Patterns and Drivers of Conductivity and pH in an Urban Stream

Mary Ann Cunningham, Cassie Stirpe ('15), Kirsten Menking, John Brandt ('16)

Vassar College

Introduction:

Urbanization is the second greatest cause of stream impairment, after agriculture, in the United States (Paul and Meyer, 2001). The "urban stream syndrome" (Walsh et al., 2005) can include physical, chemical, and/or biological impairments, resulting from multiple, often interacting, stressors (Wenger et al., 2009). Impervious surface cover, in particular, accelerates storm discharge and pollutant runoff. Impoundments also affect in-stream conditions. Urban ponds are typically shallow, but they are surprisingly resistant to mixing. Both thermal and chemical stratification (e.g. variations in salt concentrations) can reduce mixing of nutrients, oxygen, and contaminants. Stratification can be especially strong in summer (McEnroe et al., 2013; Song et al., 2013).

We examined effects of impervious cover and an impounded lake on specific conductance and on pH in the Fonteynkill, a small stream (~0.1 m3/sec discharge) that is a Hudson River tributary in Poughkeepsie, NY. We used sondes to monitor continuously at 20 minute intervals for 3.75 years.

Sondes were placed at three sites (Fig. 1): the first was in a shaded stream reach that drains Poughkeepsie city streets; the second was below a medium-size (11,300 m3) impounded lake; the third site was several hundred meters farther downstream, below a wetland and a vegetated riparian zone. This is an exploratory study, but we suggest some general findings that can be drawn from our data.

