

Anthropogenic Impacts to the Hydrothermal System within the Old Faithful Area, Yellowstone National Park



Figure 1. Helicopter-oblique view of the Upper Geyser Basin taken on 20 August 2009. The total number of geysers in the world is approximately 940, with Yellowstone having over $\frac{1}{2}$ of the world's active geysers (Barrick, 2010). The Upper Geyser Basin contains about 180 geysers of Yellowstone's total of 500 geysers. View is to the southeast.

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INTRODUCTION

The purpose of this brief report is to provide examples of anthropogenic impacts to the hydrothermal system within the Old Faithful area, Yellowstone National Park. The examples consist of thermal infrared images acquired from a variety of platforms over multiple years. References provide examples of ground-based documentation of anthropogenic impacts on the hydrothermal system.

The impacts described in this report are not meant to be a complete nor exhaustive list of impacts. Instead, the impacts represent the variety of anthropogenic impacts to the hydrothermal system in the Old Faithful area.

DEFINITIONS

The discussion of anthropogenic impacts to the hydrothermal system requires a clear definition of terms.

A hydrothermal system is a spatially continuous area that usually includes one or more hydrothermal features. The surficial boundary of a hydrothermal area marks the maximum spatial extent of hydrothermally altered ground, thermal deposits, geothermal gas emissions, or heated ground.

Thus, a hydrothermal area is much more than individual thermal features such as hot springs, geysers, steam vents, and mudpots.

An **active** hydrothermal system is a subset of a hydrothermal system. The term **active** refers to the presence of hydrothermal features, high ground temperatures, significant heat flow, or measureable concentrations of geothermal gases (primarily carbon dioxide or hydrogen sulfide).

For this report, an **adverse** impact to the hydrothermal system is considered a non-natural change to the hydrothermal system. Adverse impacts include (1) change in the movement of air and/or water through heated rock or sediments, (2) change to the cold water recharge, (3) change in the proximity of hot and warm water to the heat source, or (4) change in the hydrostatic pressure of the system.

Long-term change in the hydrothermal system is considered an **adverse** impact lasting beyond the mechanism causing the impact. For example, the hydrothermal system at the Old Faithful interchange was adversely impacted during construction of the interchange in the late 1960's. The adverse impact continues today and thus is a long-term, adverse impact.

For this report, a **major**, adverse impact is an impact that is *measureable*. Examples of measureable impacts include (1) change in the eruptive interval of a geyser, (2) change in the temperature of hydrothermal features, (3) change in the heat flow, or (4) changes in either the temperature or heat flow patterns of a hydrothermal system.

EXAMPLES OF MAJOR, LONG-TERM ADVERSE IMPACTS

Figure 2 shows specific localities at Old Faithful area discussed in this report where the hydrothermal system has experienced major, long-term, adverse impacts. Each area (A through F) will be discussed separately.

