GPS Mapping and Water Source Analysis: Establishing a Baseline for Reforestation

Samantha Behrent, Adaire Chatry, and Noah Jouett
BIO 3416 Field Ecology Course Mayterm 2008

INTRODUCTION

Costa Rica has been a leader in environmental protection since the 1980s, giving it the reputation of the "green republic". As a result, there is a high a level of public awareness in contemporary Costa Rica of the nation's environmental concerns and plans for improvement, as described in Blum (2007). A current trend in environmental protection is reforestation, which brings back historically degraded and depleted forest. The Costa Rican government offers prime incentives for investors in reforestation projects. However, reforestation requires time and careful planning to be successful. As emphasized by Kalascka, *et al* (2008) conducting a baseline assessment creates a standard against which future changes and improvements in the project can be measured. Mapping is essential to the baseline data collection effort, as it enables documentation of the current state of the habitat and the progress made through the reforestation program.

The advent of the Internet as a medium for ecological cartography paves the way for a new generation of maps that enhance user accessibility via clickable icons and panoramic photos (Peterson 2003, Cammack 2003, Taylor 2003). Indeed, this elevation in user accessibility is paramount to ecological cartography inasmuch as it engages the user to see what is being mapped and thus allows the user to virtually connect with the mapped area (Taylor 2003). The goal of this study was to create a GPS map of a young reforestation project in a tropical wet forest near Arenal Volcano in Costa Rica. The map will serve as a tool for future planning and as a means of combining GPS data with data from bird, plant and water surveys from the same property. The second objective of the study is not only to locate, but also to collect stream flow data and investigate the possibility of one of the springs being a hot spring warmed by volcanic activity. It is expected that the reforestation will enhance the water availability at the site, and may result in an increase both in the number and water volume of springs and creeks.

MATERIALS AND METHODS

This study was conducted at Leaves and Lizards Volcano Cabin Retreat in northwestern Costa Rica near Monterrey and slightly northeast of Arenal Volcano. The property is in a region of tropical wet forest, and the forest reforestation project began in 2007. Seventy-four species of birds and a few mammals had been reported on the property before this study. Our work was conducted between 26 May and 31 May 2008. These dates fell during Costa Rica's rainy season, which was an important consideration in designing the methods used to collect water data for springs on the site.

Mapping the boundaries, paths, plant areas and bird points required the use of a compass and the Trimble GeoXM handheld. This field computer is a handheld pc with GPS capabilities that allowed us to record positions on the property with as little as one meter error once the correction data was received from San Jose. First, a base point was established that helped us align the preexisting property boundaries on a grid. Then a line feature was used to map the bird path and the roads around and throughout the property. The line feature recorded one point every second. The hiking trail up to Arenal Volcano was also mapped using this method.

Fourteen points labeled A-N approximately 100m apart on the bird trails were established by the group inventorying birds and mapped using the point feature on the Trimble. For each point, between 15-20 satellite positions were recorded and averaged to get the final location. A series of attributes was also recorded at each of these points. These were recorded using a data dictionary on the Trimble, and included forest type, forest status, major vegetation, soil type, soil moisture, proximity to water and proximity to buildings. At each of the bird points, 360-degree panoramic pictures were taken. Using a tripod to steady and rotate the camera, 18 frames 20 degrees apart were taken at each location and stitched together on the computer. Most of the pictures were taken in the early to late morning with the remaining few taken in the afternoon. All of the pictures were taken on two clear days.

The locations of four springs on the property were plotted as points on the map using the Trimble. Because the GPS does not get good satellite reception under dense canopy cover, these points were estimated by taking a point at a distance from the spring and inputting a compass direction and the approximate distance in meters. The streams were placed on the map using information from a previous map because we were unable to walk the lengths of the streams due to dense vegetation and steep valleys.

