Streamflow and weather at the Prospect Mountain Nordic area
Woodford, Vermont
2016-2025

23 March 2022

21 March 2023

City Stream at Prospect Mountain, view to north

David P. Dethier and Jason Racela
Environmental Analysis Laboratory
Williams College

Summary

City Stream flow and water temperature have been monitored at Prospect Mtn since December 2016 and weather measurements that help support area operations at Prospect Mountain began in December 2018. At the Prospect Mountain gage (Fig. 1), elevation is ~ 2150 ft (656 m) and the drainage area is 2.5 mi^2 (6.5 km^2). Records from City Stream, a tributary of the Walloomsac River, were calculated using data from water-level sensors, calibrated by field

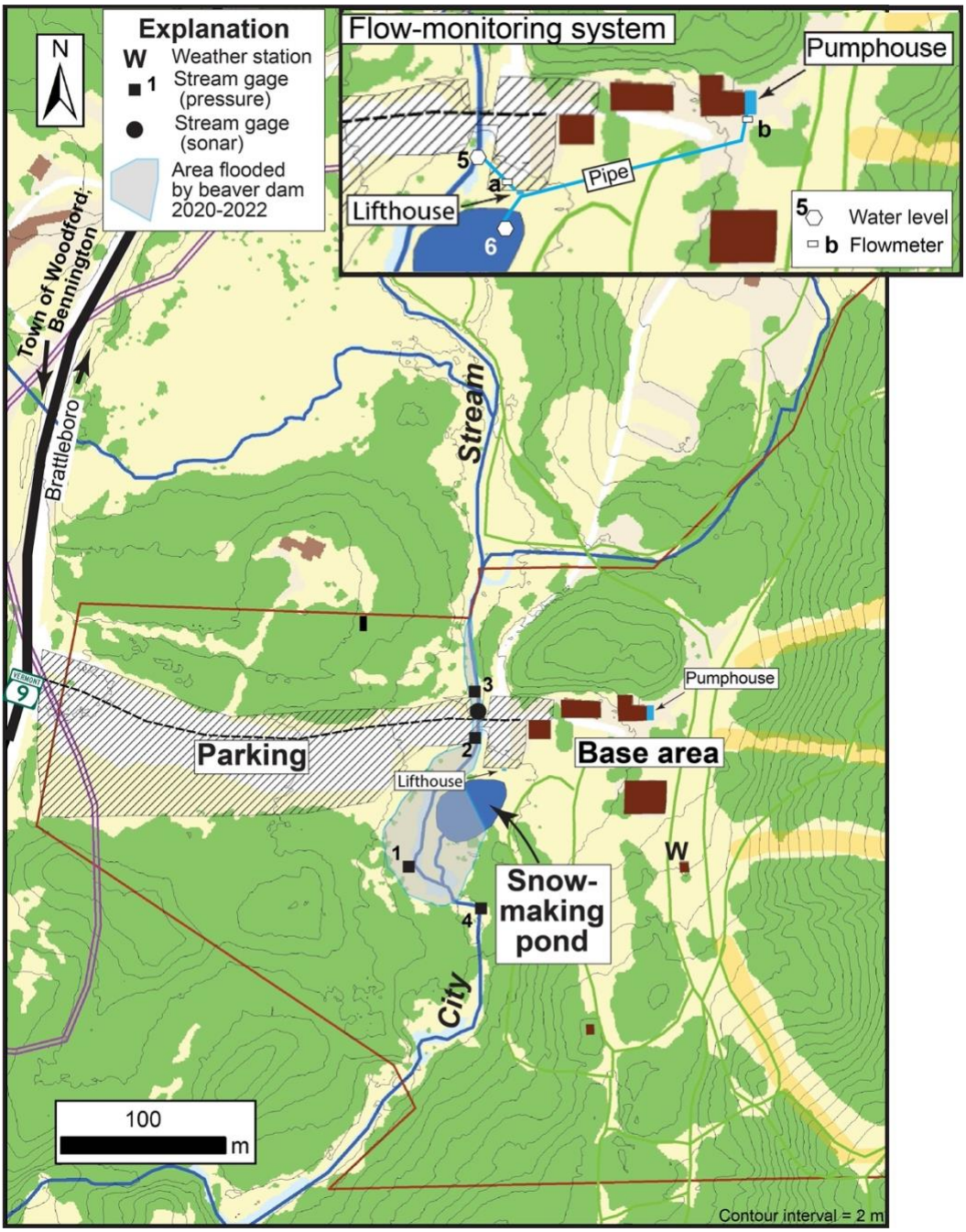

Figure 1. Map showing City Stream and the location of stream gages (1, 2, and 3 have been replaced) and weather station at Prospect Mountain.

