4.0 Raised Bog Water Chemistry (Biogeochemistry)

The chemical characteristics of bog water help to further identify the type of bog (Damman 1987), which specialized plants will grow, and the peat-forming processes essential to sustain the bog. Generally, the surface and near-surface flowing waters of raised bogs tend to be low in minerals and rich in dissolved organic substances, and have extremely strong acid reactions (low pH). The colour of bog water is brown to dark brown because of humic acids released through decomposition (Hebda *et al*. 2000). Biogeochemical processes in the aerated zone (acrotelm) and non-aerated zone (catotelm) lead to different water chemistries. Water chemistry is also influenced by the rate of peat accumulation, which shows higher concentrations of ions in more slowly accumulating peat. Fire, erosion and peat mining can also affect water chemistry by increasing the supply of nutrients.

The study of bogs requires an understanding of the chemical ecology that drives the acid-base chemistry of this ecosystem. *Sphagnum* bogs are biogeochemical systems of striking complexity (Kilham 1982). The following factors play a role in the acid-base chemistry of a bog ecosystem:

- cation-exchange by living *Sphagnum* and peat,
- the chemistry of atmospheric precipitation,
- the net biological uptake of ions by vegetation,
- the oxidation and reduction of sulphur compounds,
- the production of soluble organic acids by *Sphagnum* and other plants, and
- the hydrologic regime.

For nearly 20 years, cation-exchange by *Sphagnum* has been considered the predominant chemical process controlling bog water chemistry. Up to 21.5% of the dry weight of *Sphagnum* is polygalacturonic acid (PGA). Cation-exchange occurs when the hydrogen ions of this organic acid are exchanged for other cations in the environment (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, etc.). In other words, a solution containing Ca^{2+} and SO_4^{2-} before cation exhange would become a solution of H_2SO_4 after cation-exchange.

When a plant takes up a positively charged ion (e.g., NH_4^{+}), a positively charged ion such as hydrogen (H^{+}) is released into the environment. *Sphagnum* species growing highest above the water level of a bog have the highest PGA content (Spearing 1972) and, thus, the greatest cation-exchange capacity. Kilham (1982) considers reduction of environmental pH by *Sphagnum* to be an adaptive metabolic process that regulates its internal environment. He hypothesized that *Sphagnum* plants do not merely exist in bogs; they are the dominant competitors. They assume this role because they have metabolic control over nutrient levels and hydrogen-ion concentrations in environments having certain prerequisite hydrologic and geologic characteristics, namely, environments where cation-loading rates are minimal. Ombrotrophic bogs that receive cations primarily from atmospheric deposition provide this type of environment.

4.1 pH

Bog water typically has a pH range of 3.3 - 5.5, and transitional bog waters have a pH in the range of 4.5 - 6.0. Numerous studies at Sifton Bog have shown the pH to be quite variable and infrequently less than 4.5. Differences in sampling methodology by different investigators make direct comparisons difficult; however, there are some trends that can be shown.

In 1926, Margaret Crawford extracted water from *Sphagnum* mosses around Sifton Bog and found the pH levels to be close to neutral (6.9 - 7.0). Proctor and Redfern (1979) found that pH varied from 5.8 - 6.7. Colozza (1987, unpublished) measured the pH in numerous quadrats throughout the site and found the pH ranged from 4 - 7, with zonal gradients influenced by

Sphagnum biogeochemistry. The range of pH in bogs appears to vary with climate, season, *Sphagnum* moss activity and depth below the peat surface. Precipitation in the London region is generally acidic, and this may contribute to the acidity of the bog. However, precipitation also contains significant quantitites of cations and anions (e.g., nitrogen as NH_4^+ and NO_3^-) that are important in plant nutrient and energy transformation (Kilham 1982).

The UTRCA has sampled the pH in the water at the north and south ends of Redmond's Pond since 1992. The pH fluctuated from 4.9 - 7.3 but was most frequently in the 5.6 - 6.4 range. There appears to be some correlation between bog water pH and water level, although this has not been analyzed. Generally the data show a decrease in pH with an increase in water level. Between 1998 and 2000, bog water levels were very low due to drought conditions and pH was more or less neutral.

