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Delineating the Water Source of Two Ponds Flowing into a Mountain Bog in the Southern Appalachians

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Abstract

Mountain bogs in the Southern Appalachians are rare and delicate habitats, greatly influenced by the hydrology of the area. Riverbend, located in Henderson County, NC, is one such bog containing endangered and threatened species and has undergone multiple management approaches to try to maintain the site. Not much is known about the hydrology of the two ponds located within the site and how they might affect the quality of the bog. This study monitored the water levels of seven installed wells within the bog site over a period of four months to better understand the hydrology of the two ponds. An infra-red imaging camera was used to confirm the presence of groundwater seepage into both ponds from the south and southwestern boundaries of the site. Stormwater runoff was shown to have a profound effect on one of the ponds, but did not greatly impact the other. Surface runoff from agricultural land upslope of the site may have a detrimental effect on the bog, but water quality analysis suggests that the runoff is not far reaching. Further research needs to be done to determine the effects of stormwater runoff from the southwest pond into the site.

1. Introduction

Mountain bogs are rare and unique habitats that harbor a wide diversity of plants and animals[1]. They are characterized by relatively flat or slightly sloping topography, allowing water to accumulate near or above the ground surface[2]. Mountainous regions, such as the southern Appalachians, have very few areas naturally suitable for wetlands; however, small pockets do exist in select regions. The word "bog" is often used to describe any general wetland area[2,3]. Technically, bogs are defined as having precipitation as the predominant water source, in contrast to "fens" which are defined as having a predominantly-groundwater water source[2-5]. Other factors such as plant species, nutrient concentrations, and pH may also be used to define whether a wetland is a bog or a fen. In the case of mountain wetlands, most are fed by groundwater, but also have traits commonly associated with bogs such as low pH and nutrients. Most mountain wetlands would technically be considered "nutrient-poor fens" by definition of water source, but are referred to here as bogs to be consistent with the terminology used by the Nature Conservancy and the U.S. Fish and Wildlife Service [2,5].

The importance of mountain bogs is derived from the species found within them. Wetland species typically require a delicate balance of environmental conditions to survive[1]. Simply put, there are many species of plants and animals not capable of living in any other habitat. A total of thirteen threatened and endangered species have been identified at mountain bog sites across southern Appalachia by the U.S. Fish and Wildlife service. Additionally, the bog sites are used by migratory birds while traveling and provide habitat for other indigenous wildlife[1]. Inherent value also comes from increased biodiversity the bog sites provide to the region. The Fish and Wildlife service have proposed a Mountain Bog National Refuge program that, if accepted, will allow specific bog sites to be protected and preserved for future generations[1].

2. Site description

The study site for this project, designated as Riverbend, is a small wetland of roughly 6 acres located in Henderson County, NC (Figure 1). Riverbend contains well-established populations of the endangered mountain sweet pitcher plant (*Sarracenia rubra ssp. jonesii*), as well as the threatened swamp pink plant (*Helonias bullata*) and bog turtle (*Clemmys muhlenbergii*). The site faces particular concern over water quantity, water quality and shrubby succession. There are two small ponds located within the site, believed to collect surface water runoff from agricultural and residential slopes to the south. Since the site was purchased by The Nature Conservancy in 1982, it has undergone multiple management strategies in an attempt to preserve the area. Recent management strategies include the employment of goats and cattle to eat successive shrubbery and the periodic, manual removal of invasive species. One of the ponds receiving runoff from a drainage ditch was enlarged in 1995 and dredged in 2010 to prevent stormwater flow into the site[6]. This study focused on the hydrologic flow of the two ponds, which are believed to have a strong impact on both water quantity and quality on the site. The research goal was to assess the primary water source for the two ponds and their effect on the bog, which has been inconclusive in the past. The pond with the drainage ditch (Pond 2) is expected to be more susceptible to flooding and have lower water quality than the other pond (Pond 1) because it receives more direct stormwater flow. Ultimately, the study was designed to provide management suggestions to the U.S. Fish and Wildlife Service, The Nature Conservancy, and other partnering agencies in an effort to better preserve and maintain the Riverbend site.