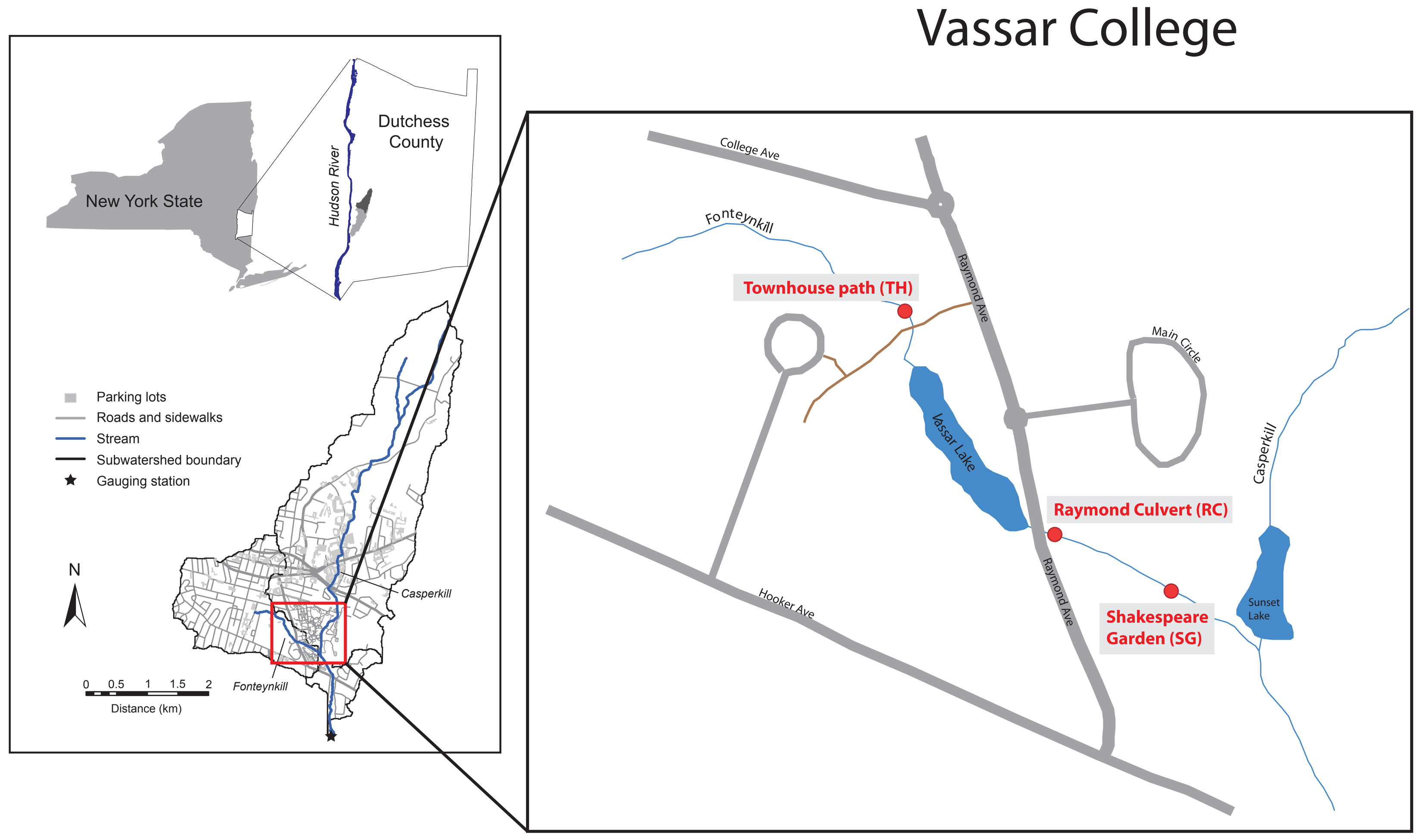

Figure 1. Location of the Fonteynkill in Dutchess County, NY. Red circles show location of three sondes, in a forested stream reach that drains Poughkeepsie city streets (TH), below the impoundment at Vassar Lake (RC), and in a low-impervious campus landscape (SG). vegetated wetland.

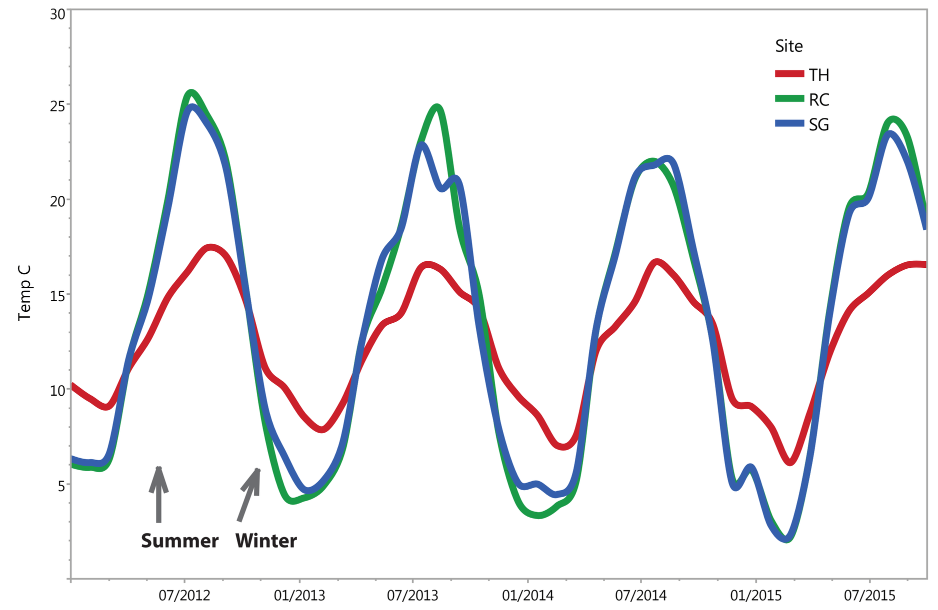

Figure 2. Stream temperature, January 2012 - September 2015. Smoothed data show cooler summer and warmer winter temperatures the forested TH site, relative to the RC and SG sites below the impoundment.