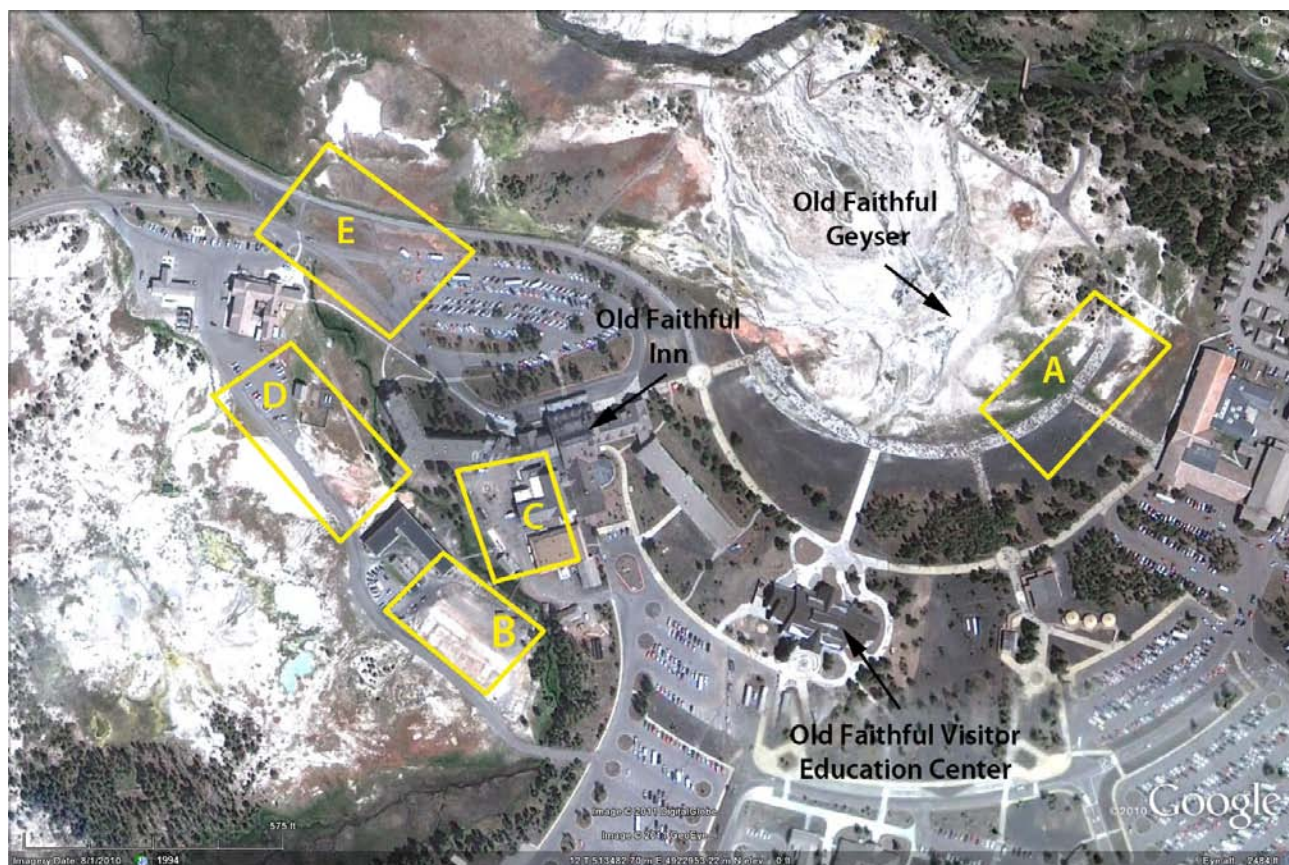


Figure 2. A Google Earth map showing location of the adversely impacted areas discussed in this report (areas A through E). Area F is the Old Faithful overpass located to the west (left) of this image.

Example A. Abandoned sewer line, southeast of Old Faithful Geyser

On 10 & 11 May 2004, Carolyn Loren and Beth Taylor (Division of Interpretation, Old Faithful) notified Hank Heasler about an area of steaming ground located between Old Faithful Geyser and the Old Faithful Lodge (Heasler and Jaworowski, 2004). A temperature of 200.7 °F (93.7 °C) was measured at a depth of 2 inches (5 cm) in the area of concern. Jim Knolke, Old Faithful Maintenance Chief in 2004, indicated that the hot area was near a manhole that had been removed for an abandoned sewer line. According to Mr. Knoelke, the sewer line had been abandoned, but not removed, because the ground was too hot for a useable sewer line.

Notice the area of the abandoned sewer line (Area A on Figure 2) in both visible (Figure 3) and daytime thermal infrared (Figure 4). The concentration of heat and temperature by the sewer line is easily visible in the *daytime* thermal infrared image taken on 2 October 2011.



Figure 3. Visible, helicopter-oblique photograph taken 2 October 2011. View to the northwest.

