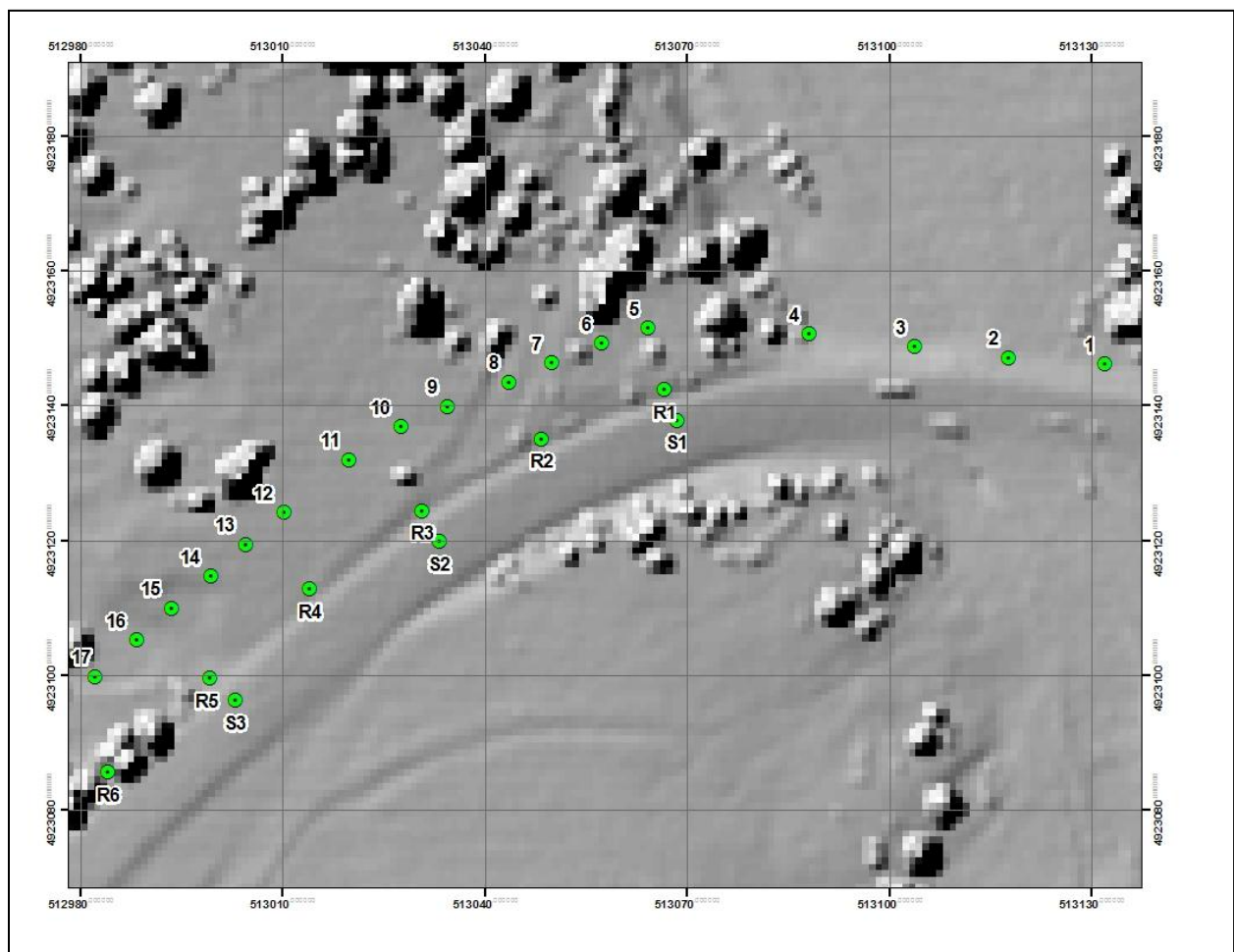


Figure 3. A LiDAR base map showing locations (1-16) assessed for subsurface temperatures, hydrothermal gases, and stratigraphy along proposed routes of the Old Faithful sewer line on 15 May 2014. Locations R1 – R6 and S1 – S3 were assessed on 24 July 2014. The NSF EarthScope project funded the acquisition of this geodetic-grade imagery (publically available at www.opentopography.org) of the Upper Geyser Basin.