3. Methods

3.1 Monitoring wells

A traditional approach to study the hydrology of an area is to install monitoring wells. Five wells were installed manually with a hand auger on October 18, 2012. An additional well was installed in Pond 1 on January 11, 2013. A data logger was placed near the bottom of each well for data collection. Another data logger was placed inside an existing deep well. The locations of the installed wells are shown in Figure 1. A deep well (w27D) and shallow well (w27S) were installed side by side within the area of the mountain sweet pitcher plant clumps. The data loggers were set to automatically record the barometric pressure for every hour, on the hour. A data logger suspended inside a well, high above the water table, was used to compensate for changes in the atmospheric barometric pressure. With the included adjustment, the water levels of the other wells could be accurately derived. The well elevations were surveyed on January 20, 2013 and tied-in to previously installed wells with known elevations, relative to an arbitrary datum. The determined elevations were then used for overall comparison of water levels and the water table. The data were collected from the data loggers on three separate dates: January 11th, 20th, and February 16th, 2013. The depths to water from the top of the well casing (TOC) were manually measured on these dates with a water level tape. A rain gauge was also installed inside the site to measure the amount of rain received in hundredths of an inch every hour.

3.2 Water quality analysis

Water samples from Pond 1, Pond 2, and a pooled up area of water located directly beside mountain sweet pitcher plants were collected on February 16, 2013. The samples were analyzed at the Environmental Quality Institute (Asheville, NC) for general water quality parameters, including nutrient levels, pH, total suspended solids, conductivity, turbidity, and alkalinity.

3.3 Use of infra-red imaging

The use of infra-red thermal imaging technology is a relatively recent approach in environmental field work, with a wide variety of potential applications. Hydrology is one such area where the application of thermal imaging is significantly helpful[7,8]. Because the heat capacity of water is large and tends to change temperature slowly[8,9], water from varying sources may be distinguished via minute temperature differences. Groundwater temperatures stay relatively constant and equal to the average annual air temperature of the region. In contrast, surface waters are subject to diurnal and seasonal temperature variations[8]. Based on this information, discharge of groundwater may be readily identified from seeps, springs, stream banks, and other areas according to the thermal signature[10].

A FLIR T640 camera was rented and taken into the site on two separate occasions to take thermal images of the bog; once in the August 2012 (summer) and once in January 2013 (winter). Groundwater in the study site region would be expected to give a warmer thermal groundwater signature relative to colder surface temperatures in the winter, and a colder thermal signature during the warmer summer months[8,11]. All photos were taken in the early morning daylight hours (8-10 a.m.) to minimize radiation reflected from surrounding vegetation.