measurements. Average daily discharge during the measurement period was ~8.5 cubic feet per second (cfs) with a minimum daily value of ~0.25 cfs and a peak flow of ≥160 cfs on 18 December 2023. Daily discharge was highly correlated with discharge measured downstream on the Walloomsac River near North Bennington Vermont (https://waterdata.usgs.gov/nwis/uv?01334000), where the drainage area is 111 mi^2. Ice on City Stream affected measurements an average of 850 hr a year between December and late March. Thaws occurred frequently during most winters, here taken as 15 December to 15 March, producing periods of high streamflow.

Average stream temperature was ~8.70 °C during the measurement period, including high temperatures >24 °C each summer. Water temperatures exceeded 21°C for an average of 650 hr each year. Between fall 2019 and late fall 2021, an active beaver dam flooded the area of City Stream near the base of Prospect Mountain, forcing relocation of stream gages and the cross-sections where discharge was measured. Installation of additional water-level recorders with the snowmaking system (12/23) is proving essential for long-term monitoring of streamflow and water withdrawals for snowmaking.

Introduction

Streamflow and weather are monitored at the Prospect Mountain Nordic area (Woodford, VT) in support of area operations, including the snowmaking system installed in the fall of 2023. Data from stream sensors are collected manually on a bimonthly basis, compiled, and stored at the Environmental Analysis Laboratory at Williams College. Data from the Prospect weather station are streamed (https://prospectmountain.com/) and stored (https://hobolink.licor.cloud/dashboards/public/55306557-f475-4d7e-850b-1f638e1988f0/true). Snowfall and precipitation are not measured at Prospect Mountain. Snowfall records from the SCAN station at Lye Brook, ~15 mi north of Prospect, help to illustrate the yearly variability of snow conditions in the southern Green Mountains (https://wcc.sc.egov.usda.gov/nwcc/site?sitenum=2042).

After an absence of ~ 15 years, beavers returned to City Stream near the base of Prospect Mountain in the spring of 2019, rebuilding and raising a dam, which they enlarged in 2020, flooding City Stream past the Prospect access road. Flooding forced us to change where we measure and monitor flow several times. Beavers abandoned the area during the fall of 2021, but the breached dam ponds flow at high discharge and during the winter when the narrow outlet freezes.

Flow and temperature measurements on City Stream

Since December 2016, water level in City Stream has been recorded hourly, using Onset HOBO pressure transducers and data loggers (HOBO Water Level U20L-04) in standpipes, supplemented by additional water-level recording beginning in 2019. After correction for atmospheric pressure variation (if necessary), data are converted to water depth. Water temperature was recorded near the stream bed every hour at the same sites as water level. Under the supervision of personnel from MSK Engineers (Bennington, Vermont), measured stream depths were converted to discharge using rating tables (Fig. 2) based on field measurements of streamflow. Since 2016, discharge has been measured ~190 times at channel cross-sections by wading and using a Price pygmy current meter, or surface floats when high flow made City Stream unsafe to wade. Discharge values <30 cfs have an uncertainty of ± 15%; discharge values >40 cfs were estimated by interpolation of the rating table and using hydraulic geometry

techniques (Mackey et al, 1998; Vermont Department of Environmental Conservation, 2006) and have an estimated uncertainty of ± 30%.

