Restoration of Burns Bog, Delta, British Columbia, Canada

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Summary

Over the past 70 years, Burns Bog, the largest raised bog on the west coast of the Americas, was degraded by peat extraction, draining, and deposition of mineral and other fill. Acquired in 2004 by government, the bog is being restored with hydrology as the principal focus. A comprehensive piezometer network has been established and is being monitored. Drainage ditches are being blocked to increase the retention of winter rain into the dry summer. Restoration goals are to return a high water table in the bog, to re-establish *Sphagnum* cover, and to re-start the peat forming process in degraded sectors. Three years of vegetation plot data reveal that new *Sphagnum* colonies have become established, a first indication that the water table is rising and that peat-forming vegetation may be responding positively.

Key index words: raised bog, hydrology, ecology, restoration, British Columbia

Introduction

Globally, raised or domed bogs are recognized as hydrologically and ecologically unique systems (Rydin and Jeglum, 2006). European raised bogs are of major interest and conservation concern and are a focus of restoration efforts (e.g. Schouten, 2002). The moist and cool-mild climate of northwest North America sustains extensive zones of peatlands (MacKenzie and Moran, 2004) among them the largest raised bog on the west coast of the Americas, Burns Bog (Hebda *et al.,* 2000) (Fig. 1). Following public concern and a major scientific review (Hebda *et al.,* 2000) Burns Bog was purchased by a consortium of Federal, Provincial, Regional and Municipal governments to be maintained in perpetuity as an ecological conservancy area. The bog's ecological integrity faces challenges resulting from decades of peat extraction, drainage, filling, agriculture, and urban and industrial use. As part of a management strategy, ecological and hydrological monitoring and restoration have begun in the bog (Munson and Hebda, 2005; Whitfield *et al.,* 2006).

Burns Bog is a large oval-shaped peat mass developed over the last 3500-4000 years on silt and fine sand top-set sediments of the Fraser River Delta (Hebda, 1977). The bog originally had an area of about 48 km^2, with the peat mass standing 4-5 m above sea level compared with 0.5-1.0 m for the adjacent delta surface. During the 20th century the bog's area was reduced to about 30 km^2 following extensive harvesting and conversion, and an average elevation closer to 2-3 m above sea level with west and south portions remaining unexcavated.

Pre-disturbance vegetation consisted mainly of a lodgepole pine (*Pinus contorta*)-heath- *Sphagnum* raised bog community, characterized by dwarf pines, Labrador tea (*Ledum groenlandicum*) and a suite of hummock, hollow, and lawn-forming *Sphagnum* species (Hebda *et al.,* 2000). The lagg zone of Burns Bog was originally complex (Whitfield *et al.,* 2006) and was occupied by hardhack (*Spiraea douglasii*), hardhack and sedge thickets, and mixed conifer forests in transition to widespread delta-top, minerotrophic wetlands (Hebda *et al.,* 2000). The inferred water table position fluctuated between 0-0.5 m below the surface over the year supporting typical acrotelm-catotelm subsurface structure (Hebda *et al.*, 2000).

One hundred years of peripheral drainage and lowering of the bog surface favoured widespread expansion of Pine-