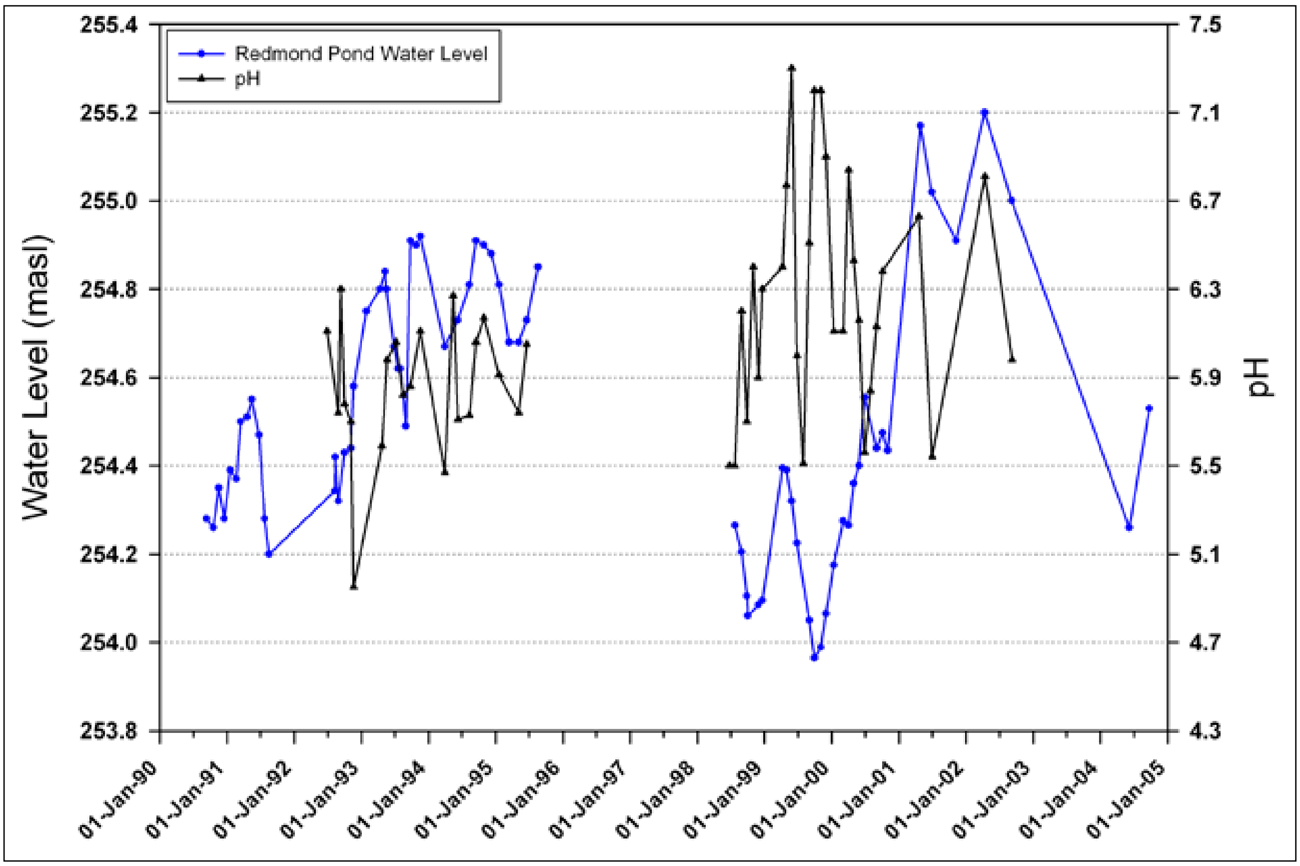

Figure 10. Water level *vs.* pH at Redmond's Pond, 1988 – 2004 (UTRCA data)

Applegate Groundwater Consultants (1998) found the surface water of Redmond's Pond to be slightly acidic (pH 4.9 - 6.4) and quite fresh, with electrical conductivity measurements of 15 - 66 µmhos/cm. The acidic pH and low conductivity of the water in Redmond's Pond distinguish it from groundwater in the vicinity of the bog.

Groundwater from both shallow and deep monitoring wells is slightly alkaline (about pH 7.2 - 8.1) and is significantly higher in electrical conductivity (400 - 700 µmhos/cm) than is the pond water. This is further evidence that groundwater does not discharge to the bog.

4.2 pH, Nitrates and Phosphate

The most comprehensive and quantitative study related to water chemistry and plant associations of the Sifton Bog was completed by Wu (1989). From September to November 1988, pH, nitrate and phosphate were recorded from a series of 90 quadrats laid out over the open peat bog. Five replicates for each variable were taken from each quadrat and the mean value per quadrat was used in the data matrix. The pH level ranged from 3.5 - 6.0, with the majority of samples in the range of pH 4.0 - 5.0. The lowest pH values were recorded in the north end of the bog and the highest pH was recorded in the northwest to southeast diagonal section, which includes Redmond's Pond and areas where cattail is more abundant.