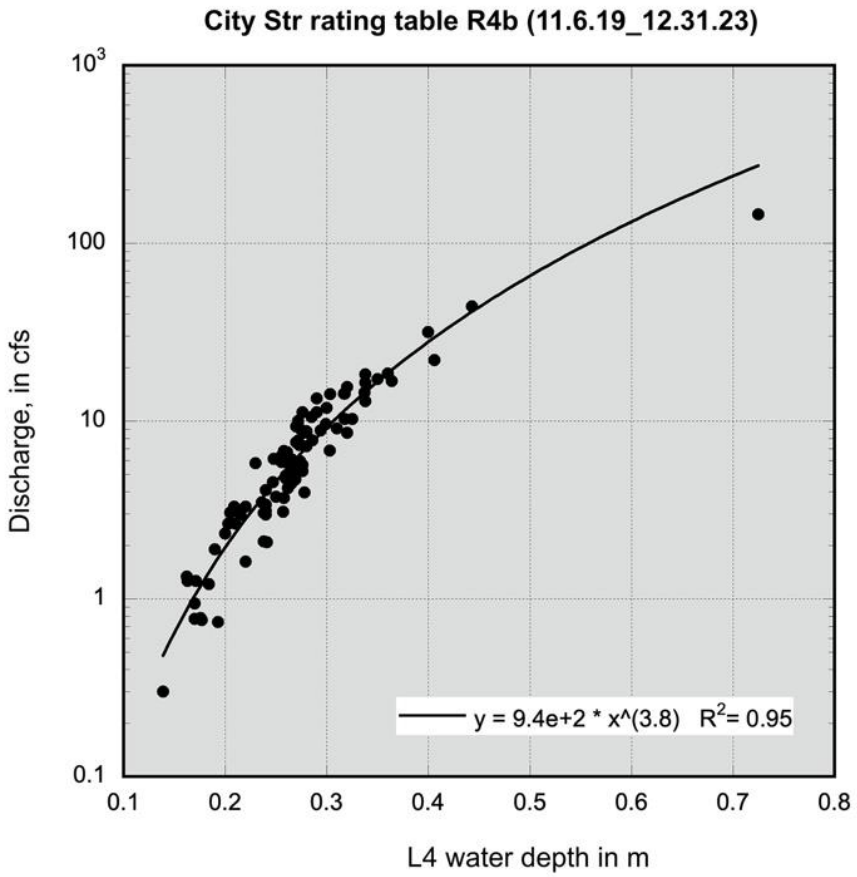

Figure 2. Example rating table (R4b) using measured discharge and stage height at site 4, downstream of the beaver dam site

The surface and edges of City Stream freeze during the winter, altering depth-discharge relationships and field measurements of streamflow were made after breaking a channel cross-section through the snow and ice cover. Discharge values during ice-over periods (an average of ~850 hr a year) were estimated after detailed analysis of measured depth data using the prorated flow method (Melcher and Walker, 1992). Missing daily values (data-logger failures 8.27-10.21.20 and 1/5-3/26/2024) were estimated from Walloomsac River records (City Stream Q = 0.0064 * Walloomsac Q ^(1.3), r^2= 0.89) (https://waterdata.usgs.gov/nwis/dv/?site_no=01334000.

We have monitored water levels at additional sites on City Stream using a down-looking sonar (beginning in September 2019) and Keller Acculevel water-level recorders (beginning December 2023) . Sonar data were transmitted using WiFi at 2.4 GHz until 2022, when we switched to radio transmission (434 MHz) from the sensor to a base station, producing a more stable signal, which is then uploaded to the internet. Since December 2023, City Stream and snowmaking pond levels (Fig. 1) have been monitored hourly as part of the Prospect Mountain snowmaking system. Data are displayed on a PLC screen in the pumphouse and downloaded manually on a monthly basis.

City Stream discharge data—Daily discharge on City Stream ranged over several orders of magnitude during the study period, with lowest flows mainly during the summer and mid-winter months; peak flows displayed no clear pattern (Fig. 3). Average daily flow during the measurement period was 8.46 $ft^3\ s^{-1}$ (cfs), equivalent to 3.38 $ft^3\ s^{-1}\ mi^{-2}$ (cfsm) with a minimum value of 0.25 cfs and a maximum of >134 cfs. Annual flow is equivalent to a runoff depth of 45" (1146 mm), consistent with the 60-70" (1524 to 1778 mm) of annual precipitation that is modeled for the City Stream watershed (https://prism.oregonstate.edu/normals/). The four highest daily flows occurred after 2022, as did some of the lowest flows. For October, November, and the winter months, measured unit discharge (Table 1) was variable, but median values