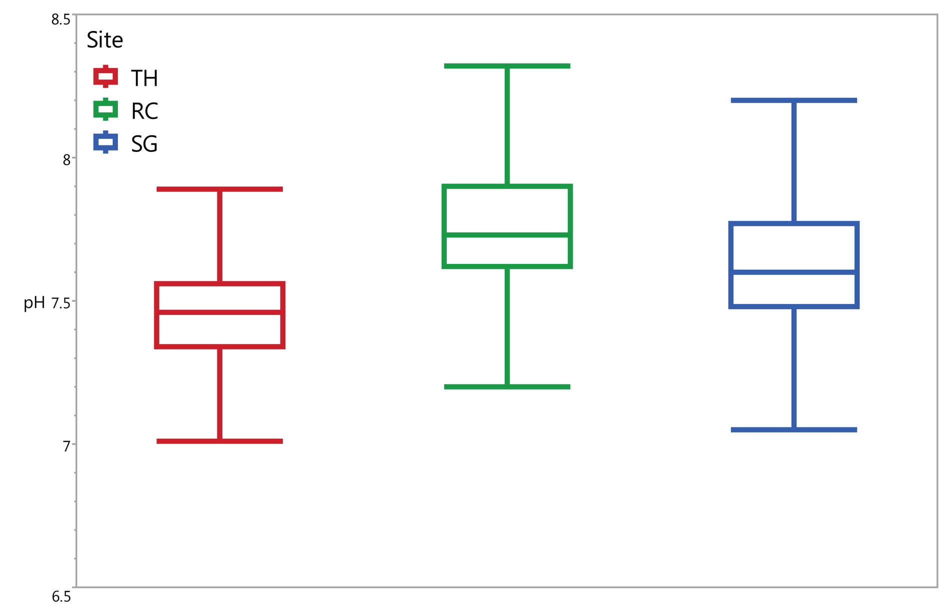

Figure 3. Distribution of pH at the three study sites, using 3.75 years of monitoring data. Median pH values were 7.46 at the TH site, 7.73 at the RC site, and 7.60 at the SG site. The two sites below the impoundment (RC and SG) consistently show higher pH values than the TH site.

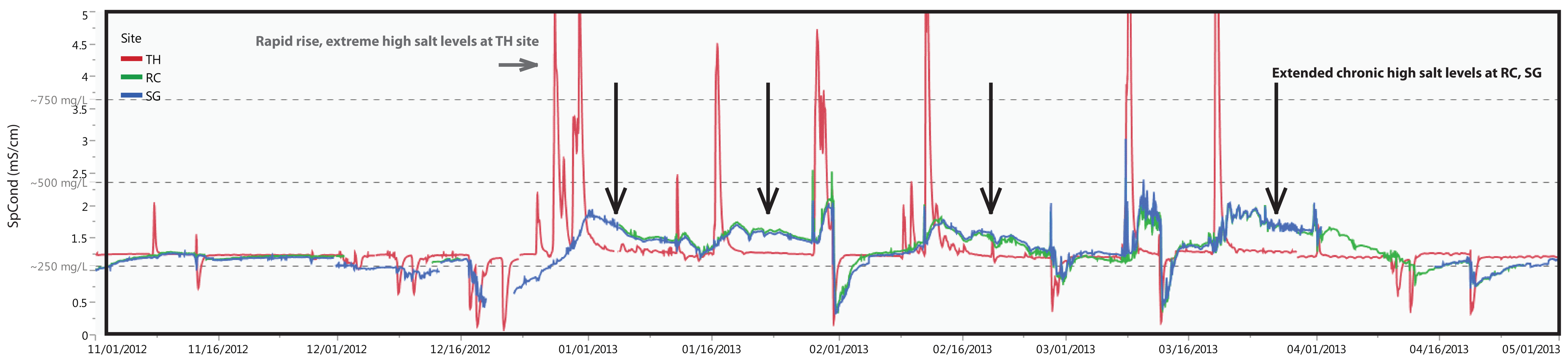

Figure 4. Winter conductivity response to precipitation.

Peaks in conductivity correspond to road salting events following precipitation of snow and/or ice.

The TH site shows rapid and dramatic responses to salting, as well as higher accute salinity values.

The RC and SG sites show lower acute values, but longer chronic chloride exposure (black arrows).

Approximate equivalent chloride concentrations are marked on Y axis.