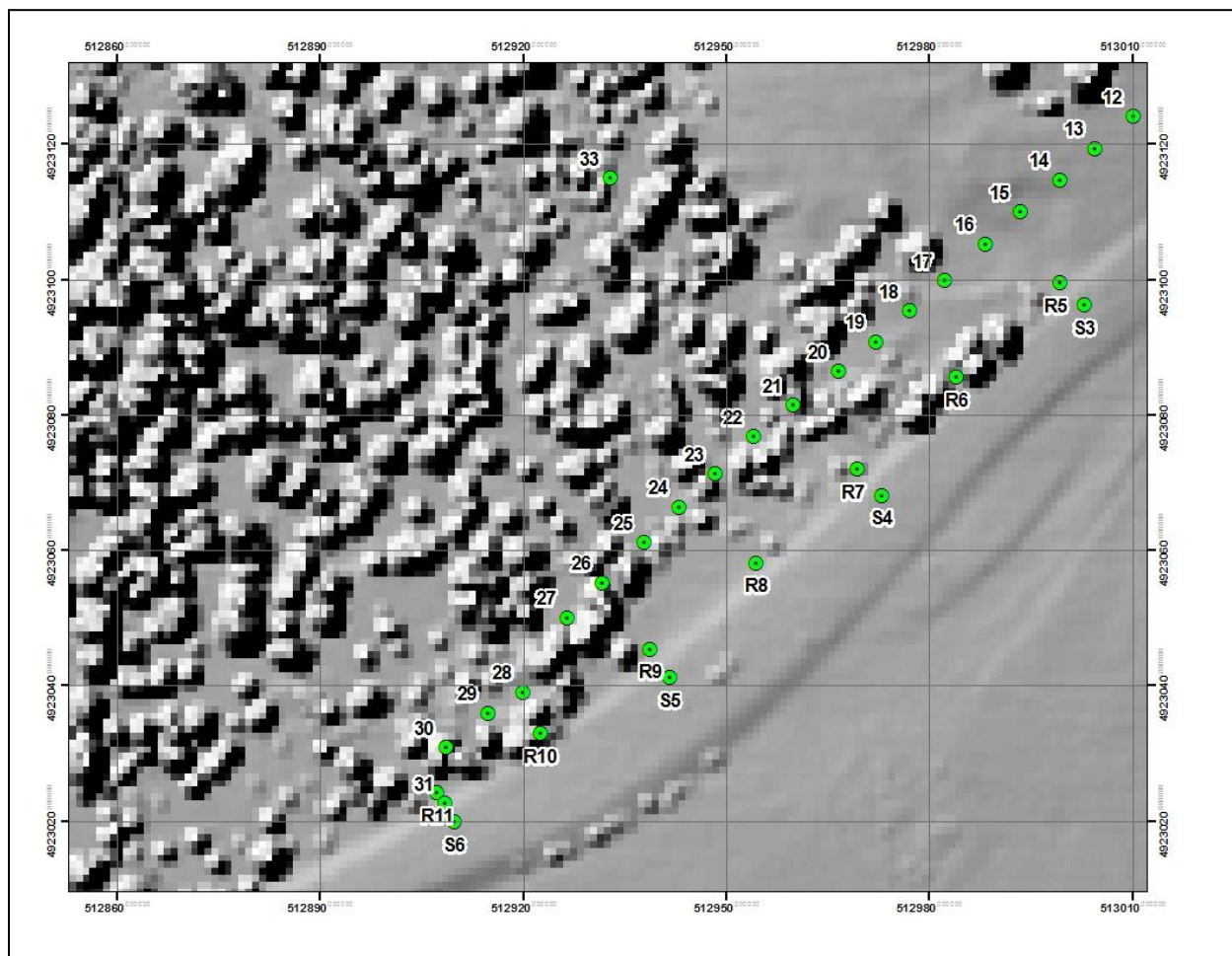


Figure 4. A LiDAR base map showing locations (16-31) assessed for subsurface temperatures, hydrothermal gases, and stratigraphy along proposed routes of the Old Faithful sewer line on 15 May 2014. Locations R5 – R11 and S3 – S6 were assessed on 24 July 2014. Hole 33 was the location of the standard hole. The NSF EarthScope project funded the acquisition of this geodetic-grade imagery (publically available at www.opentopography.org) of the Upper Geyser Basin.