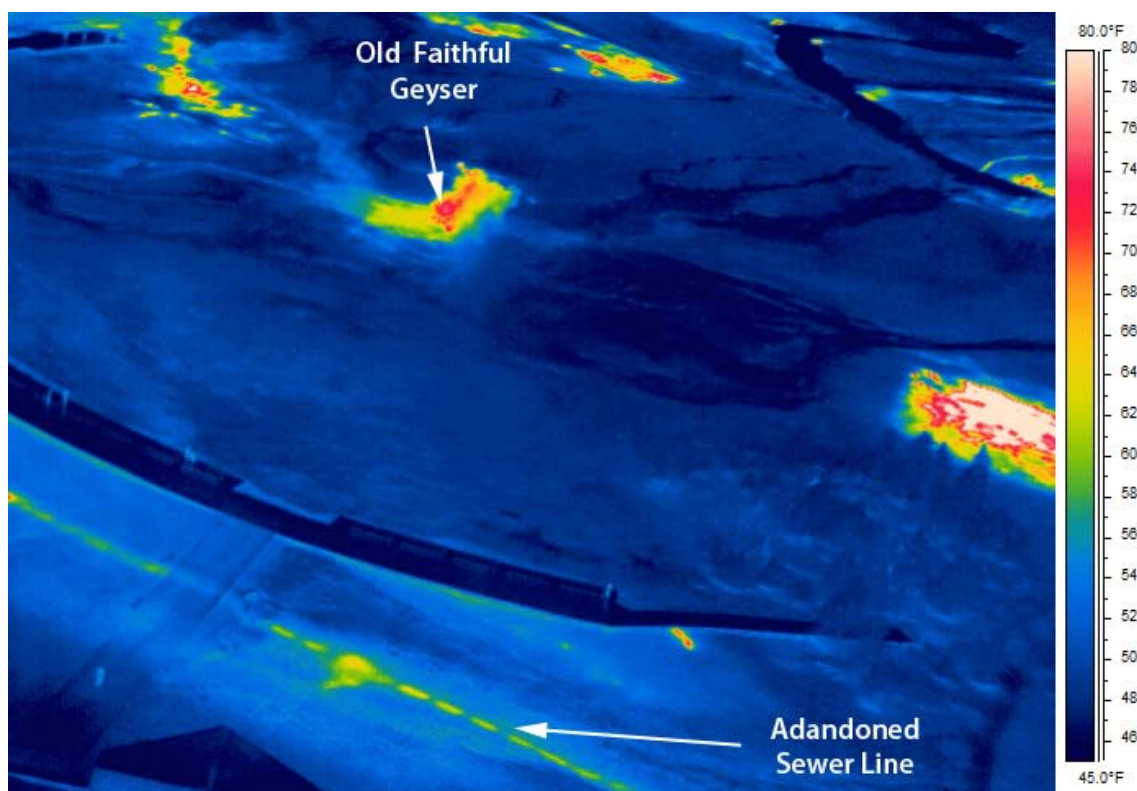


Figure 4. Daytime, thermal infrared image taken 2 October 2011. View to the northwest.

Example B. Old Faithful Historic Pub Site and Infrastructure.

Two reports detail the *active hydrothermal system* that was found at the historic Old Faithful pub (Heasler et al, 2009a, Heasler et al, 2009b). The active hydrothermal system included the following (1) geothermal gases (>100 ppm hydrogen sulfide and 24.9% carbon dioxide), (2) boiling temperatures at two locations at depths of 30 and 38 inches (76 and 96 cm), and (3) construction equipment, a fork lift, that twice broke the ground surface into the active thermal system on 12 August 2009 between 3 to 3:30 pm MDT.

Because of the **active** hydrothermal system at the historic Old Faithful pub site, Yellowstone National Park Superintendent Suzanne Lewis terminated the pub construction project.

Both visible (Figure 5) and thermal infrared (Figure 6) show the area of the historic Old Faithful pub (Refer to Area B on Figure 2). Anomalous high temperatures associated with the historic pub infrastructure are visible in the 2 October 2011 daytime thermal infrared image (Figure 6). Figure 6 also indicates a narrow, linear pattern of high temperatures extending from near the historic pub site towards the Old Faithful Inn. These anomalous temperatures were documented in the 2009 YCR reports. This linear pattern is most likely associated with unknown infrastructure.



Figure 5. Visible, helicopter-oblique photograph taken 2 October 2011. View to the southeast.

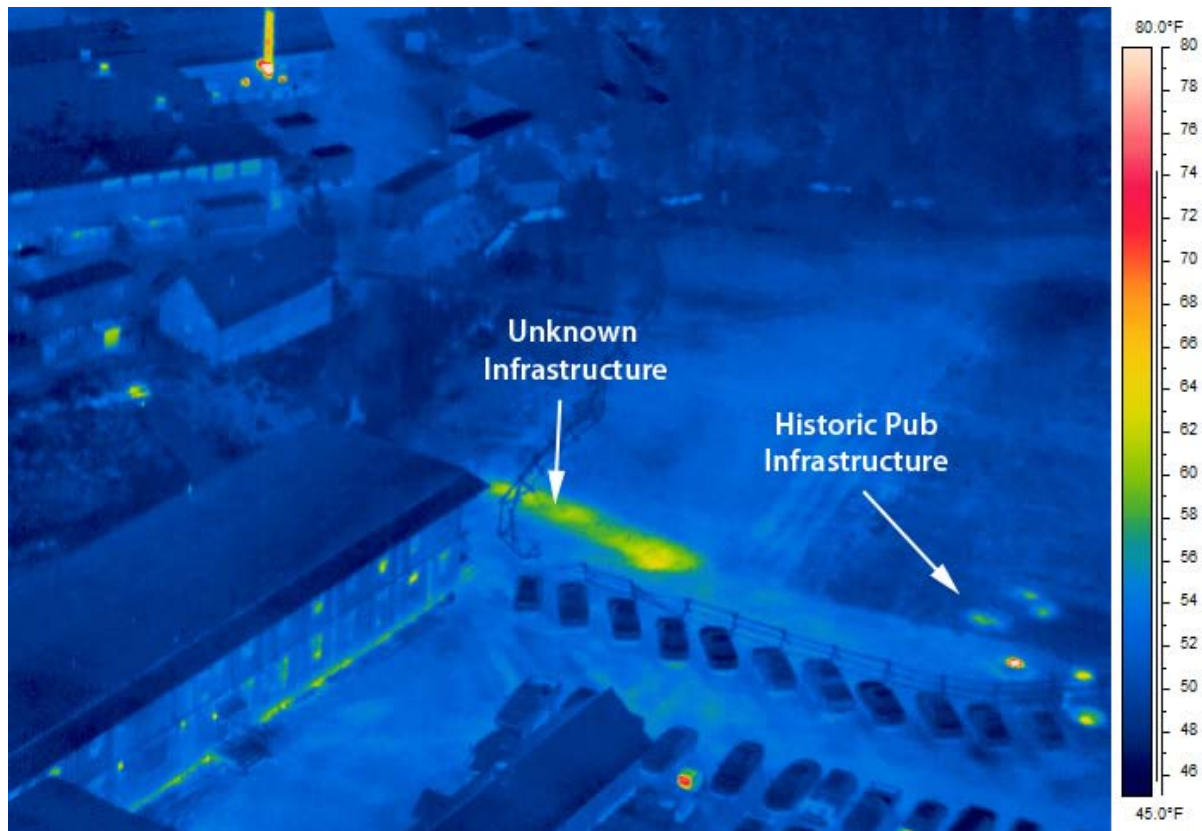


Figure 6. Daytime, thermal infrared image taken 2 October 2011. View to the southeast.