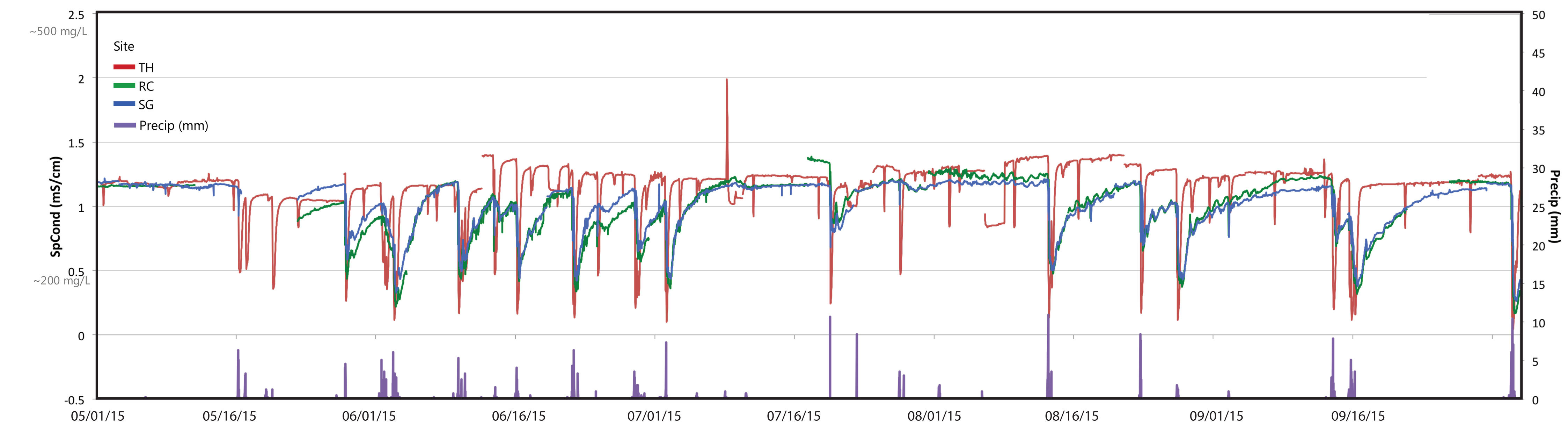

Figure 5. Summer conductivity response to precipitation.

Groundwater baseline conductivity is ~1.2 ms/cm (~250 mg chloride/L). Rain events (shown in purple) dilute the stream temporarily. which returns to baseline levels rapidly above the impoundment (TH) and gradually below it (RC, SG).

The lake thus dillutes and dampens the chloride peaks in the same way that it moderates discharge peaks below the lake.

Approximate equivalent chloride concentrations are marked on Y axis

Results and Discussion:

Despite the short length of the Fonteynkill, the three sites studied showed different physical, chemical, and biological characteristics. **Elevated temperature**, a symptom of the urban stream syndrome (Paul and Meyer, 2001), was exaggerated by the impoundment in summer, where water can be heated for 1-2 days (the lake's turnover time), as shown by warmer temperatures below the impoundment in summer (Fig. 2). Winter temperatures were cooler below the impoundment, either because of groundwater contributions to small discharge above the lake (TH site) or because of cooling in the exposed lake surface.

The impoundment also appears to **elevate pH** (Fig. 3), presumably because of biotic activity. High pH levels can be associated with high rates of photosynthesis (as CO2 and carbonic acid concentrations decline). Low pH levels would be associated with abundance of carbonic acid, presumably accompanying high respiration rates. We found high pH levels at both sites below the lake in winter (Fig. 7) and at the RC site (just below the lake) in summer (Fig. 8). Heavy shade at the TH site (and moderate shade at SG) evidently reduce photosynthesis. Diurnal variation in pH also responds to sunlight, especially at the TH site before leaves fill out in spring (Fig. 7). Although bedrock generally influences stream pH in the area, in-stream photosynthesis and precipitation inputs strongly influenced pH.