The four water sources were located and named Spring 1, 2, 3 and 4. The streams that flow from these springs were named Stream 1, 2, 3, and 4. Stream 1 was the easiest to access after some of the grass and vegetation was removed by an electric machete. Therefore all of the water flow data was collected from this stream at a place we named "stream sample point". Three trials were conducted on four days during the study. The procedure was a standard simple measurement of stream flow, a variation of which was used by Egoh, *et al* (2008). For each trial, a tape measure was used to determine a length of one meter in the stream. Then, a leaf was dropped into the stream at the start and the time in seconds that it took the leaf to be carried one meter downstream was recorded. The stream depth and width in meters was also recorded each day. To obtain our measurements of volume of the streams, we used the following equation:

$$F=(v)(c)$$

Where F is the flow rate (m^3/s), v is the velocity of the floatable object in m^2/s and c is the cross-sectional area represented by the following formula:

$$c=[(d)(w)]/2$$

Where d is the depth of the stream (m) at its deepest point and w is the width of the stream at its widest point (m).

Prior to the study, the property owners speculated that Spring 2 may be a hot spring. We devised a procedure to test this hypothesis. Using two HOBO thermometers, we were able to monitor the temperatures of two different areas over the same period of time. Three trials were executed: one ~24 hour control trial and two ~48 hour variable trials. For the first trial, one HOBO was tied to a piece of rebar with a zip tie and submerged under the water at the stream sample point in Stream 1. The other HBO was tied to a branch in the air directly above the HOBO in the stream. Both thermometers were programmed to record the temperature every 15 minutes. The trial ran from May 26 to May 27. The second trial ran from ~48 hours from May 27 to May 29. After the data from the first trial were transferred the sensors were deployed with the same 15 minute interval settings—one back into Stream 1 at the sample point and the other into Spring 2, the "hot" spring. The HOBO at Spring 2 was covered by leaves in an attempt to eliminate the effect of solar warming at the location. After 48 hours, the temperature data were collected and processed. The results of this trail were compared to the results from the first (control) trial. The effects of heavy rain and runoff were considered and a third trial was conducted. The reset HOBOs were again deployed, one back into the "hot" spring and the other at Spring 1 (upstream of the sample point). However, instead of submerging them only a few inches deep, they were placed in holes approximately .5 m deep in an effort to eliminate the effects of runoff, rain and sunlight on the spring temperature. The location of the cold HOBO was changed to Spring 1 to minimize the differences in temperature that can arise from being further downstream rather than at the ground source.

RESULTS

Figure 1 displays a map of the property and is an exact copy of the map found online, except here it indicates each stream's name and its location. Temperature data was taken in two streams in a 24 or 48-hour periods, as the rest either posed a safety hazard or, because of time, were not viable to collect data from. Ultimately, we conducted three rounds of tests: (1) comparing air temperature and water temperature for "stream sample point" over a 24 hour period, (2) comparing temperatures over a 48 hour period from "stream sample point" and a supposed hot spring, and (3) comparing temperatures over a 48 hour period at "spring 1" and the supposed hot spring.

As seen in the figure 2, the air and water temperatures intersect in the late morning and the late afternoon. Overall, however, the air temperature is characterized by a bell curve, reaching its maximum around midday, whereas the water temperature remains generally constant throughout the day. As seen figures 3 and 4, the supposed hot spring and cold spring temperatures average, ultimately, to equivalence. One degree of fluctuation is present largely in the hot spring, whereas the cold spring reflects a relatively constant temperature. The temperature average for the hot spring during our tests was around 23.5º Celsius and the average for the cold spring is 24º Celsius.

In the second comparison of the hot and cold spring we were able, through careful planning, avoid the possible confounding variable of external weather factors, especially rain run-off, which affected our previous data. Figures 5 and 6 show temperatures remain very constant, hovering around 24º Celsius.

From the 27th to the 31st of May, stream flow data was collected from "stream sample point." Table 1, fully documents the stream flow rate data, showing a slight increase from the 27th to the 28th, a steeper increase from the 28th to the 30th and a marked decrease from the

30th to the 31st. Days showing an increase in flow rate saw an increase in stream velocity, stream width and stream depth. Conversely, days showing a decrease in flow rate were characterized, mostly, by a decrease in the above factors. The 31st, an exception to this rule, saw an increase in stream velocity but a decrease in stream width and depth, accounting for its lower flow rate from the day before.