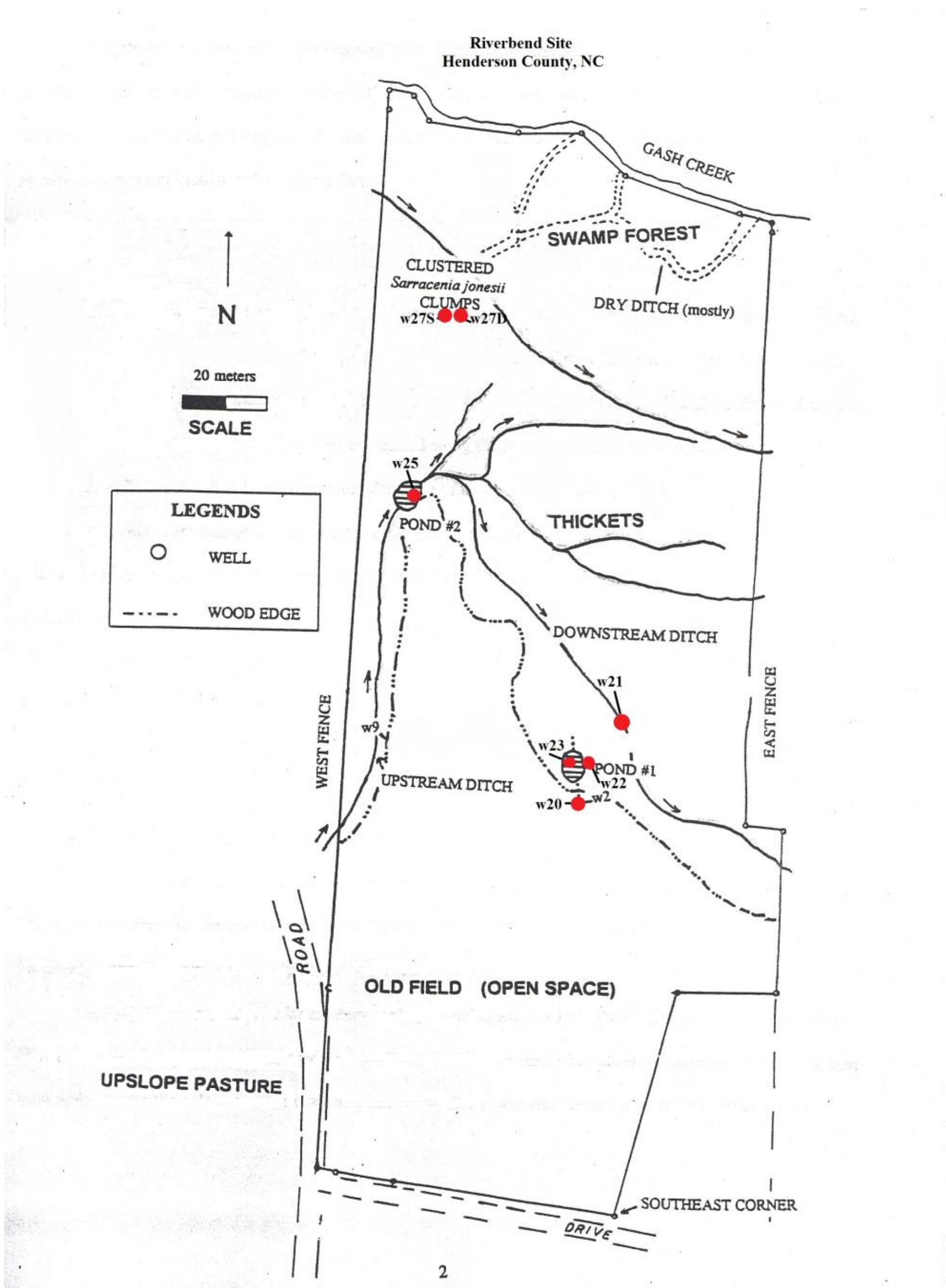


Figure 1. Location of newly installed wells at Riverbend bog site Henderson County, NC. 2013. Adapted from The Nature Conservancy's Hydrologic Summary of Riverbend[6].

4. Results

4.1 Monitoring wells

The top of casing (TOC) elevation values with the associated well numbers are shown in Table 1. The depth to the water table (DWT) is also shown for each well for the dates when the data from the wells were extracted. The TOC elevation minus the DWT was used in order to match water level elevations to the datum. This allowed for the comparison of water levels between all of the newly installed wells, as seen in Figure 2.

Table 1. Data collected for the seven newly installed wells measuring top of casing elevations, the stickup above ground level for the wells, the last two digits of the data logger serial number, and the water table level for the three dates of data collection at the Riverbend site Henderson County, NC. 2013.

Well #	TOC elevations (m)	TOC elevations (ft)	Well Depth (ft)	Stick-up (cm)	Data Logger S/N	DWT (ft bTOC) 1/11/13	DWT (ft bTOC) 1/20/13	DWT (ft bTOC) 2/16/13
20	93.865	307.96	11.30	11	55	2.43	2.15	2.42
21	93.356	306.29	5.27	87	51	2.55	0.91	2.59
22	92.969	305.02	2.87	37	46	0.94	2.55	0.95
23	93.534	306.87	4.57	92	60	2.66	2.55	2.67
25	93.843	307.88	4.91	128	65	N/A	2.65	3.71
27D	93.642	307.22	8.06	85	63	2.90	2.72	2.79
27S	93.330	306.20	4.79	55	67	1.81	1.85	1.91