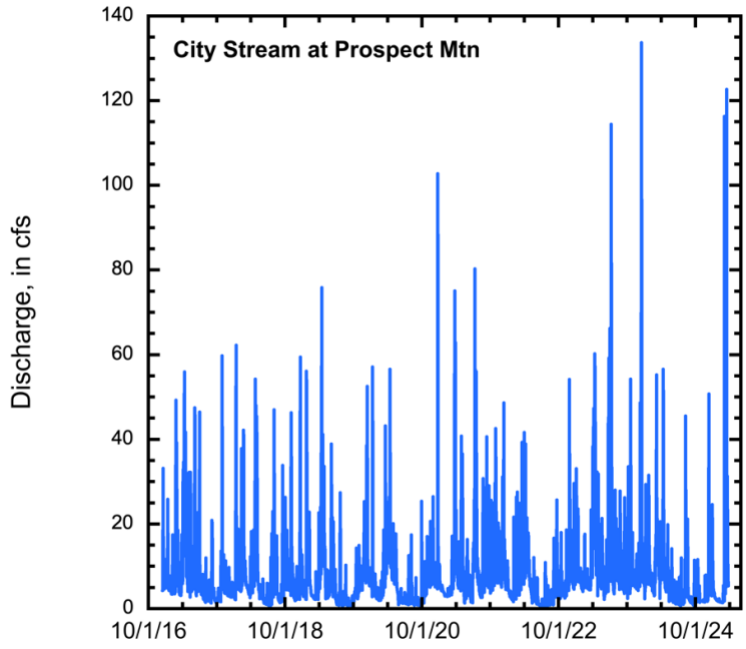

Figure 3. Plot showing daily discharge measured in City Stream at Prospect Mtn between December 2016 and April 2025.

Table 1. Daily flow on City Stream at Prospect Mountain during October, November and the winter months, 2016-2025.

Year	October			November			December			January			February			March		
	High	Low	Median	High	Low	Median	High	Low	Median	High	Low	Median	High	Low	Median	High	Low	Median
2016							13.26	1.70	2.58									
2017	23.88	0.62	0.91	5.10	1.20	1.76	3.88	1.08	1.31	10.32	1.47	2.11	19.70	1.36	1.65	15.66	1.25	2.36
2018	10.50	1.75	2.92	18.51	0.76	1.50	23.78	0.85	1.42	24.90	0.84	2.00	16.86	1.63	3.04	4.92	1.04	2.00
2019	5.73	0.62	1.48	8.57	1.66	2.92	16.28	2.13	3.16	22.44	0.86	1.60	9.11	1.18	1.98	9.05	0.87	1.04
2020	6.82	0.52	1.36	8.25	2.00	2.96	41.10	1.88	2.74	22.82	1.10	2.04	2.64	0.76	1.03	17.29	1.03	3.35
2021	17.01	1.47	2.92	11.73	2.11	3.56	19.46	1.77	3.51	4.22	1.24	1.82	1.91	1.14	1.25	30.03	1.30	2.61
2022	7.20	0.93	1.53	21.65	1.00	2.02	11.83	1.84	3.21	4.51	0.71	1.17	11.02	0.65	1.49	15.71	1.27	3.33
2023	21.69	0.96	2.40	5.17	1.88	2.63	53.48	1.72	3.56	13.21	2.18	3.24	7.05	1.62	2.11	9.35	1.77	1.97
2024	5.13	0.52	0.78	3.59	0.54	0.70	17.99	1.11	2.27	15.74	2.37	3.80	11.42	1.35	2.53	24.23	3.11	5.59
2025										5.66	1.18	1.59	4.07	0.8	1.18	6.76	1.16	4.21

All values in CFSM ($ft^3\ s^{-1}\ mi^{-2}$); measurements began in December 2016.

generally exceeded the conservation flows required for City Stream by the Vermont Department of Environmental Protection in their snowmaking flow determination letter:

"The …system will fully comply with Section 16-03 and 16-06(2) of the Rules as they pertain to new systems ….a conservation flow of 0.80 csm, or instantaneous inflow if less, shall be maintained below the City Stream withdrawal at all times. The applicant shall not withdraw any greater than 50 percent of the portion of streamflow between 0.80 csm and 1.4 csm from October 1 to November 30 and 50 percent of the portion of streamflow between 0.80 csm and 1.1 csm from December 1 to March 31. Any portion of the streamflow above the 1.4 csm or the 1.1 csm may be withdrawn up to a total diversion rate equal to the proposed diversion capacity." (from Vermont DEC flow determination letter 13 April 2017).