CONCLUSIONS

This student-conducted study established and documented a baseline for the reforestation project at the Leaves and lizards property. The data collected on the Trimble was translated into a multilayered map, complete with inventory data about water sources, paths, plant plots, and other features of the land.

The water temperature data collected over three trials was carefully and deliberately analyzed throughout the study. After the control trial, the development of each successive procedure was a result of the analysis of the data from previous trial(s). By using only Spring 1 as a cold spring control in all three trials, we eliminated the temperature variation that may arise between distinct cold springs. From Figure 1 and the control trial we concluded that air temperature does have an effect on the water temperature but that water temperature remains more constant than air temperature throughout the course of a 24-hour period. According to Nichol (1994), the spatial characteristics of the canopy are important in maintaining a constant air temperature in the rainforest. Because the canopy of this young reforestation property is not very dense, the air temperature varies more than it would in a primary rainforest.

In trial 1, we obtained boxcar graphs from our data with the hot spring averaging about 23.5 degrees Celsius and the temperature for the cold spring averaging about 24 degrees Celsius. We were unable to form a conclusion based on this data due to concerns about the difference between the spring and the runoff, so we devised a third trial that involved digging holes and submerging the probes deeper in the water. The HOBO probes were not only submerged in deeper water with less runoff and solar effects, but they also were more submerged under loose mud which insulated the surrounding temperature and further reduced external variables. The graphs produced with this data allow us to confidently conclude that Spring 2 is not a hot spring and would not necessarily produce a worthwhile investment. The hot spring graph from trial 2 reveals a straight line consistently at 24 degrees Celsius throughout the 48 hour trial. Although the spring 1 graph oscillates slightly (~0.3 degrees), there is much less variation than in the trial one graph. This indicates that our method was successful in eliminating external variables using the equipment available.

A possible improvement to the study would be to more precisely locate the origin of each spring and run the tests. This may not be possible, however, because we believe that they originate from several seeps in the soil, not a single source. One aspect of the property that was not examined in the study was the soil. Inventorying the soil could provide insight into many aspects of the water sources as well as plant and animal life on the property. It would also be a good feature to include in a baseline study because soil changes can be monitored and interpreted over time.

LITERATURE CITED

Blum, Nicole. (2007) Environmental education in Costa Rica: building a framework for sustainable development? International Journal of Educational Development 28: 348-358. (Accessed 2008 May 20)

Cammack, Rex G (2003). Cartography, Virtual Reality, and the Internet: Integrating Abstract Models of the Environment Via the Internet. Maps and the Internet 2003: 359-370

Kalacska, M., et al (2008) Baseline assessment for environmental services payments from satellite imagery: A case study from Costa Rica and Mexico. Journal of environmental management. 88: 348-359 (Accessed 2008 May 21)