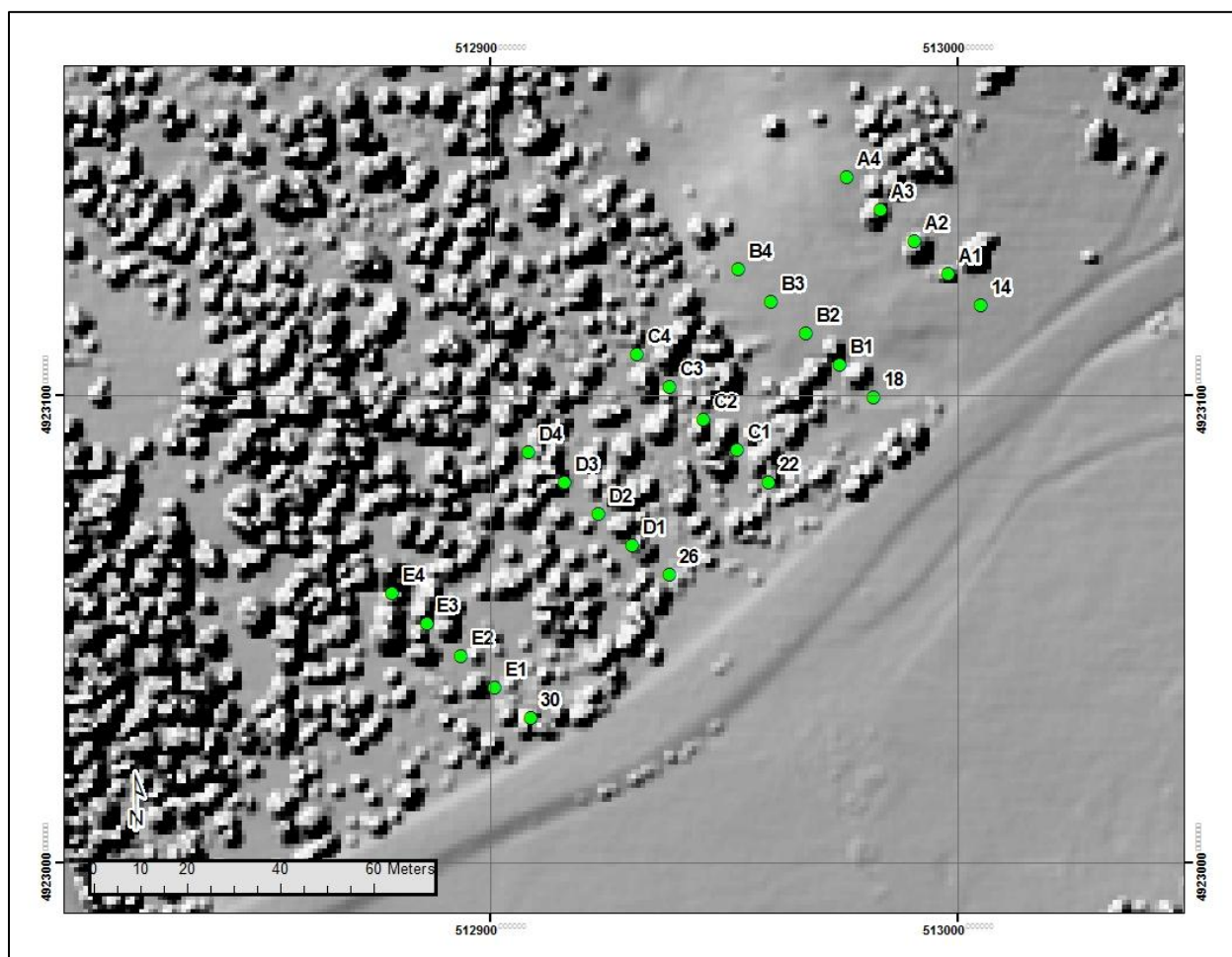


Figure 5. A LiDAR base map showing locations (A1-E4) assessed for subsurface temperatures, hydrothermal gases, and stratigraphy along proposed route of the Old Faithful sewer line on 24 June 2014. Holes 14, 18, 22, 26, and 30 from the 15 May 2014 assessment are shown as reference locations for the sewer line route. North-northwest of the Three Sisters, hole number B2 had the highest subsurface temperature (72.5 °C, 162.5 °F) for the 24 June 2014 assessment. The NSF EarthScope project funded the acquisition of this geodetic-grade imagery (publicly available at www.opentopography.org) of the Upper Geyser Basin.

Hydrothermal Gas Measurements

Hydrothermal gas concentrations within holes provided another means of assessing the *active* hydrothermal system. Gases were measured at 85 cm (33.5 inches) depth using a Dräger X-am 7000 that could detect the following gases: carbon dioxide, sulfur dioxide, hydrogen sulfide, oxygen and methane. On 15 May 2014, 24 June 2014, and 24 July 2014, carbon dioxide was the primary hydrothermal gas detected. Gas measurements could not be made in all holes either due to the presence of water, collapsing of the hole, or inability to deepen the hole to 85 cm (33.5 inches) depth.