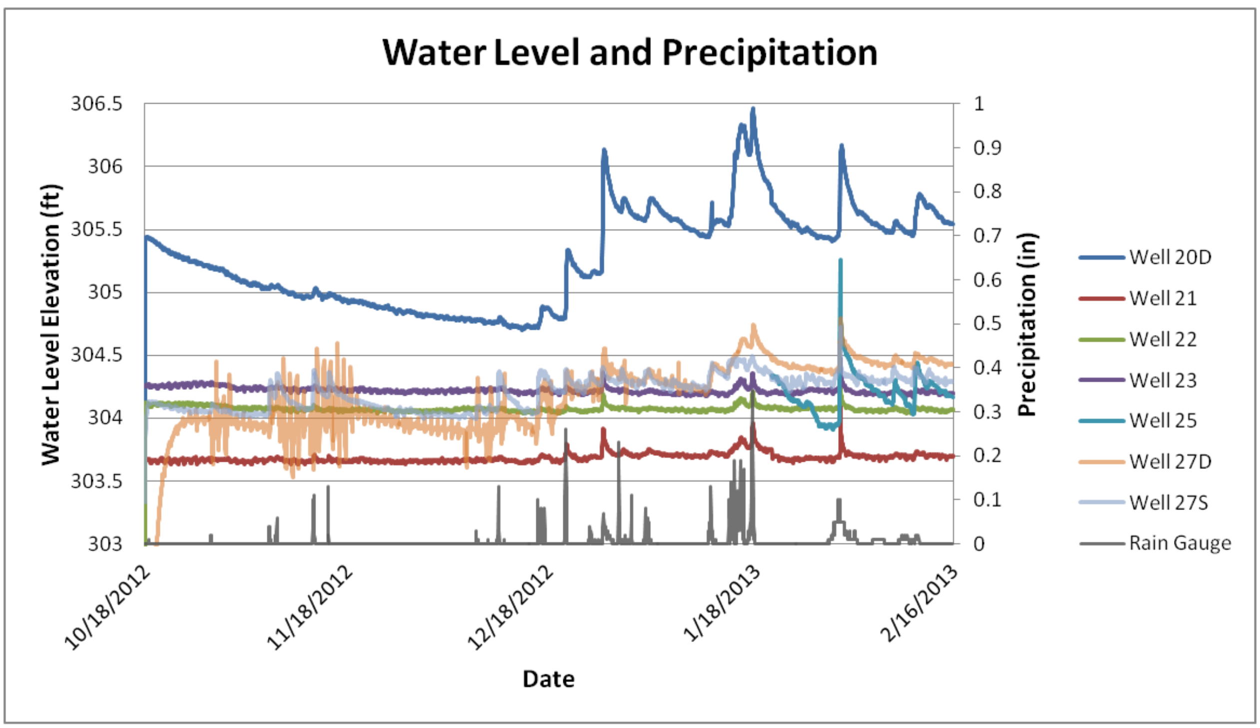


Figure 2. Water level and precipitation data collected from the data loggers of the installed wells based on surveyed elevations for equal comparison at the Riverbend site Henderson County, NC. 2013. *Rain gauge data after 1/20/13 was based on a nearby rain gauge in Fletcher, NC[12].

Precipitation from the rain gauge on site is shown in gray on the bottom of Figure 2. It should be noted that the precipitation data after January 20th was based on a rain gauge located nearby in Fletcher, NC. The water table data shows that well 20, which is a deep well, has a much higher water level than the other wells. The lowest water table elevation is at well 21. The other wells have similar water table elevations that usually stayed within the 303.5 ft and 304.5 ft range. Well 25 had the largest spike in elevation out of all the wells during a rain event on January 30th.