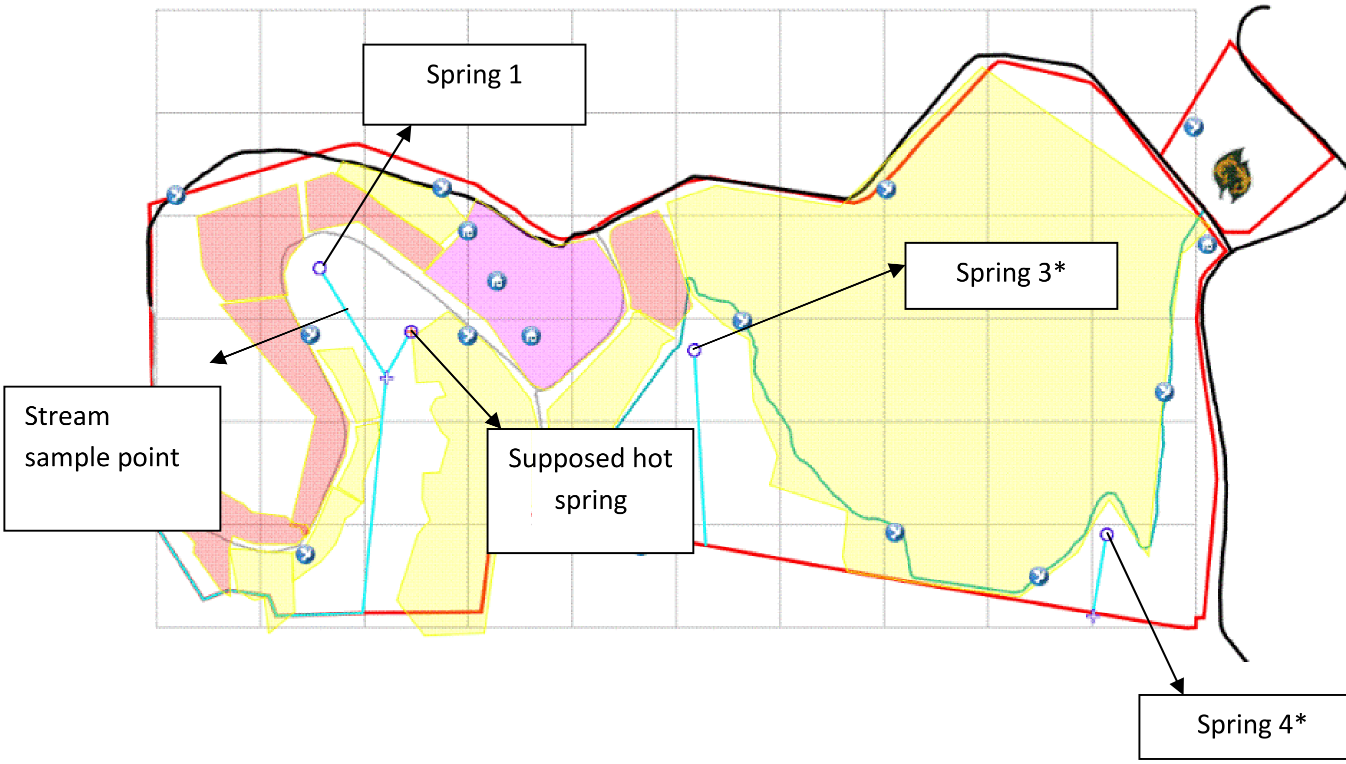
Peterson, Michael P. (2003). Maps and the Internet. Maps and the Internet 2003: 1-14

Taylor, Fraser D.R. (2003). The Concept of Cybercartography. Maps and the Internet 2003: 437-445

Table 1: Summary of stream flow data for “Stream Sample Point”

Trial	27 May	28 May (heavy rain)	30 May (heavy rain)	31 May
1 Velocity	2.75 m/s	4.63 m/s	3.68 m/s	5 m/s
2 Velocity	2.28 m/s	4.50 m/s	3.47 m/s	4 m/s
3 Velocity	2.87 m/s	5.12 m/s	3.15 m/s	4 m/s
Average Velocity	2.63 m/s	4.75 m/s	3.43 m/s	4.33 m/s
Stream depth	0.21 m	0.3 m	0.3 m	0.25 m
Stream width	0.5 m	0.7 m	0.8 m	0.65 m
Cross sectional area	0.0525m^2	0.105m^2	0.12m^2	0.08125m^2
Flow Rate	0.01996 m^3/s	0.02211 m^3/s	0.03498 m^3/s	0.01875 m^3/s

Figure 1. Map of the Leaves and Lizards Arenal Volcano Cabin Retreat property



* No data taken at these points. See section 4.1.1.1 for more information

Figure 2: A graph comparing air and water temperatures over a 24 hour period in stream sample point.