City Stream temperature--Stream temperature records show that City Stream warms dramatically during the summer months, reaching temperatures > 25°C during most years.

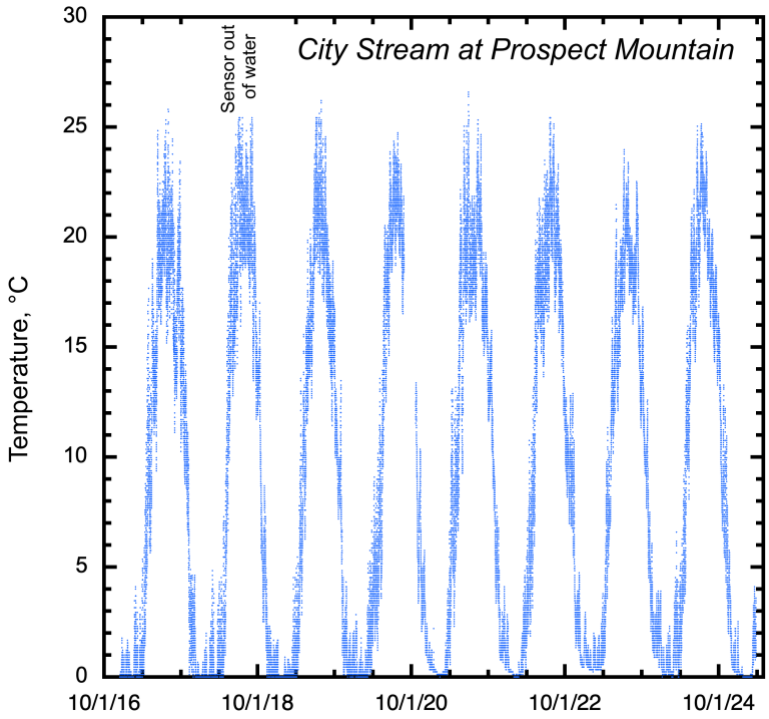

Figure 4. Water temperature near the streambed in City Stream at Prospect Mountain

Relatively shallow lakes and ponds upstream, extensive open areas and the absence of cool-water tributaries or groundwater point sources contribute to the warm summer temperatures at the Prospect Mountain site. Stream temperatures generally were <5 °C by mid-November.

Prospect Mountain weather

Temperature, wind speed and direction, relative humidity, dew point temperature and barometric pressure were sampled at 10-minute intervals using a HOBO RX3000 weather station mounted on the Prospect timing building at an elevation of ~2180 ft (664 m). Wet-bulb temperatures were estimated from these data. Weather data are streamed and plotted on the Prospect Mountain web site (https://prospectmountain.com/). Temperature and wind speed during the measurement period, summarized in Table 2, show that Prospect Mountain is a cool,

relatively windy spot. Regional data demonstrate the need for snowmaking to compensate for variable snowfall and frequent winter thaws. We do not measure precipitation or snowfall at Prospect, but PRISM data (https://prism.oregonstate.edu/normals/) suggest that mean annual precipitation is between

Table 2. Summary of temperature and wind speed measured at Prospect Mountain, 2018-2025

Year	Average temperature, °F	Highest temperature, °F	Lowest temperature, °F	Average temperature on coldest day, °F	Peak wind gust, in mph	Average daily wind gust, in mph	Average daily wind, in mph
2018*		53.5	-3.3	9.88	29.9	8.7	
2019	41.3	85.4	-16.1	-11.2	47.8	17	2.65
2020	43.76	87.8	-17.5	4.2	42.6	16.8	2.48
2021	43.1	86.2	-13.6	-1.3	38.8	16.3	2.5
2022	38.4	88.7	-17.9	-9.1	38.8	16.2	2.61
2023**	44.1	85.2	-24.8	-22.4	33.6	15.8	2.4
2024	44.4	86.5	-13	-0.94	43.3	16.1	2.4
2025***	22.8	65.1	-19.5	-6.95	38.8	21	3.9

* Record for December only

**10-minute average values for daily wind gust after 3/22

*** 1 January-31 March

60 and 70” (1524 to 1778 mm). Snowfall at Prospect probably exceeds 100” in most years; peak midmountain snowpack depth generally reaches 25 to 40”. Measurements at the Lye Brook snow course, a slightly drier site 15 mi (27 km) north of Prospect, illustrate the yearly variability of snow conditions (Table 3) in the southern Green Mountains and highlight the thin snowpack during 3 of the past 4 winters. Winter losses are substantial in most years.