4.2 Water quality analysis

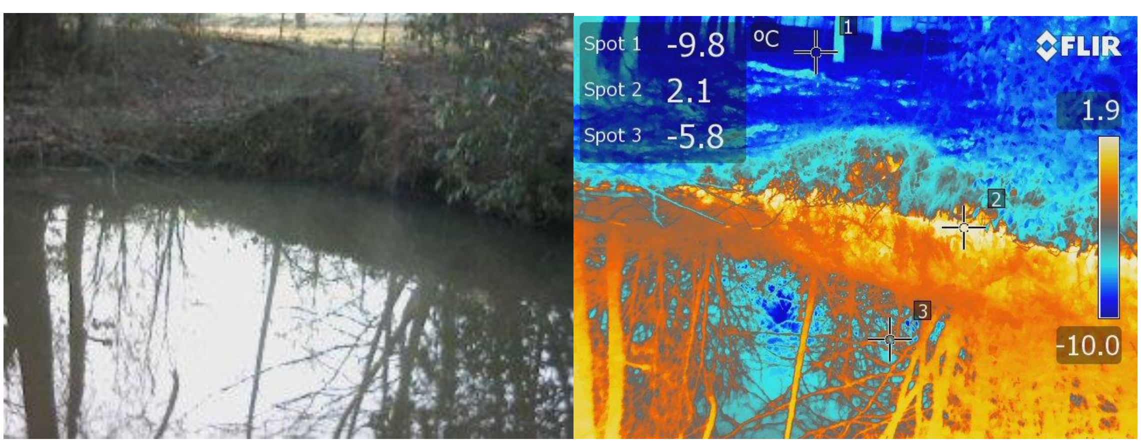
The results of the water quality analysis for the three sample locations are shown in Table 2. Additional average regional stream values are provided for comparison. The highest content of ammonia nitrogen was nearest to the pitcher plants at 0.60 mg/L compared to the second highest, 0.23 mg/L, at Pond 1. The pH was also lowest near the pitcher plants at 4.6. Nitrate-nitrogen was highest at Pond 2 with 1.8 mg/L and the other samples containing effectively none. In contrast, orthophosphate and ammonia nitrogen were both lowest at Pond 2.

Table 2. Water quality report from analysis of Pond sites 1 and 2, pooled area next to mountain sweet pitcher plants at Riverbend site Henderson County, NC. Regional stream average provided for comparison. 2013.

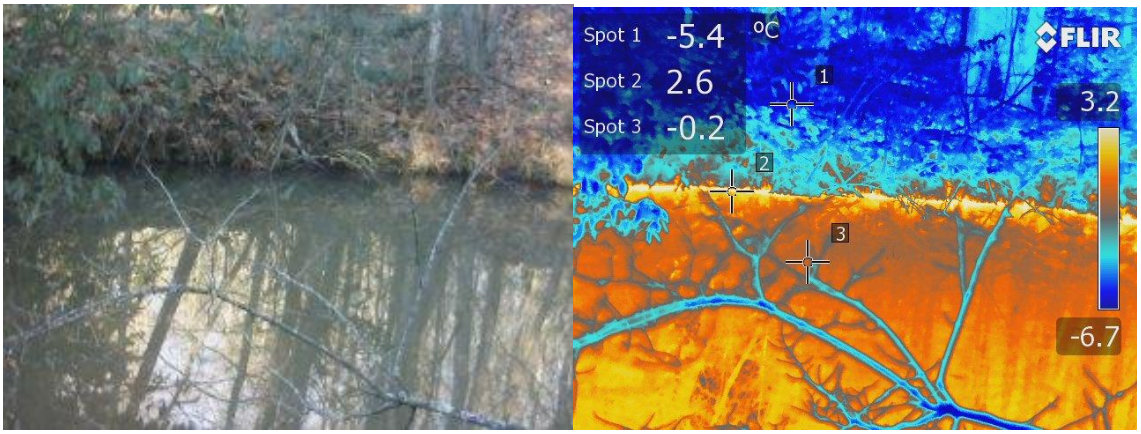
Site	NH3-N (mg/L)	NO3-N (mg/L)	PO4 (mg/L)	Turb (NTU)	TSS (mg/L)	Cond (umhos/cm)	Alk (mg/L)	pH
Pond 1	0.23	0.0	0.05	5.9	25.6	21.8	9.0	5.4
Pond 2	0.10	1.8	0.02	11.0	1.6	48.9	12.0	6.0
Pitcher Plants	0.60	0.0	0.04	340.0	48.8	22.0	2.0	4.6
***regional stream average median**	*0.09**	*0.5**	*0.09**	*5.9**	*5.4**	*62.7**	*22.3**	*7.0**