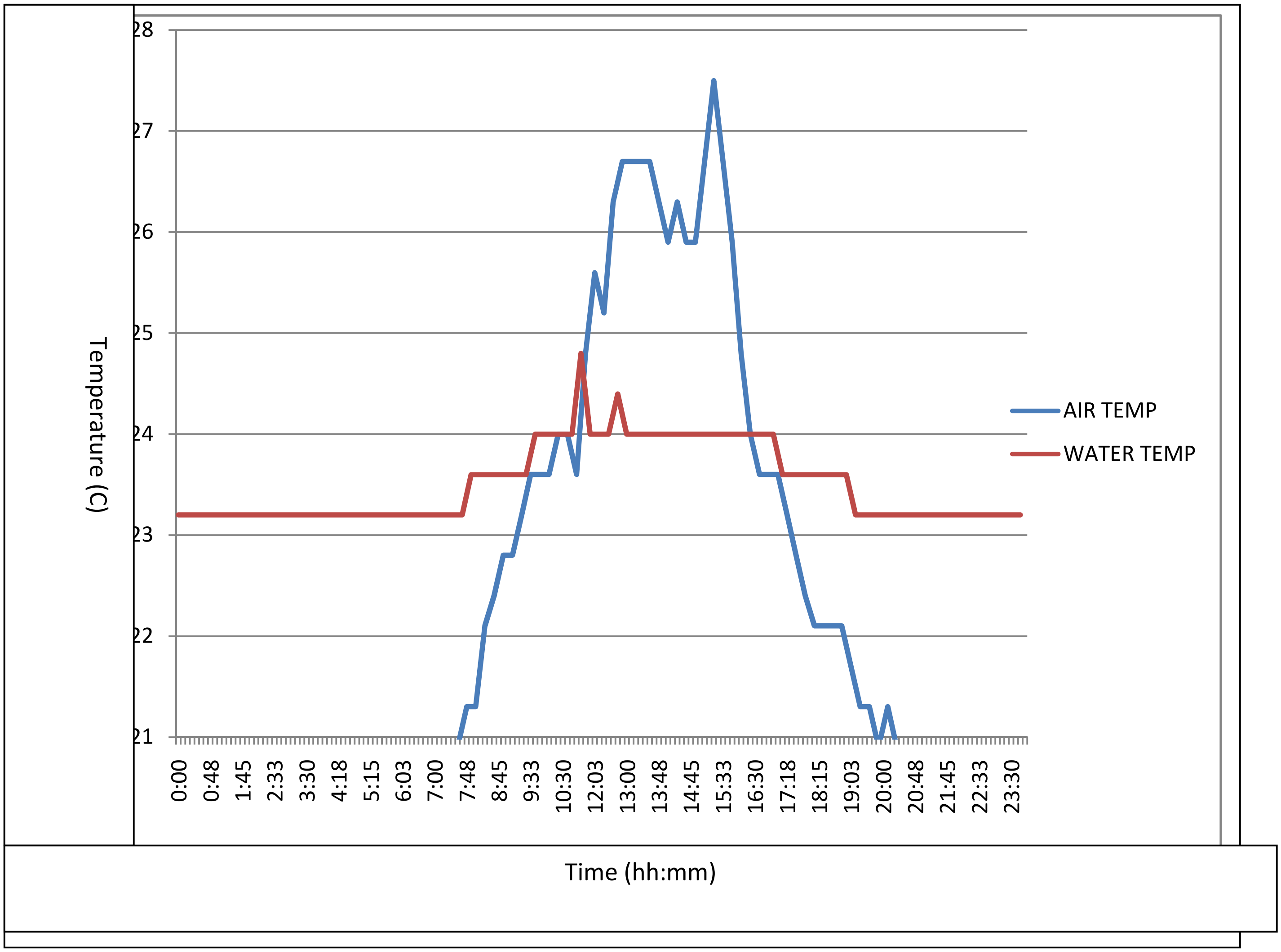


Figure 3: A graph representing the temperature of the supposed hot spring over a 48 hour period.