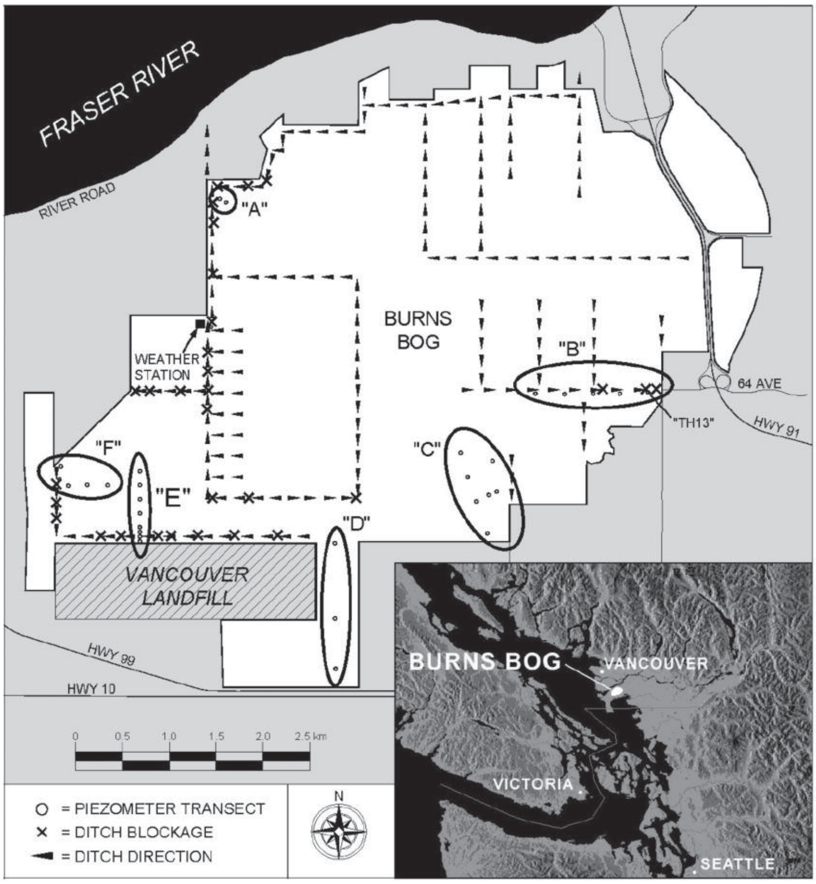

Figure 1. Burns Bog, showing locations of piezometer transects (A-F), weather station, ditch network, and ditch blockages. Vegetation plots are associated with Transect E, and with control sites at Transect C. Inset map: Location of Burns Bog in Delta, British Columbia, Canada.

salal (*Gaultheria shallon*) forest and invasion of non-bog trees such as western hemlock (*Tsuga heterophylla*). Extensive birch woodland arose and expanded particularly on burned and cleared sites. The lagg zone was especially impacted by filling and conversion to agriculture such that little of it remains intact today either ecologically or hydrologically. The water table near the bog margins was sharply lowered, and it now declines to more than 1.0 m below the surface in the Pine-salal zone. The result is a patchwork of regenerating plant communities of various ages (Hebda *et al.,* 2000).

Blocking of ditches began in 2002, with intensified efforts after acquisition of Burns Bog in 2004. The purpose was to raise the water table in the peat mass, kill off the bog edge Pine-salal forest and re-activate *Sphagnum* growth in the forested zone. Previous observations indicated that abandonment and natural blockage of old ditches had fostered *Sphagnum* growth in pine forest and the decline of tree growth (Hebda, 1977). A program of systematic monitoring of water levels and plant communities, especially *Sphagnum* growth, was begun in 2005 to verify that bog recovery was indeed taking place in response to ditch blocking.

Methods

Hydrology monitoring and management

A comprehensive network of piezometers was installed in the bog beginning in 2005 (Fig. 1). These comprise slotted PVC tubes that are attached to steel rods, which are driven into the underlying silt layer, enabling measurement of water levels and the bog surface, relative to mean sea level. In this paper, we report in detail on one transect ('E') that runs from the interior to the edge of the bog where it meets a large peripheral ditch, and one piezometer ('TH13') which is influenced by an above-bank blockage on an internal ditch located within the bog.

The purpose of ditch blocking is to reduce overall drainage and sustain a high summer water table. At first mainly peripheral ditches were blocked using steel V-notch weirs, then in 2007 widespread ditch blocking focused on major interior ditches using wood/peat dams. Below-bank damming (e.g. steel weirs) does not overflow the bank of the ditch, but above-bank damming (e.g. wood/peat dams) overflows the bank and floods the adjacent bog surface.