Average winter temperatures and snowfall should result in relatively low, declining discharge in City Stream after mid-December. However, thin snowpacks, extended winter thaws, and rain events that produced discharge peaks (Fig. 5) occurred frequently during the period of measurement. Data in Table 3 suggest that in the present climate, substantial winter melt of the snowpack may be typical of small, mid-elevation watersheds in central and southern New England.

The winters of 2020-21and 2024-25 were exceptional. After the early winter snowpack melted on 24-25 December 2020, flow in City Stream was stable and ski conditions at Prospect Mountain were excellent from mid-January until ~15 March, when the thin snowpack

Table 3. Snow measurements at the Lye Brook site, 2008-2025.

Snowfall season	Accumulation* (1 November-1 May), in inches	Days with <4" on ground (15 December-15 March)	Winter loss** (15 December-15 March), in inches	Maximum depth, in inches
2008_09[1]	93	8	53	34
2009_10	93	0	41	44
2010_11	104	0	67	33
2011_12	50	32	34	14
2012_13[2]	62	7	33	20
2013_14[3]	48	15	25	21
2014_15	88	0	46	42
2015_16	27	51	22	10
2016_17	106	0	48	31
2017_18	164	6	94	44
2018_19	94	0	41	26
2019_20	73	4	37	26
2020_21	70	10	41	34
2021_22	65	40	56	11
2022_23	90	21	43	39
2023_24	94	25	43	23
2024_25	101	0	42	32

* Calculated from data collected at Vermont (AST) SCAN Site Lye Brook (Bennington County, (43°3'N, 73° 2' W, 2435 ft) - NRCS National Water and Climate Center - Provisional Data - subject to revision. https://wcc.sc.egov.usda.gov/nwcc/site?sitenum=2042 https://wcc.sc.egov.usda.gov/nwcc/site?sitenum=2042

**Calculated as the difference between accumulation and snow depth; includes compaction and melt

[1] First 10 months missing

[2] Missing 10 days in February

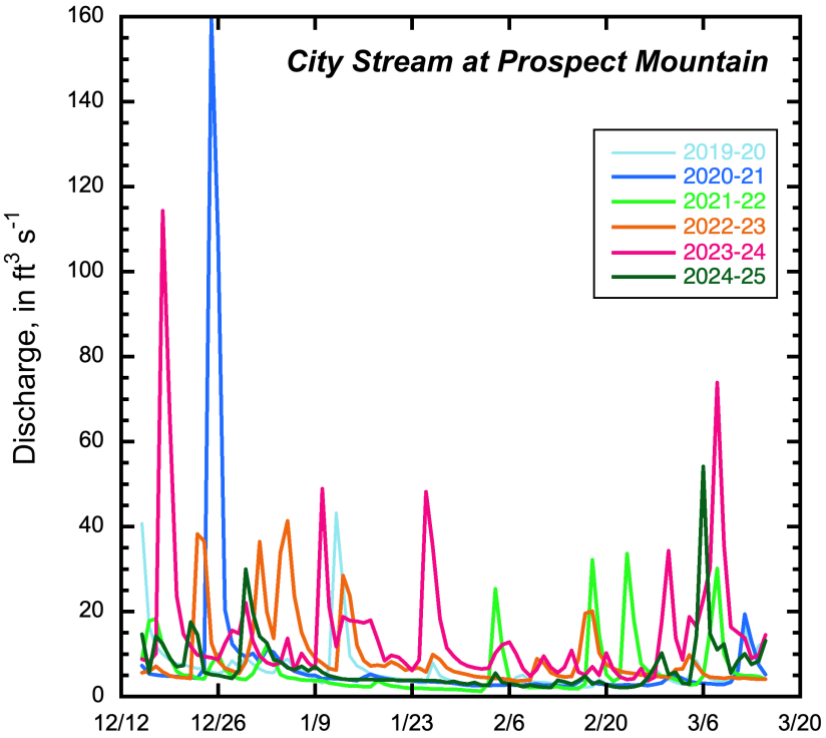

Figure 5. Selected winter discharge records for City Stream from 15 December to 15 March