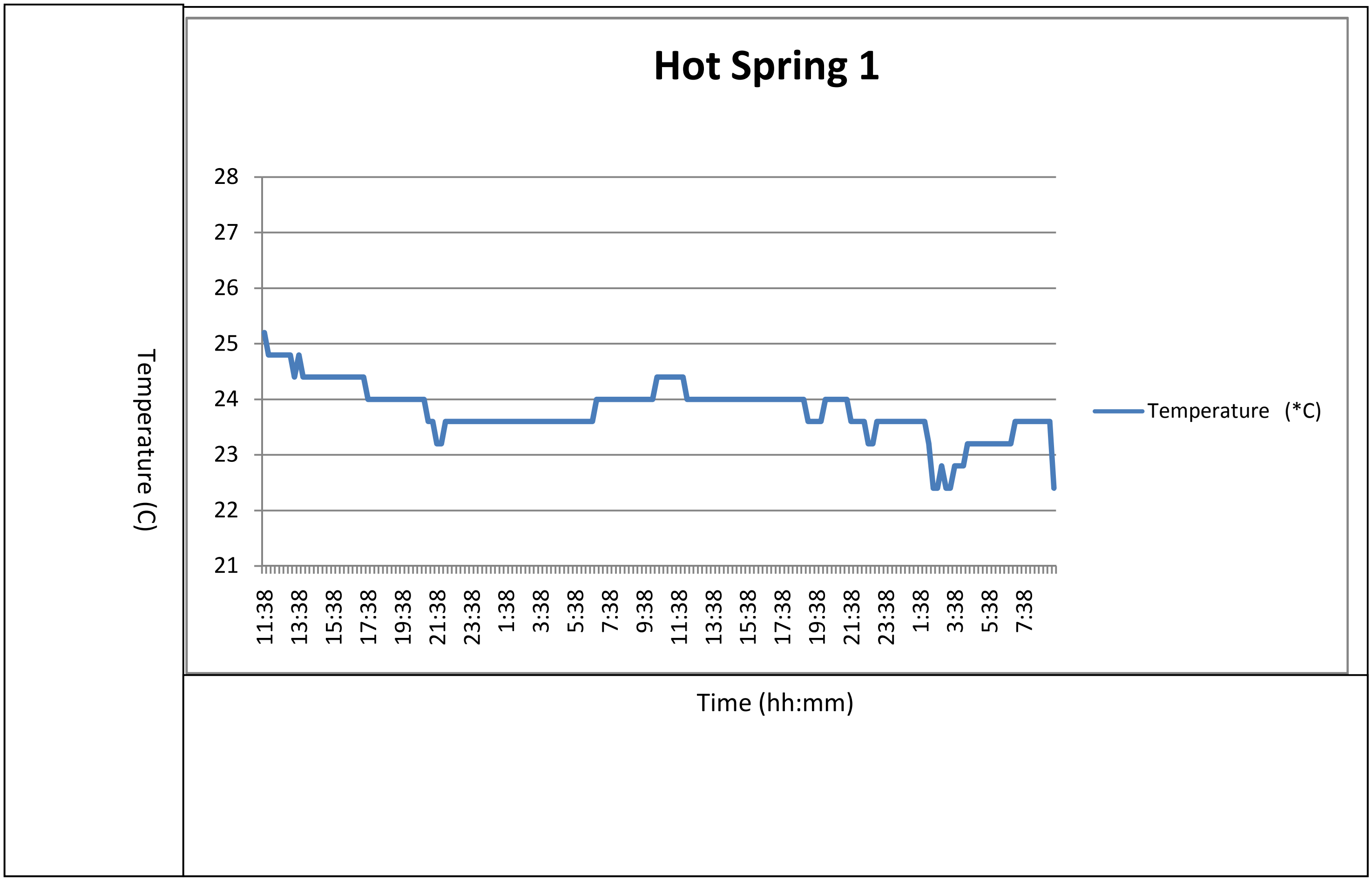


Figure 4: A graph representing the temperatures of stream sample point over a 48 hour period, serving as our control.