Nitrate and phosphate are important macro-nutrients and are often limiting factors in bogs. Nitrate concentrations were below the accepted level of sensitivity of the test used (< 2 mg/L) so were not mapped. However, the water chemistry data collected by Wu was analyzed through canonical correlation and found to show a meaningful correlation that contributed to the observed vegetation pattern represented in the bog. There was also a positive correlation between the type and location of plant species and phosphate concentration. Phosphate concentrations were highest in the northeastern and southeastern part of the bog and lowest in the southwestern quadrats, indicating east-side enrichment from agricultural lands and from the parking lot. Nitrate concentrations (< 5.0 mg/L) have been relatively low and consistent in Redmond's Pond and the underlying shallow aquifer. The slope vegetation and the lagg zone of the bog provide a natural processing of surface inputs of nitrate and phosphate. A target of 15 - 30 mg/L nitrate from the SWM (stormwater management) pond runoff would reflect pre-development conditions (BioLogic 1999). Phosphate concentrations from the SWM pond runoff were established at a target of 0.5 mg/L. The outlet for the SWM pond is shown on Map 6.

4.3 Conductivity

Historical conductivity measurements available from 1979, 1990 and 1991 (UTRCA 1992) and 1998 - 2000 (BioLogic 2001) show a small but steady increase in the geometric mean conductivity in Redmond's Pond. Literature values for conductivity within bog waters are less than 80 µmhos/cm. In 1991, the maximum value recorded in Redmond's Pond was 60 µmhos/cm and in 1998 it was 70 µmhos/cm. Mean values for Redmond's Pond reflect typical bog water concentrations. However, conductivity levels of the shallow groundwater wells located in a transect from Redmond's Pond to the lagg zone ranged from 365 to > 600 µmhos/cm and reflect non-bog water conditions. Generally, the trend shows an increase of conductivity radiating outward from the bog to the margins, as indicated by this following series of measurements:

- well 1: 375 µmhos/cm,
- well 2: 525 µmhos/cm,
- well 9: 550 µmhos/cm,
- well 14: 575 µmhos/cm, and
- well 15: >600 µmhos/cm.

Map 5 shows the locations of the wells. Surface flow channels were measured at the north entrance and eastern tablelands and showed a range of conductivity from 319 - 588 µmhos/cm. A maximum target for conductivity of 500 µmhos/cm was established for the stormwater management pond discharge (BioLogic 1999).

4.4 Calcium

Literature suggests that an elevated pH in combination with elevated calcium can have negative impacts on *Sphagnum* growth (Wilcox 1985). Typical concentrations of calcium for surface water (e.g. watercourses) range from 15 to 100 mg/L. The trend for calcium concentrations in Sifton Bog samples appears to reflect a gradual increase over time. Readings recorded from 1998 to 2000 showed Redmond's Pond calcium levels were 10 mg/L on average, with a range of 3 - 31 mg/L, which reflects a transitional bog water calcium level. Calcium levels at the five shallow groundwater aquifer wells were in the range of 75 - 125 mg/L, reflecting non-bog water conditions. The calcium values were as follows:

- well 1: 75 mg/L,
- well 2: 95 mg/L,
- well 9: >100 mg/L,
- well 14: 125 mg/L, and
- well 15: 125 mg/L.

Map 5 shows the locations of the wells. The surface flow channels had a calcium level in the range of 36 - 81 mg/L, which are non-significant. A maximum target for calcium discharge from the SWM facility was established at 80 mg/L (BioLogic 1999).

4.5 Chloride

The trend analysis for the shallow groundwater samples taken from the tableland between January and June 1999 shows highest chloride concentrations in wells 2 and 14, which are near St. Aidan's church parking lot and the Oxford Street bog entrance. These levels support the theory that there may be occasions when the surface water can travel to the bog centre. This was especially evident in 1993 when the highest chloride levels recorded in the bog were observed during a year when the water levels were high. Values of chloride also exhibit spikes from single source inputs such as snow melt and pool water discharges in the fall. No specific target was established for chloride, which is to be controlled by directing all paved and road surface water away from the bog, particularly in wet years where a low bog/aquifer hydraulic gradient permits surface runoff to move towards the interior of the *Sphagnum* mat (BioLogic 1999).