melted during an extended period of late winter warm weather. The winter of 24-25 provided a superb ski season that began with early snow, weakened after 3 extended thaws in December, but recovered with nearly continuous cool weather and moderate amounts of snow until ~6 March, when a series of thaws effectively ended the season. The winters of 2022-23 and 2023-24 both were typical of many recent winters, marked by warm temperatures and extended thaws in January and February. However, snowmaking provided a thaw-resistant base in the stadium area in 2024, allowing youth programs, recreational skiing and racing events to take place despite the thin cover of natural snow.

Snowmaking at Prospect Mountain 2023-2025

After years of planning and construction, the Prospect Phase 1 snowmaking system began producing snow on 20 December 2023; Phase 1a was complete in late 2024. The system consists of 1.2 km of pipe and electric cable, and water circulation consisting of a roughing, lift and main pump that connect City Stream, the snowmaking pond and 16 hydrants (Fig. 6). Pond storage is 380,000 gallons and maximum pumping rate is 250 gpm. Three-phase power is provided by a rented diesel generator. Total snowmaking coverage is potentially ~5.8 acres, mostly near the

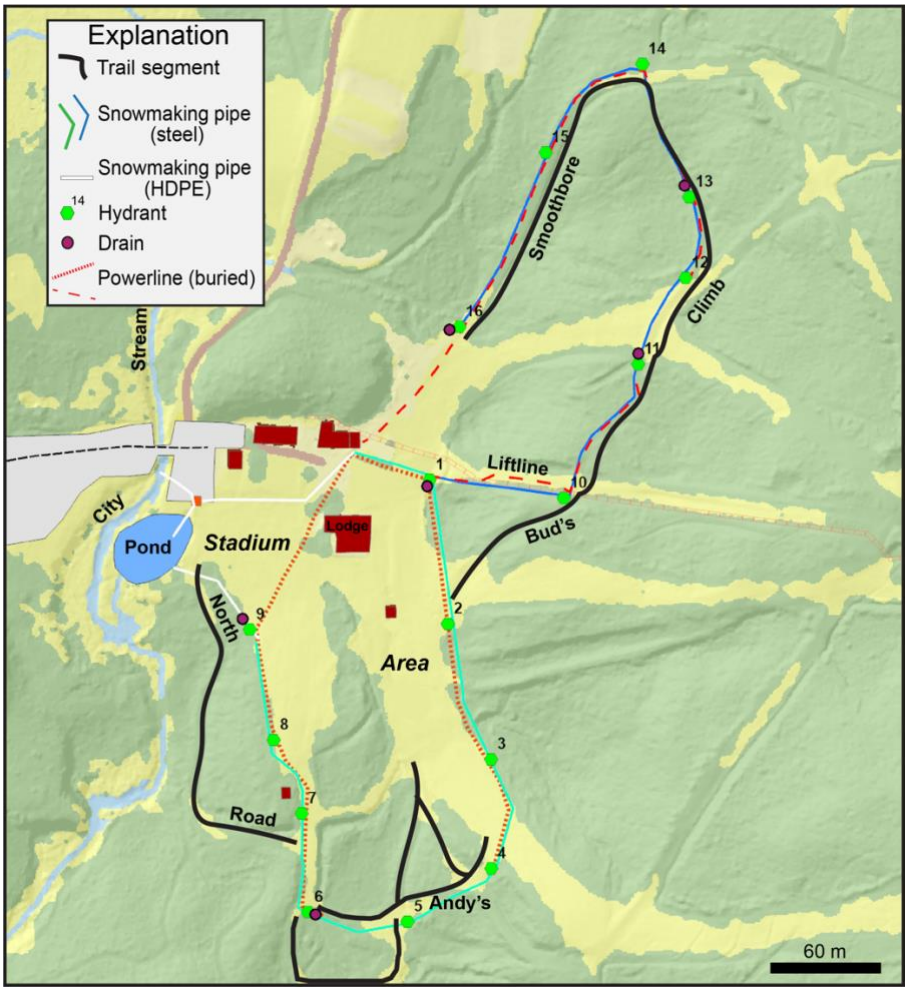

Figure 6. Prospect Mtn. snowmaking system and associated trail segments.