Vegetation monitoring

One vegetation transect and one cluster of plots were established in spring 2005 to monitor changes. The transect of 40 1 x 1 m plots is designed to detect vegetation and hydrological responses to damming of drainage ditches in the southwest corner of the bog next to the Vancouver Landfill where most of the intact peat-forming vegetation remains. The 700 m transect extends N-S from bog edge Pine-salal forest to mixed *Rhynchospora–Sphagnum* and Pine-low shrub-*Sphagnum* communities. The cluster of 10 1x1m control plots is located in the southeast part of the bog in Pine-low shrub-*Sphagnum* vegetation, (no nearby water table manipulation), to record natural variation as control for the transect (Fig. 1). In the transect, 10 clustered plots were placed in each of: Pine-salal forest and Pine-high shrub-*Sphagnum*, Pine-low shrub-*Sphagnum*, and *Rhynchospora–Sphagnum* communities.

Recognising *Sphagnum* as an indicator, we used two approaches to measure its response to raised bog water levels. In the Pine-salal zone, there is almost no *Sphagnum*, so we assessed new colony appearance by measuring the distance from a fixed point to the nearest *Sphagnum* colony and the appearance of *Sphagnum* in the sample plots themselves. In the other three vegetation types, we estimated changes in *Sphagnum* percent cover for the three most common species (*Sphagnum capillifolium, Sphagnum tenellum, Sphagnum papillosum*) and other attributes (Munson, 2005). Separate permanent plots were established to measure *Sphagnum* growth in hollows and in hummocks. We also measured the distance from a fixed point to the periphery of selected *Sphagnum* colonies to detect growth (expansion) of colonies over time. Percent cover of each of the herbaceous species on the plots was also estimated. For *Sphagnum* hummock sites, the vegetation quadrat grid served to locate the placement of nine crank wires into the surface of the hummock, according to methods of Clymo (1970) and used to measure vertical hummock growth.

Results

Hydrology monitoring and management

Figure 2 illustrates water level and bog surface elevations from September 2005 to February 2008 for one of the piezometer transects (E). Piezometer '05-01' is at the outer edge of the bog, adjacent to the ditch separating the bog from the Vancouver Landfill; the piezometers then run numerically toward the centre of the bog, with '05-08' being at the most interior location. The water levels and bog surfaces fluctuate seasonally, with the highest levels in the wet winter months, and the lowest levels at the end of summer (Whitfield *et al.*, 2006). The amplitudes are greater at the drier, forested edge of the bog, compared to the interior sites with more typical raised bog vegetation. The positive changes in surface elevation associated with raised water levels during winter are believed to be 'mire breathing' (Whitfield *et al.,* 2006).

In 2007 the moisture deficit volume, the extent to which the water level drops below the acrotelm, assumed to be 50 cm thick in Burns Bog (Hebda *et al.,* 2000), declined compared to previous years (Fig. 2). The moisture deficit