Elevated baseline conductivity equivalent to ~250 mg/L chloride occurred at all sites. This finding is consistent with other studies (Brown et al., 2009). This baseline persisted in summer and winter, indicating that road salt contamination persists in groundwater, which provides the stream's baseflow. Winter conductivity (our proxy for chloride) spiked after precipitation (and salting) events. Summer conductivity declined because of dilution after rain events, then returned to high baseflow levels. Both winter and summer effects were dampened below the impoundment (Fig. 4, Fig. 5) because stormwater was mixed with lakewater that entered between storm events. The highest acute concentrations were above the lake (TH site), but chronic elevated levels were present at the RC and SG sites (black arrows, Fig. 4). Many aquatic species can tolerate brief, acute exposures to chloride, but fewer can tolerate chronic contamination.

References:
Brown, L, T. e al. 2009. "Urban Streams across the USA: Lessons Learned from Studies in 9 Metropolitan Areas." Journal of the North American Benthological Society 28 (4): 1051–69.
Findlay, S. and V. Kelly. 2011. "Emerging Indirect and Long-Term Road Salt Effects on Ecosystems." Annals of the New York Academy of Sciences 1223 (1): 58–68.
McEnroe, N. et al. 2013. "Thermal and Chemical Stratification of Urban Ponds: Are They 'Completely Mixed Reactors'?" Urban Ecosystems 16: 327–39.
Paul, M., and J. Meyer. 2001. "Streams in the Urban Landscape." Annual Review of Ecology and Systematics 32 (January): 333–65.
Song, K. et al. 2013. "Thermal Stratification Patterns in Urban Ponds and Their Relationships with Vertical Nutrient Gradients." Journal of Environmental Management 127: 317–23.
Walsh, C. et al. 2005. "The Urban Stream Syndrome: Current Knowledge and the Search for a Cure." Journal of the North American Benthological Society 24 (3): .706–23.
Wenger, S. et al. 2009. "Twenty-Six Key Research Questions in Urban Stream Ecology: An Assessment of the State of the Science." Journal of the North American Benthological Society 28 (4): 1080–98.

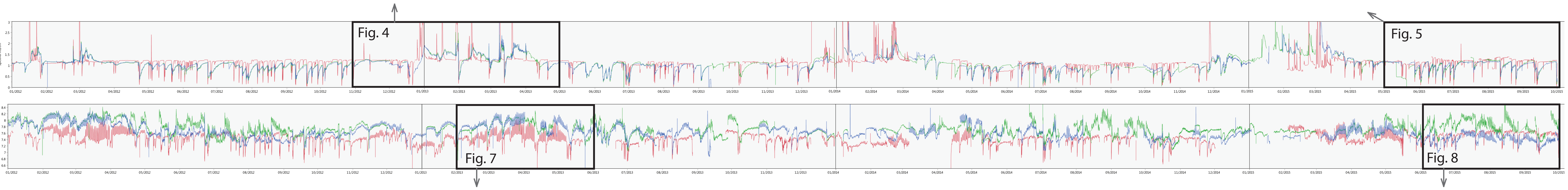

Figure 6. Specific conductance (mS/cm: top) and pH (bottom) for 3.75 years of monitoring. Black boxes indicate sections magnified for Figures 4, 5, 7, and 8.

Gaps in the data represent equipment failures; otherwise measurements were taken taken every 20 minutes. .