Example C. Old Faithful Inn Kitchen Renovation Project Area.

In 2010, a concrete pad was placed for refrigeration units to cool both the Old Faithful kitchen and the food storage area to the south of the kitchen (Refer to Area C on Figure 2 as well as Figures 7 & 8). Trenches for refrigeration pipes were dug and backfilled in spring 2010. The five-foot deep trenches were dug into red-to-white, hydrothermally altered clay that commonly forms a seal to the hydrothermal system in the Old Faithful area (Heasler and Jaworowski, 2010).

Figure 8 shows the higher temperatures associated with one of the refrigeration pipe excavations. Another relatively high temperature linear trend can be seen extending from the back of the Old Faithful Inn. This trend is labeled as unknown infrastructure in Figure 8.



Figure 7. Visible, helicopter-oblique photograph taken 2 October 2011. View to the east.

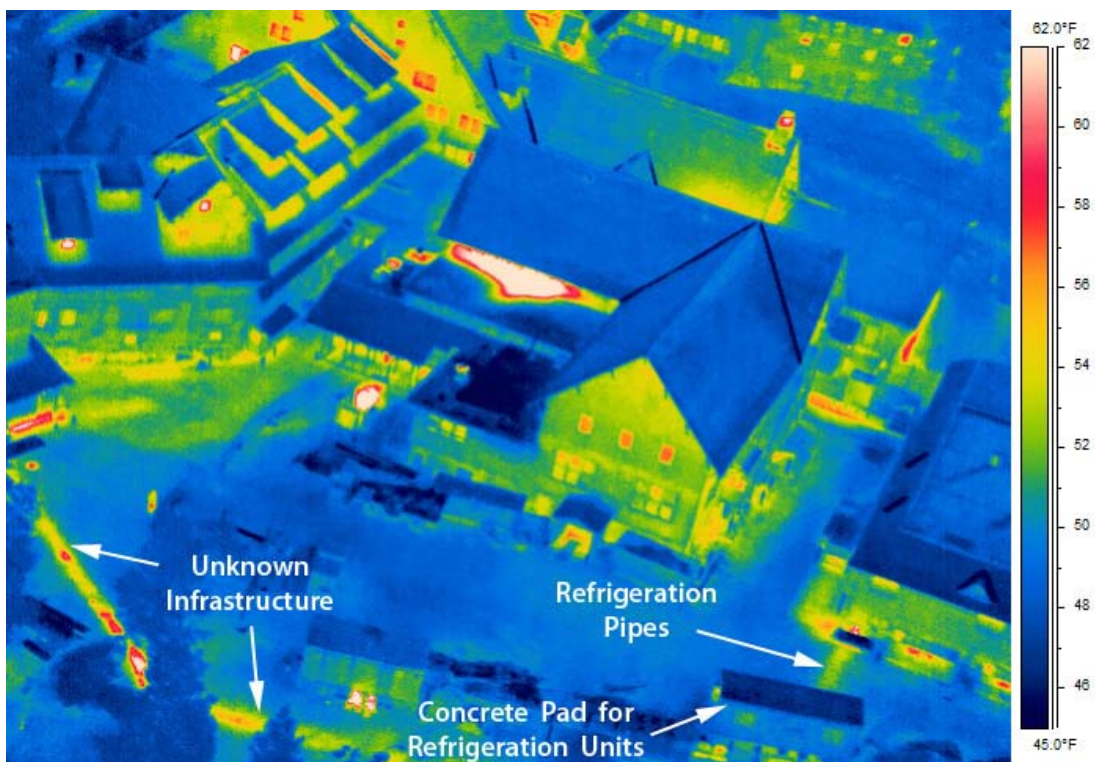


Figure 8. Daytime, thermal infrared image taken 2 October 2011. View to the east.

Example D. . The Service Road Behind the Old Faithful Inn

This service road connects the lower Yellowstone General Store and the lower gas station with the west parking lot (Refer to Area D on Figure 2). Figures 9 and 10 show the service road behind the Old Faithful Inn and its location with respect to the *active hydrothermal system of the Myriad Group*. The asphalt of the road traps vapor-transported heat and also greatly decreases the infiltration of surface water.

Previous construction of a water line along this service road also provides evidence of this **active** hydrothermal system. The construction of this water line resulted in the demise of Round Geyser either immediately or soon after construction around 1980 (Personal Communication, Jennifer Whipple, 2009). A fire hydrant associated with this water line ejected steam when opened. The thermal effects of trenching for the water line can be seen in Figure 10.