Lodge and includes ~ 2 km of trail, served by 3 snow guns that are moved using the groomer. In the winter of 2023-24, 1.08 million gallons was pumped from the snowmaking pond on 8 days during 90 hrs of snowmaking by Prospect staff and volunteers. Coverage was limited to areas in and near the stadium and reached by hydrants 1-9. In 2024-25, 0.8 million gallons was pumped from the pond during 82 hours on 8 days by Prospect staff and volunteers. The area covered was extended to include Bud's Climb and Smoothbore, but was less extensive than 2024 in the stadium area (Fig. 7). Because the fall and early winter of 2024-25 were exceptionally dry, pumping from the stream into the pond was limited at times by the terms of our withdrawal permit. Snowmaking provided much needed "insurance" for the stadium area used by all skiers, particularly our youth programs, but was hampered by equipment malfunctions and by the many additional demands on Prospect staff time. Levelling snow mounds over areas not covered by snowmaking and grooming them took tens of hours in each year, adding additional strains to the Prospect PB-100 groomer.

Pumping from the snowmaking pond at 240 gpm produced drawdowns of 1 to 2 feet over periods of 6-8 hours, but affected stream levels by < 1" (Fig. 8). Pond recovery, mainly by

Figure 7. Two HKD fanguns and one towergun on old ropetow hill, Prospect Mountain, Winter 2025.

seepage from City Stream, occurred over periods of 5 to 10 days during the low stream levels of mid-winter 2025. Small increases of stream levels after pumping stopped likely reflect return flow from snowmaking pipes back into City Stream.

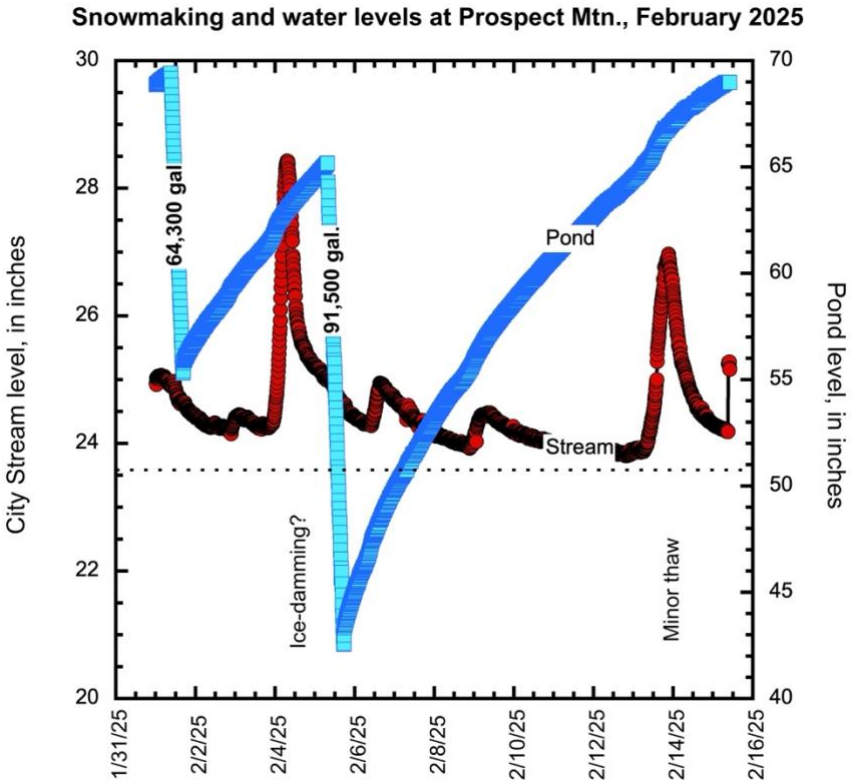

Figure 8. City Stream and snowmaking pond levels during late January and early February 2025 snowmaking. The 4" increase in stage on 2/5/2025 may reflect temporary ice-damming at the beaver-dam site.

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