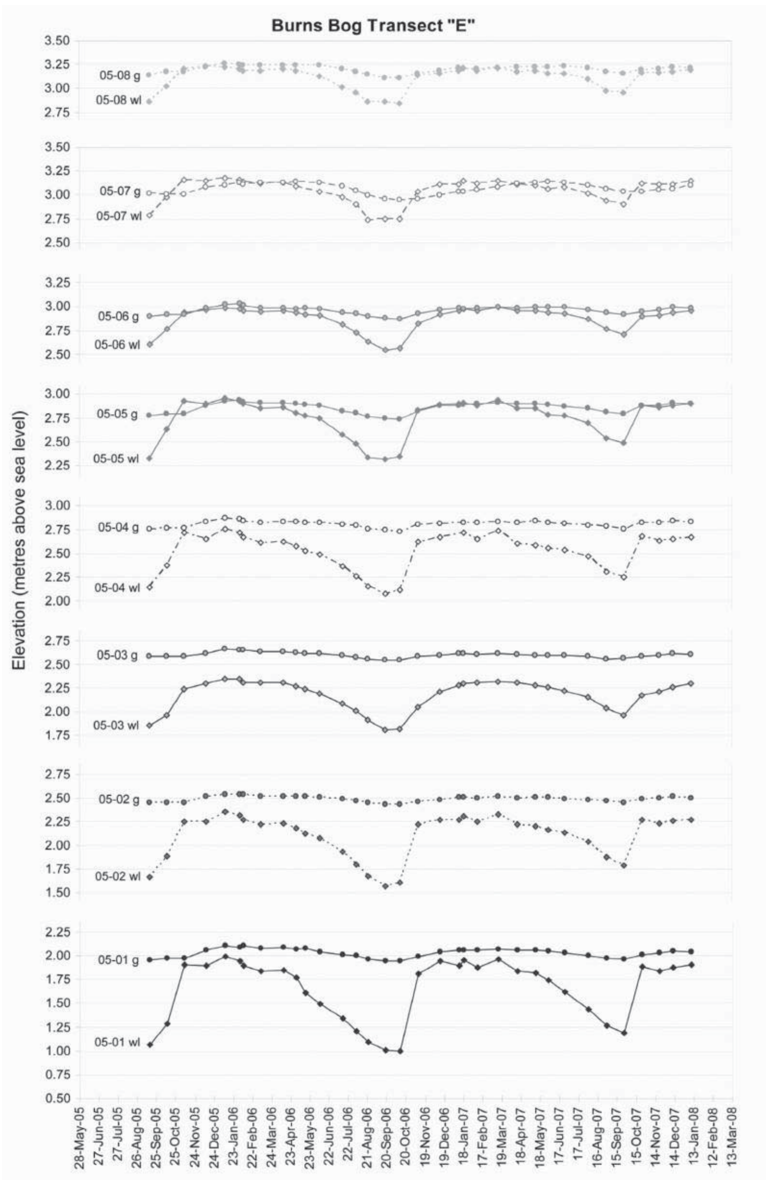

Figure 2. Bog surface (circles) and water level (diamonds) elevations for eight piezometers (Transect E). These stations are ordered downwards from the bog centre (at the top) to the margin (close to a large ditch).

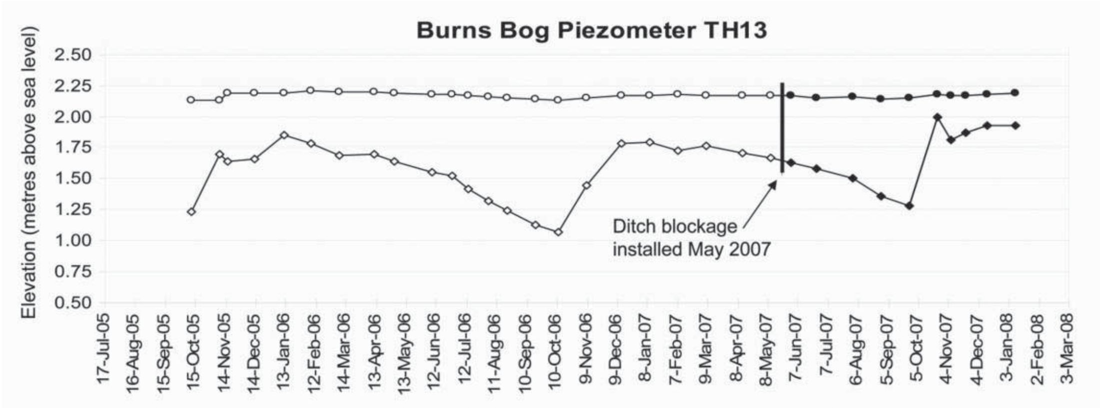

Figure 3. Bog surface (circles) and water level (diamonds) elevations for piezometer TH13; September 2005 – February 2008. Solid symbols indicate the period following blocking of the ditch.

interval, the time when water table drops below the acrotelm, decreased. Water levels in piezometers near the centre of the bog remain within the acrotelm all year, whereas water levels near the edge of the bog fluctuate much more and fall deeply below the desired acrotelm depth of 50 cm in the dry summer months. This could be explained by higher permeability of the catotelm at the edge of the bog, and/or by the influence of peripheral ditch water levels.