A hot area to the northwest of Laurel Dorm also is evident on Figure 10. The origin of this hot area, anthropogenic or natural, has not been investigated.



Figure 9. Visible, helicopter-oblique photograph taken 2 October 2011. In the center of the photograph, the red-orange clay left of the road and the pale-white ground to the right of the road outline the surficial extent of the Myriad Group. Compare this visible image with a corresponding thermal infrared image in Figure 10. View to the southeast.

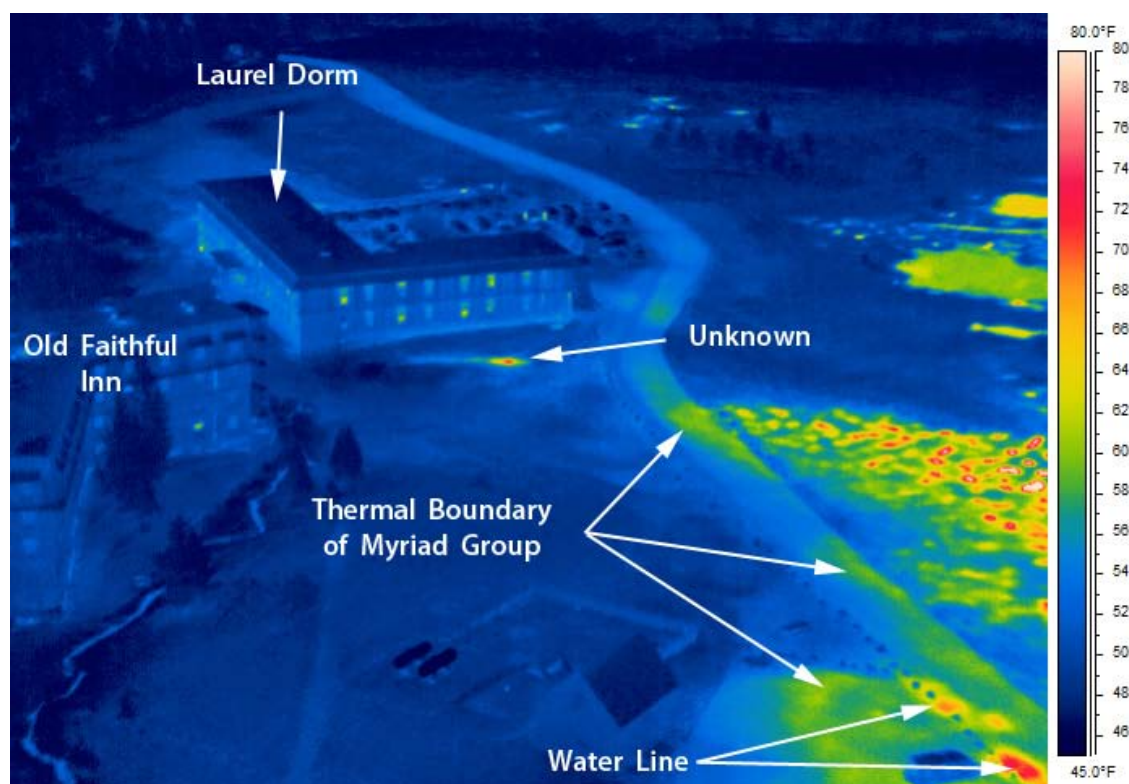


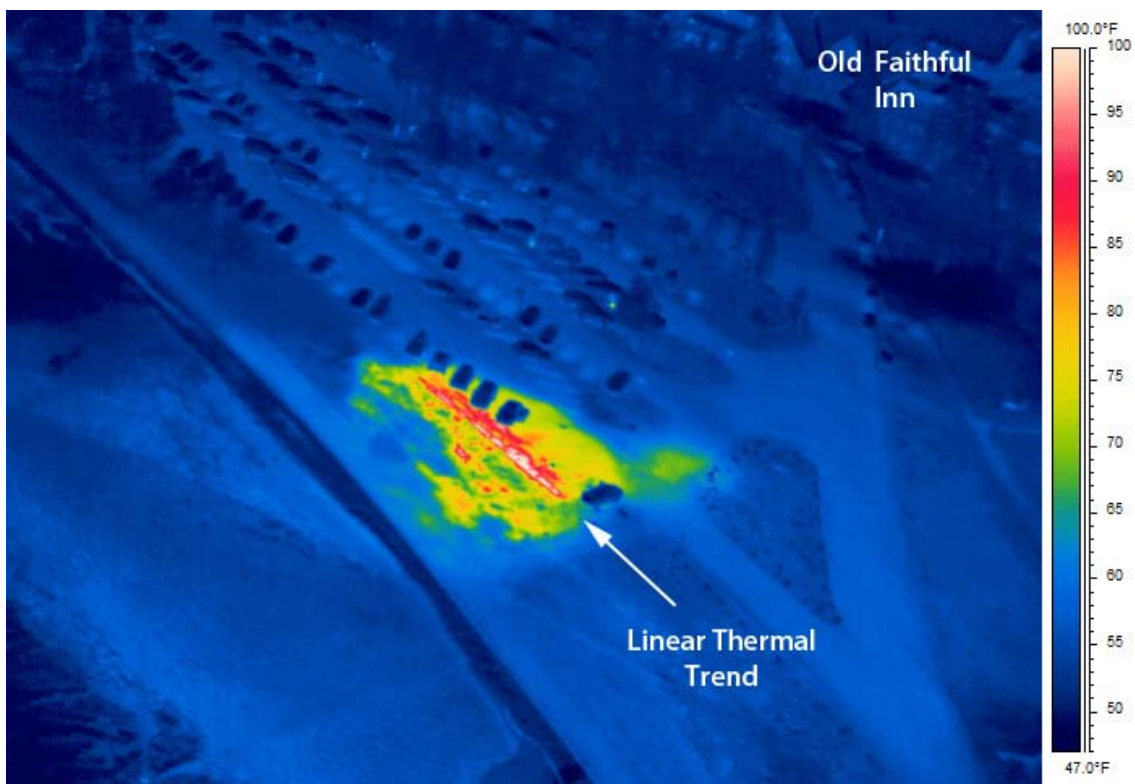
Figure 10. Daytime, thermal infrared image taken 2 October 2011. View to the southeast. The hot-to-warm portions of the hydrothermal system appear as bright colors (red, orange, yellow, and green). Notice that the cooler portion of the active hydrothermal system extends towards Laurel Dorm as a lobe of hydrothermal activity. Compare with visible image in Figure 9.