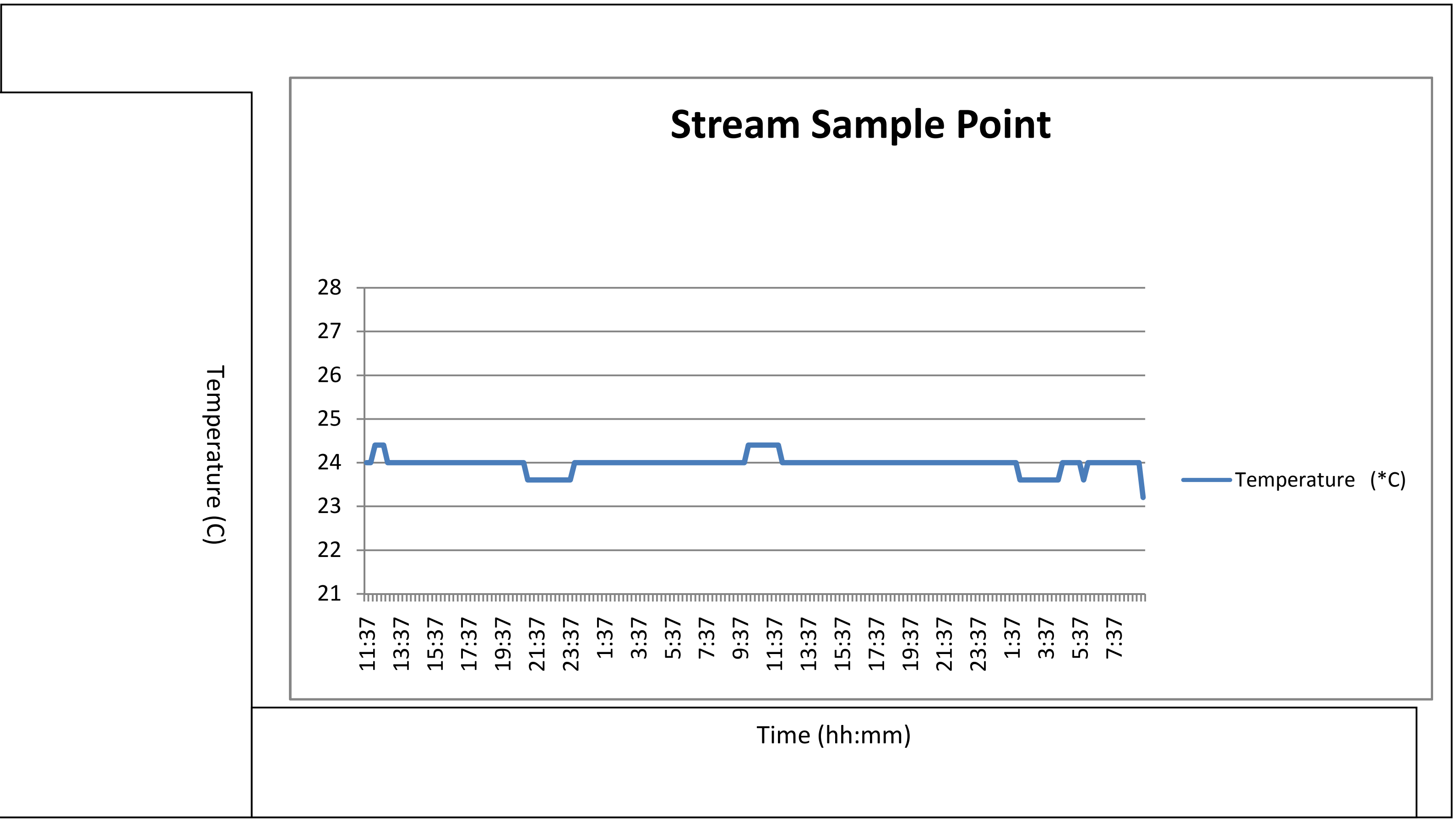


Figure 5: A graph representing the same hot spring's temperature over a 48 hour period. The probe was put in a .56 m hole and about 10 cm was under loose mud.