Figure 6 presents carbon dioxide gas concentrations measured at 85 cm (33.5 inches) depth on 15 May 2014, 24 June 2014, and 24 July 2014. (see Figures 3 through 5 for locations and Appendix A for 24 July 2014 data values). On 15 May 2014, the maximum carbon dioxide gas concentration was 3.5% in hole 22. On 24 June 2014, the maximum carbon dioxide gas concentration was 2.70% in hole C1. On 24 July 2014, the maximum carbon dioxide gas concentration was 3.80% in hole R5.

Some background information on carbon dioxide (CO₂) gas can place the measured values in perspective. The concentration of CO₂ in fresh outdoor air is approximately 330 ppm (0.033%). Indoors, CO₂ can become slightly elevated where there is insufficient ventilation. The American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) currently recommends that indoor CO₂ levels not exceed the outdoor concentration by more than about 600 ppm (Western Area Power Administration, 2008). The Occupational Safety and Health Administration (OSHA) identifies 5000 ppm (0.5%) as the permissible exposure limit of CO₂ contaminant in air, over an 8-hour time-weighted average (OSHA, 2006). OSHA recommends immediate evacuation of an area containing 5% or more CO₂.

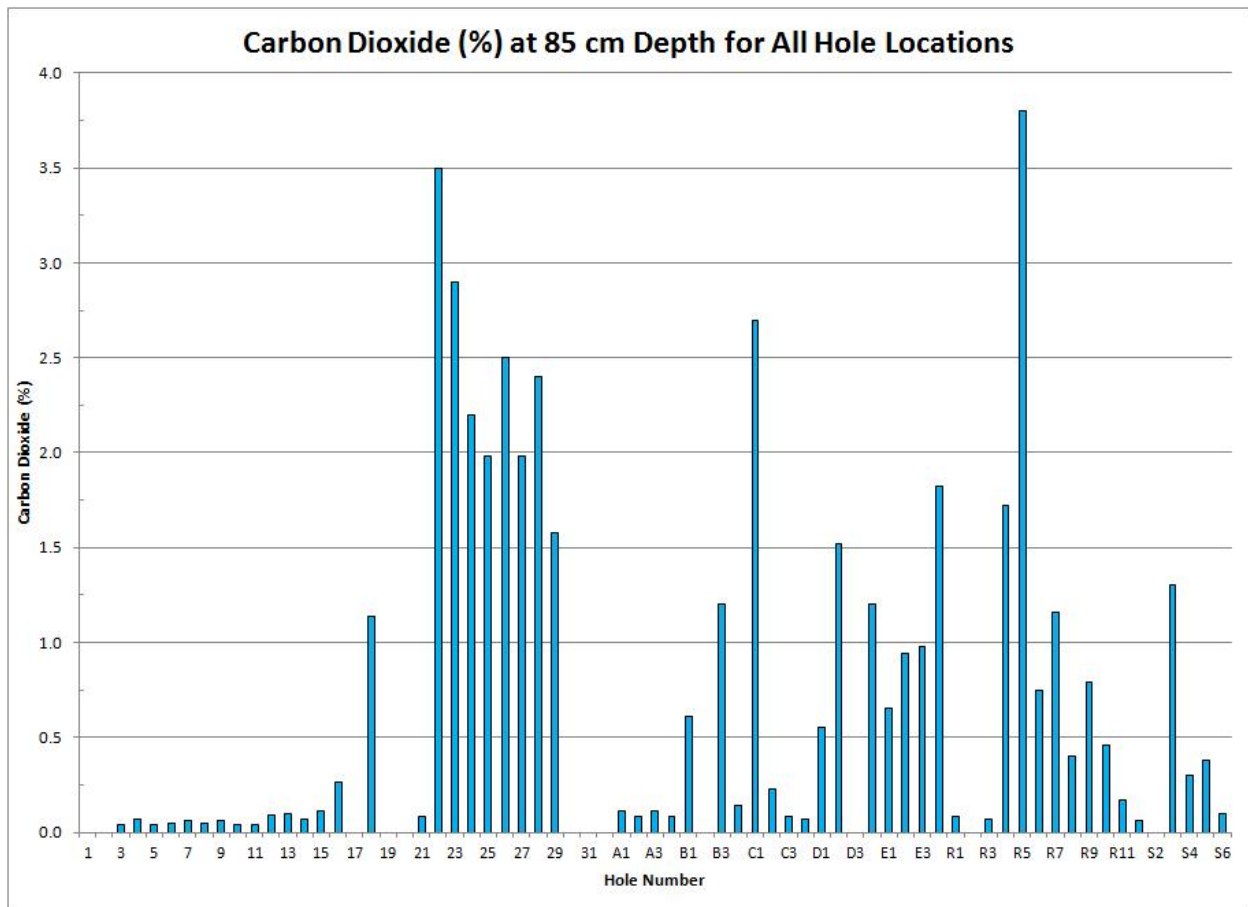


Figure 25. Graph showing CO₂ gas concentration at 85 cm (33.5 inches) depth for all holes. See Figures 3–5 for locations. Gas measurements were not possible in all holes either due to water in the holes, collapsing holes, or holes that could not be drilled to 85 cm (33.57 inches) depth due to hardness of the substrate. Holes 1–32 were drilled 15 May 2014. Holes A1–E4 were drilled 24 June 2014. Holes R1–S6 were drilled 24 July 2014.

DISCUSSION

A comparison of the temperatures drilled on the three dates (15 May 2014, 24 June 2014, 24 July 2014) should be approached cautiously. A significant increase in ground temperature is expected from May to July a result of the high heat flow in the area interacting with increasing air temperatures and significant solar radiation. Thus, the pattern of high ground temperatures for a single day is reliable. Thus, it is important to recognize that comparison of temperature anomalies or their magnitude between May, June, and July contains significant error.

An example of the increasing ground temperature is clearly shown by temperatures at 85 cm (33.5 inches) depth in hole 33 (location shown on Figure 3). Hole 33 was drilled near the same location the morning of all three investigations. A temperature logger was deployed with sensors at 3 depths (0 cm, 50 cm, and 85 cm; 0 inches, 19.7 inches, and 33.5 inches) and a sensor for recording air temperature. Data from the temperature logger were used to estimate the effect of solar heating on the temperatures at 85 cm (33.5 inches) depth through the day. The relatively constant