Example E. . The Front Parking Lot of the Old Faithful Inn

It is not surprising that this snow-free area (Refer to Area E on Figure 2) during the winter emits approximately 300 to 450 kilowatts. Both the visible (Figure 11) and daytime thermal infrared (Figure 12) images show an **active** hydrothermal system near the Old Faithful Inn. In the visible image (Figure 11), golden vegetation on the meadow outlines a hydrothermal area. In the corresponding daytime, thermal infrared image a similar extent of the **active** hydrothermal area can be mapped. The daytime, thermal infrared image shows the high-temperature portion (white, red, yellow and green colors) of a hydrothermal system interacting with anthropogenic activity near the Old Faithful Inn. The hot and colorful thermal area (Figure 12) is of unknown origin. However, the narrow, linear pattern of high temperatures aligned with the edge of a parking area suggests a possible anthropogenic origin.



Figure 11. Visible, helicopter-oblique photograph taken 2 October 2011. View to the southeast.



12. Daytime, thermal infrared image taken 2 October 2011. View to the southeast.

Example F. . The Old Faithful Overpass

The impact to the shallow, hydrothermal resource in this area is apparent from 1) the need to wood-chip the pavement in the winter for over-the-snow vehicles (due to no snow on the concrete pavement) and 2) the piping and drainage system in-place to move thermal waters away from the overpass. Figures 13 and 14 show the area of the Old Faithful overpass and the **major, long-term, adverse impacts** to this shallow hydrothermal system.

The impact to the hydrothermal system is described in a 27 January 2011 email from Robert Fournier, US Geological Survey, retired.

At the time that the overpass was initially proposed, the entire USGS geothermal crew working in the Park strongly objected. I believe that Don White was the main USGS person in contact with the Park Service in this regard. I do not have any documentation of any correspondence that he might have had with the Park Service. I had previously done a survey of all the hot water discharges in the area as part of my general study of the Upper Geyser Basin hydrothermal system. The type of flora in the area, and a large flow of warm to boiling water from nearby springs at slightly lower elevations strongly suggested that the area where the overpass was to be constructed was underlain at a shallow depth by very hot water.

When the main footing for the overpass was dug, the hole rapidly filled with hot water (172 deg F), and pumps could not draw the water level down sufficiently for construction to proceed. Being practical engineers, they dug a trench to drain the water away. Then concern was voiced that the resulting large flow of hot water from the newly created spring (subsequently called Interchange Spring) might have an adverse effect on Old Faithful geyser. I was then called in by the Park Service to assess the situation because I was known to the Park Service after the Beryl Spring episode. I sampled and got chemical analyses of the new spring water, and made a detailed sketch map of the area. I found that flows of hot water from nearby hot springs had either stopped or slowed down significantly. In general, no attention had previously been paid to these springs because they are not spectacular, and nobody had realized that their water had been diverted to flow from the new drainage ditch. However, I determined that the new flow from “Interchange Spring” was greater than the previous combined flow from the other springs.

Figure 14 clearly shows the impact of the overpass to the hydrothermal system by the high temperatures in the concrete roadway under the overpass and the concentrated thermal discharges engineered to drain thermal waters away from the overpass.