The summer of 2007 was wetter than normal and the bog received 92 mm more precipitation during the 2007 moisture deficit season (April through September) than during the same time period in 2006. The water level in the bog was an average of 160 mm higher at the end of the moisture deficit season than during the previous summer. Increased precipitation was thus partially the cause of the higher water levels in 2007.

One of our Transect B piezometers (TH13) appears to have recorded a rise in water level caused by ditch blocking (Fig. 3). Compared to previous years the summer 2007 water levels were higher (partly attributable to high precipitation in 2007), but winter water levels were higher too, an indication of an overall rise in water level upstream of the ditch blockage. While preliminary observations suggest that *Sphagnum* has responded to the moister conditions, several more years of data are required to confirm that the ditch blocking is effective, or if the observed response was due simply to increased precipitation.

Vegetation monitoring

In 2005, no *Sphagnum* colonies grew in the plots established in the Pine-salal forest at the margin of the bog (Table 1). Between 2005 and 2007, *Sphagnum* colonised three of the 10 original vegetation plots ('new in plot') and new *Sphagnum* patches appeared at sites 'closer' to 5 other plots than in 2005.

Percent cover of *Sphagnum* on hollow plots increased significantly between 2005-2007 in 46.6% of the 30 plots in the pine-*Sphagnum* vegetation types inward from the bog margin. *Sphagnum* cover declined on 23% of the plots, with no change in cover on 30% of the plots. In the 10 control plots, *Sphagnum* cover increased in 30% of the plots, decreased in 20%, and remained unchanged in 50% of the plots.

Table 1. Example of changes within Sphagnum colonization in Pine – salal forest (Zone A)

Plot #	Distance to *Sphagnum* patch (m)		
	2005	2006	2007
PPA-01	15.7	15.7	10.3 (closer)
PPA-02	7.9	7.8	7.8
PPA-03	0.9	0.9	New in plot
PPA-04	6.9	6.0 (closer)	6.0
PPA-05	1.6	1.6 (closer)	1.6
PPA-06	17.2	10.3 (closer)	10.3
PPA-07	17.6	15.9 (closer)	16.0
PPA-08	1.8	1.8	1.9
PPA-09	0.5	New in plot	In plot
PPA-10	1.0	New in plot	In plot

Along the transect, all plots showed an average increase in vertical growth, though some *Sphagnum* surfaces decreased in height. The highest average annual vertical growth in a single plot was 4.76 cm, the lowest was 0.2 cm. The average vertical growth among all plots in the transect was 1.87 cm. Maximum vertical growth for *Sphagnum* hummocks on a single crank wire was 7.5 cm (2006-07 seasons). For control plots, average annual growth in 2007 was 1.46 cm.

Discussion and conclusion

Observations from an extensive piezometer network have indicated a water table rise, but it is not known how much of this can be attributed to ditch blocking and how much to higher than normal precipitation. Three years of vegetation data suggest that raised water levels promote the appearance of new *Sphagnum* colonies in Pine-salal forest and increase *Sphagnum* cover and hummock height in more typical bog vegetation. A longer time series is necessary to determine if there are different *Sphagnum* growth responses to increased water levels in the different ecological zones. Corresponding observations of the health and vigour of lodgepole pine trees are being made at each of the plots in the transect and at the control site.

We plan to continue blocking ditches each year until flow in ditch corridors is reduced to the point of creating a series of small ponds, with adjacent wetter mire surfaces, such that *Sphagnum* has the opportunity to establish. We will continue to monitor water levels and vegetation response to ditch blocking for several more years.

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