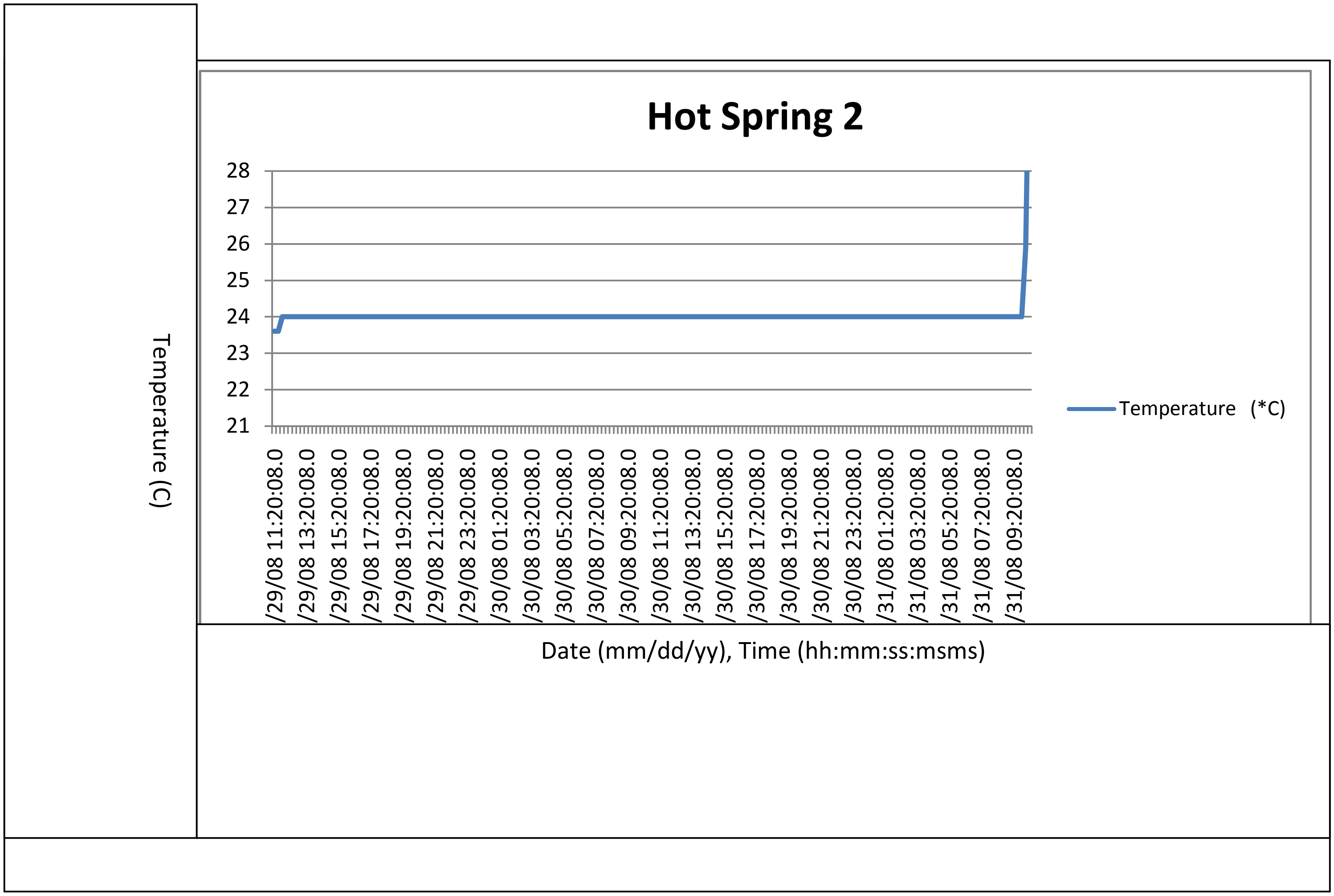


Figure 6: A graph representing the temperature over a 48 hour period in a separate point at spring 1, with the probe once again nested in a .46 m hole fewer than 10 cm of loose