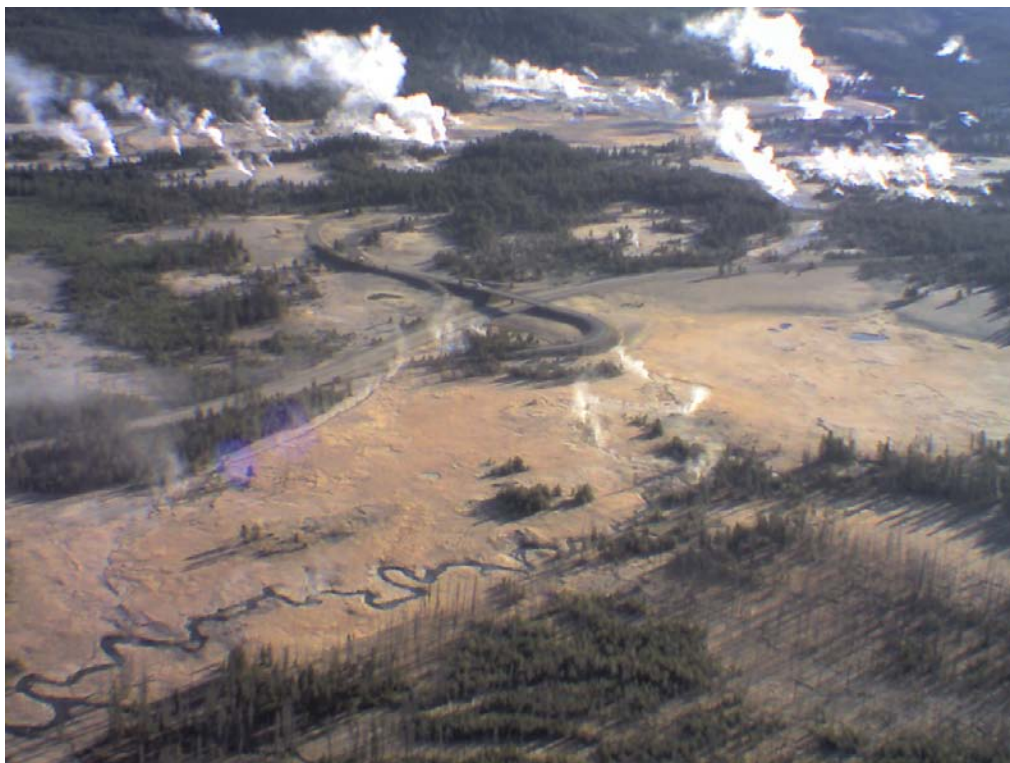
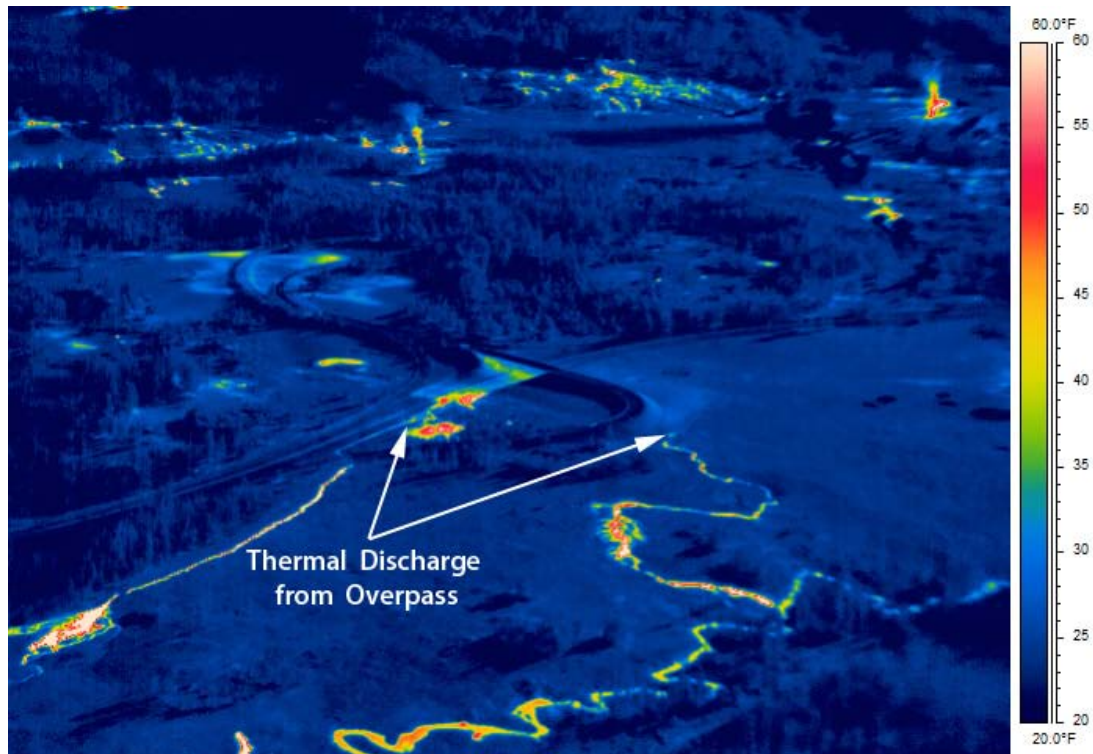


Figure 13. Visible, helicopter-oblique photograph taken 12 October 2010. View to the northeast.