4.3 Use of infra-red imaging

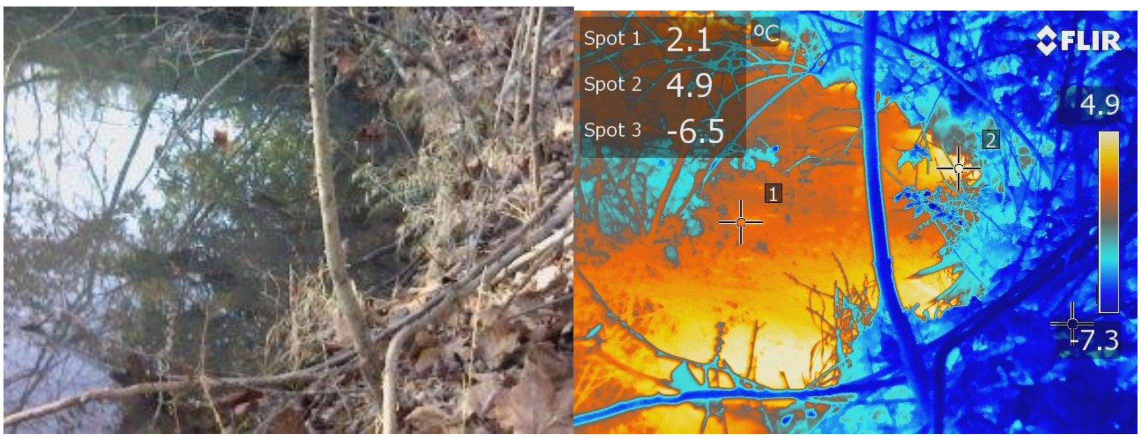
The pictures from a FLIR 640 camera taken to the site in the winter are shown in Figure 3. The camera takes an infra-red and digital photo simultaneously, which are shown next to each other for visual comparison. Warmer areas are indicated as whitish to orange, where as the colder areas are indicated as blue to deep blue. Groundwater discharge corresponds to the warmer temperatures in the winter. The scale on the right hand side of the infra-red photos shows the temperature range in Celsius degrees and is adjusted automatically to best display each area. Three spot measurements in the upper, left hand corner measure land temperature, warm groundwater temperature, and the pond water temperature. Warmer areas can be seen on the southern edges of both ponds.