temperature at 85 cm (33.5 inches) depth indicated that the temperature value of the drill hole was not affected by daily solar heating. However, the average temperature in hole 33 did change from May to July. At 85 cm (33.5 inches) depth on 14 May 2014 the temperature was approximately 13 °C (55.4 °F), on 24 June 2014 the temperature was 19.5 °C (67.1 °F), and 24 °C (75.2 °F) on 24 July 2014. This increase in ground temperature at 85 cm depth (33.5 inches) is a result of the area's high heat flow interacting with increasing air temperatures and significant solar radiation.

SUMMARY

Sixty nine ½ inch holes were drilled to assess temperatures and CO₂ gas concentrations. For data collected on 24 July 2014, Appendix A shows the values and corrected locations. To examine data collected on 14 May 2014 and 24 June 2014, please refer to the previous hydrothermal assessments (Heasler et al., 2014).

The proposed Old Faithful Inn sewer line replacement occurs within an *active* hydrothermal system. Evidence supporting this statement includes elevated subsurface temperatures, high concentrations of CO₂ gas, hydrothermally altered ground, and hydrothermal deposits. The proximity of the proposed sewer line reroute to the Three Sisters hot springs and the Myriad Group increases the likelihood of adverse impacts to individual hydrothermal features and the hydrothermal system. At this time, potential anthropogenic impacts to the hydrothermal resource and individual features cannot be determined with certainty.

REFERENCES CITED

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Appendix A

Locations and Hydrothermal Assessment Data for 24 July 2014

Data for Temperature, gas survey, 24 July 2014, Old Faithful Sewer Line Project

Datum WGS84, Blank cells = No Data Collected

Northing	Easting	Name	Depth (cm)	Temp (oC)	CO2 (%)	O2 (%)	Time (MDT)
4923143	513066.8	R1	85	27.1	0.08	20.9	13:50
4923135	513048.5	R2	85	30.5			14:02
4923124	513030.8	R3	85	28.9	0.07	20.9	
4923113	513014	R4	85	47.5	1.72	20.4	14:10
4923100	512999.4	R5	85	47.5	3.80	19.1	
4923086	512984.2	R6	85	34.5	0.75	20.6	14:35
4923072	512969.5	R7	85	42.9	1.16		14:45
4923058	512954.5	R8	85	44.6	0.40	20.9	14:48
4923045	512938.8	R9	85	37.4	0.79	20.6	
4923033	512922.7	R10	85	28.1	0.46	20.5	
4923024	512907.4	R11	85	28.2	0.17	20.9	
4923138	513068.7	S1	85	30.1	0.06	20.9	13:55
4923120	513033.4	S2	85				
4923096	513003.1	S3	85	59.9	1.30	20.1	14:30
4923068	512973.1	S4	85	41.7	0.30	20.9	14:45
4923041	512941.9	S5	85	41.8	0.38	20.9	
4923020	512910	S6	85	28.2	0.10	20.9	