14. Daytime, thermal infrared image taken 12 October 2010. View to the northeast.

CONCLUSION

Natural patterns and anthropogenic distributions of temperatures occur in the Old Faithful area (Figure 15). The night-time, thermal infrared image acquired in September of 2010 shows undisturbed patterns of temperature and heat flow of the Geyser Hill Group. West of the Firehole River only a small portion of the hydrothermal area, i.e. the western portion (left in figure 15) of the Myriad Group shows a natural pattern. The almost random, point-source pattern of temperature is clearly evident on Geyser Hill but hard to see in the Old Faithful developed area.

This report documents several areas of impact to the hydrothermal system within the Old Faithful area. Areas A through F show **major, long-term, adverse**, anthropogenic impacts to the hydrothermal system in the Old Faithful area. In these areas, linear, confined segments of increased temperature reflect the hydrothermal system's response to excavations and interaction with abandoned, buried infrastructure. Other areas of potential anthropogenic impact have yet to be identified and documented.

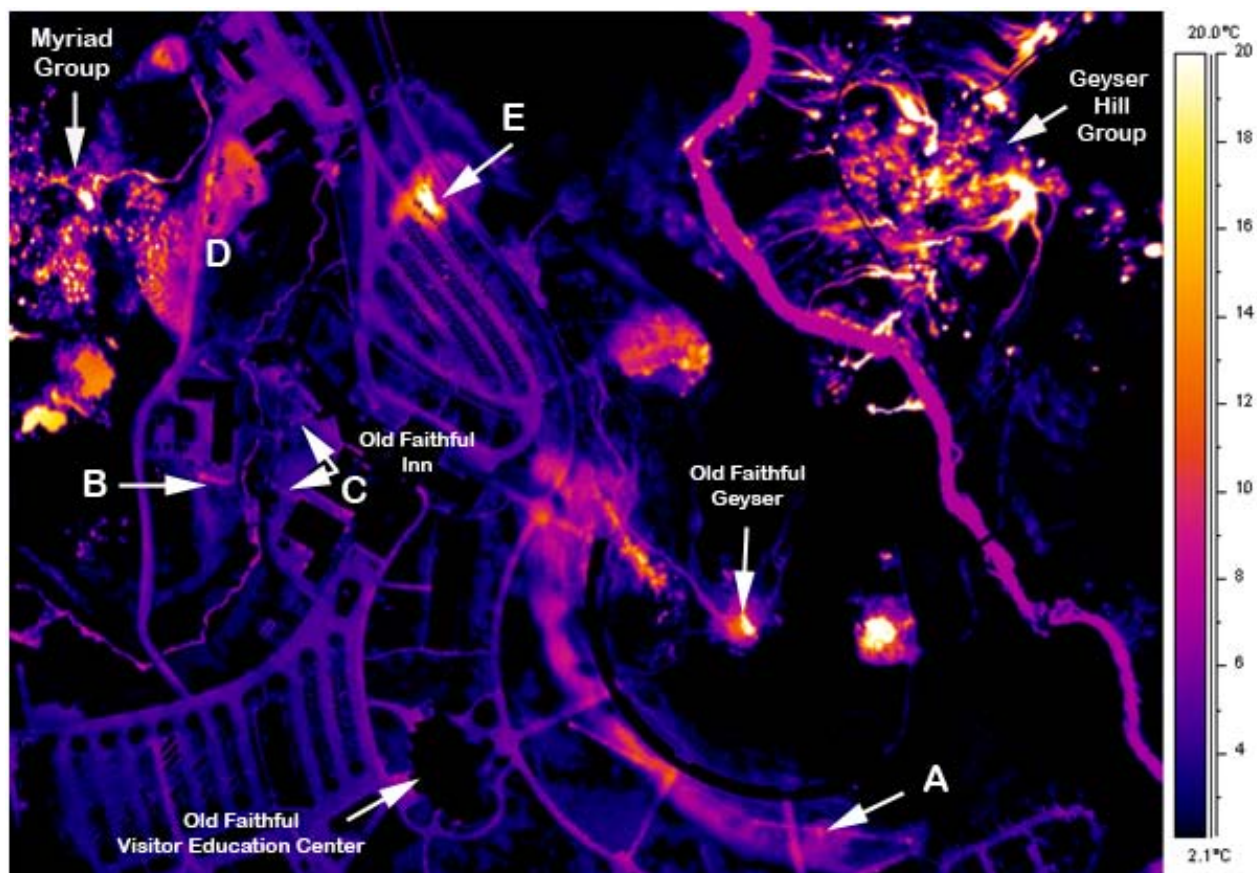


Figure 15. Night-time, airborne thermal infrared imagery (September 2010) of the Old Faithful area. The area shown in this figure is slightly larger than the area shown in Figure 2. The letters A through E refer to Figure 2 and the areas discussed in the text. This thermal infrared image has not been georectified or corrected for atmosphere and emissivity of various earth materials.

REFERENCES

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