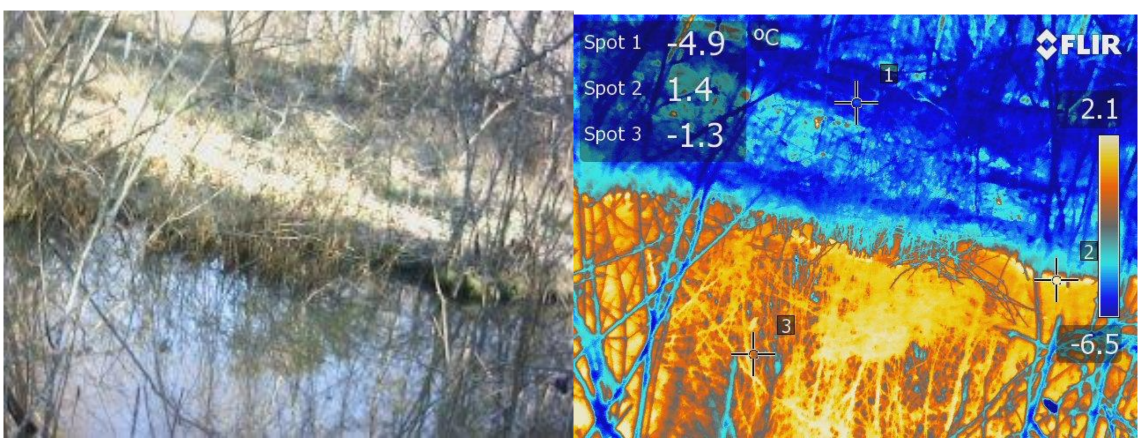
Pond 1 facing SE



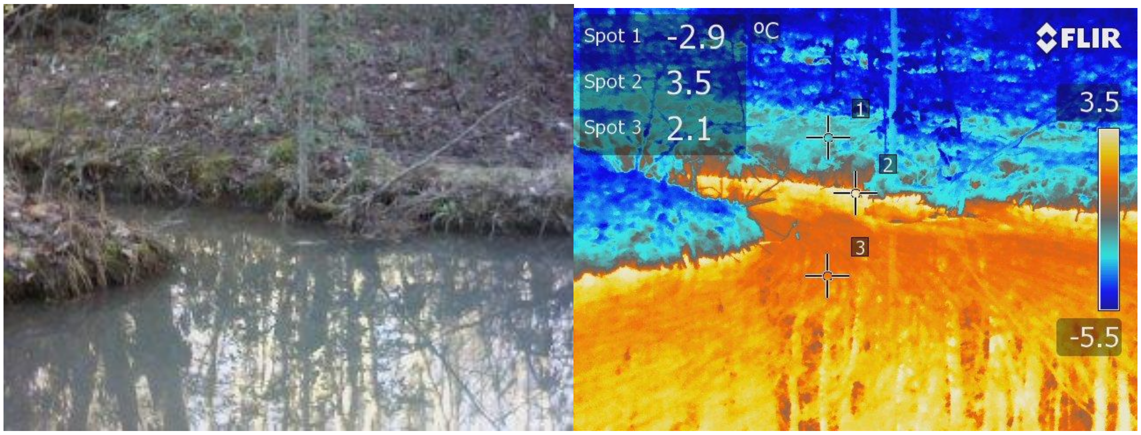
Pond 1 showing SW seep, facing W



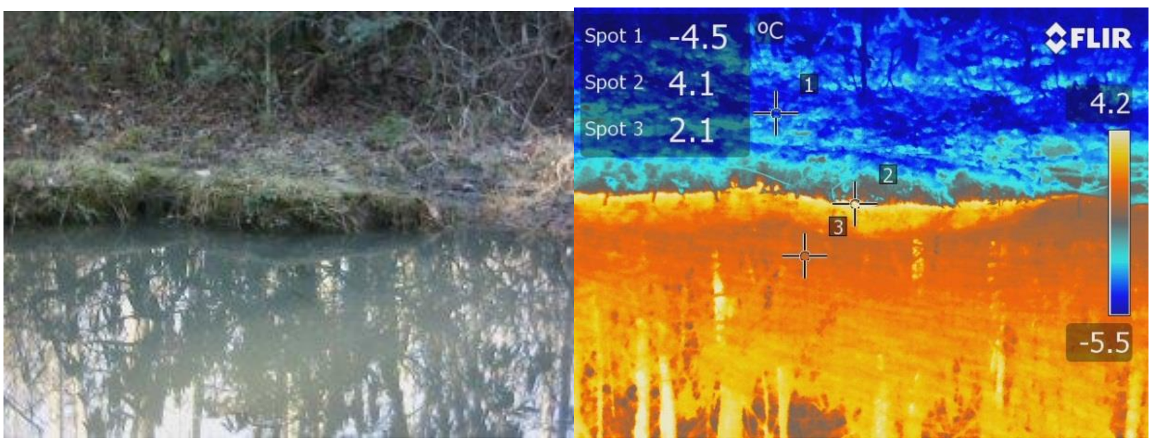
Pond 1 showing SW seep



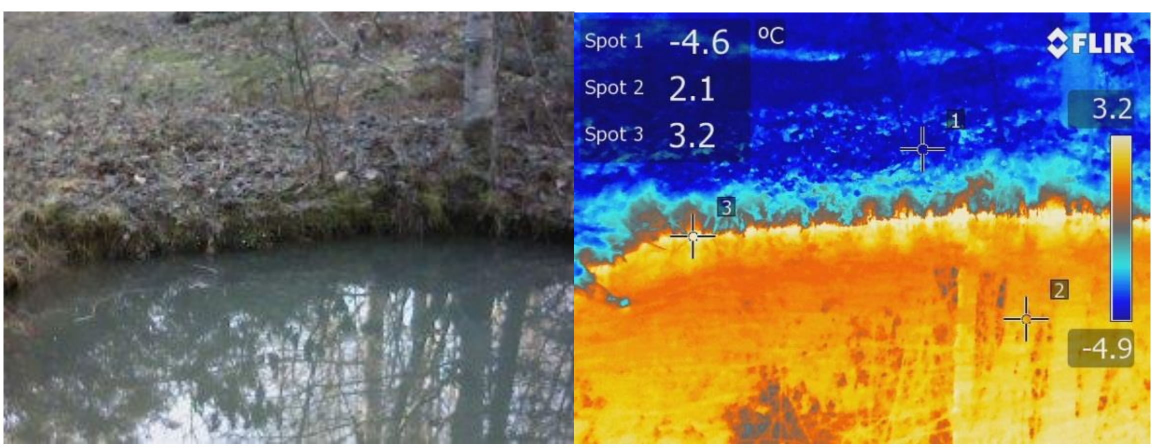
Pond 1 facing N, showing very little groundwater discharge



Pond 2 with ditch



Pond 2 facing SW



Pond 2 facing SE

Figure 3. FLIR 640 infra-red and digital photos of groundwater seepage areas during winter at the Riverbend site Henderson County, NC. 2013.

5. Discussion

The results from the water level data show that the water table slopes northeast from wells 20D, 23, 22, to 21. This indicates that groundwater is flowing towards the site from the southwest. Groundwater appears to be converging toward the ditch near well 21 and most likely flows from there towards the east of the site. The indication of drawdown in the water table towards the eastern side of the site would also suggest why shrubby succession is taking place in that area. The infra-red images show warm groundwater flowing into both ponds, including the ditch of Pond 2, from the south and southwest directions. This confirms that the wetland is technically a fen, with the majority of its water source being fed by groundwater.

The results from the water quality test are fairly inconclusive, with the exception of nitrate/nitrite levels for Pond 2. Nitrogen might be carried with runoff from the fertilizers used on the agricultural fields upslope of the site. Continued sample collection and analysis should be included after the occurrence of rain events to determine how the water quality of the ponds are affected. The amount of stormwater runoff received may then be inferred by the varying levels of nutrients after stormwater events.

Precipitation on January 30th produced the highest water-level spike at well 25 relative to any other well during the 4-month long data collection. The high fluctuation of water level in response to precipitation indicates that Pond 2 receives much more stormwater runoff than other areas of the site. All of the wells produced a slight spike in water level, but the water level of Pond 1 (well 23) remained fairly consistent, suggesting that it receives relatively little stormwater runoff.