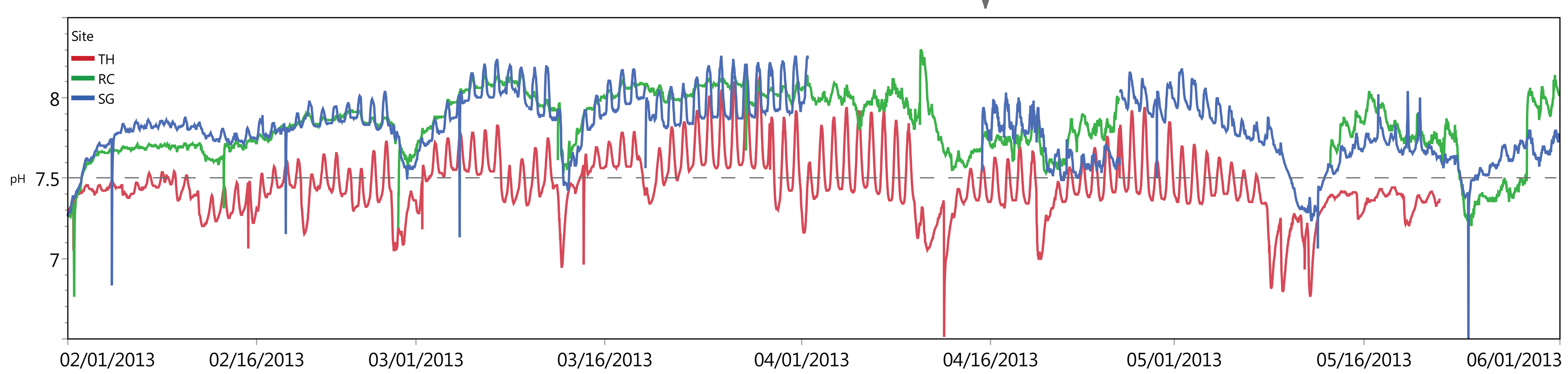

Figure 7. Spring pH pattern, showing strong diurnal variations at the TH and SG sites. These diurnal fluctuations are generally greatest in March and April, but exact timing depends on late winter/early spring weather conditions. Diurnal variations are reduced by early summer, due to trees establishing leaf cover and shading the stream.

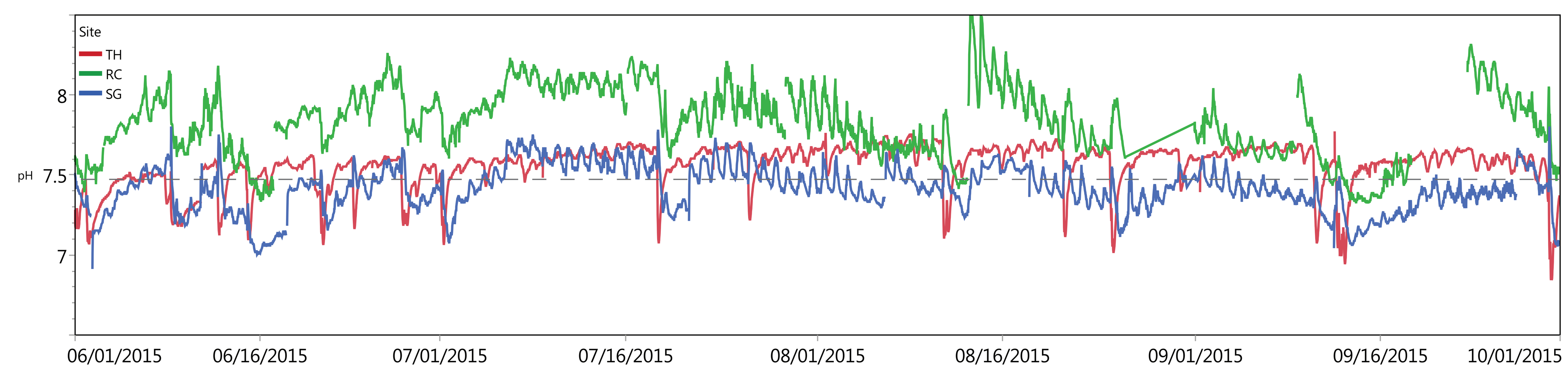

Figure 8. Summer pH patterns. During summer months (June to September), the TH site shows little diurnal fluctuation, the SG site shows a moderate fluctuation, and the RC site shows the greatest fluctuation. (The RC site also shows negative pH drift caused by algal growth on the instrument during deployment.) Overall patterns in pH variation are similar between the RC and SG sites, though the RC site's pH is consistently higher. The pH decreases are associated with precipitation events in which rain lowers the pH of the stream.