The infra-red camera images and the hydrograph confirmed that groundwater constitutes a significant water source for both ponds and explains why Pond 1 stayed relatively consistent, even during stormflow events. The infra-red images definitely indicate that groundwater is also flowing into Pond 2, but the ditch leading into the pond brings with it large stormwater surges.

6. Conclusion

This study showed that the effects of the two ponds on the Riverbend site are quite dissimilar. Overland flow from Pond 2 into the site could be potentially harmful to the habitat because of the nutrients, sediments, and other contaminants picked up by the stormwater runoff. Mountain sweet pitcher plants only thrive in low-nutrient settings where other plants have difficulty living. If nutrients enter the site from neighboring farmland, other plants might begin to grow and over take the pitcher plant habitat. Dredging of Pond 2 has probably helped capture some sediments from moving further into the site but it has not prevented stormwater overflow. Large fluctuations in the water level of Pond 2 indicate that stormwater runoff is a major constituent of its water source. Pond 1, however, seems to be relatively unaffected by stormwater runoff during rain events.

Additional research could determine if the stormwater runoff from Pond 2 is reaching the pitcher plant area or simply flowing east into the bordering Gash Creek. The well data collected beside the pitcher plants shows some indications that stormwater runoff is reaching the area during rain events, but the source of the stormwater (either the north or south end) is undetermined. Further monitoring of the wells and water quality is recommended for determining how to best manage the site. Only through data collection can proper maintenance strategies be developed and employed effectively for the site. From this, the human impact of encroachment can be minimized on rare mountain bogs such as Riverbend and these unique habitats may continue to exist for future generations.

7. Acknowledgements

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