
Appendix B

Balsams Resort Snowmelt Analysis
Letter Report by Horizons Engineering
July 14, 2015

and

The Snowmelt Report (6/23/98)
Joan Carlson and Stephen Fay
White Mountain National Forest
Laconia, New Hampshire

horizons Engineering Inc.

34 SCHOOL STREET • LITTLETON, NH 03561 • PHONE 603-444-4111 • FAX 603-444-1343 • www.horizonsengineering.com

July 14, 2015

Mr. Gregg Comstock, P.E.
Supervisor, Water Quality Planning Section
New Hampshire Department of Environmental Services
P.O. Box 95
Concord, NH 03302-0095

Subject: Balsams Resort –WQC 2014-404P-001 Revised Snowmelt Runoff Analysis

Dear Mr. Comstock:

In response to your comments forwarded to the Balsams team in an email dated July 7th, 2015, please find the following revised snowmelt runoff analysis for the Balsams Resort project in Dixville, NH as completed by Horizons Engineering, Inc. (Horizons):

Snowmelt Runoff Analysis Background Information
Horizons has completed an analysis of the contribution of melting artificial snow to flows in Clear Stream and the Mohawk River during storm events. This analysis was generally modeled on the methodology of a previous analysis completed for the Loon Mountain Ski Resort Development and Expansion project as part of the February 2002 Final Environmental Impact Statement (EIS) for the project. Section 4.2.1.2.5 of the Loon Mountain EIS references an approximate runoff depth from snowmelt of 0.5 inches of water per day. As land cover type and terrain within the Balsams project drainage areas are similar to those included in the Loon EIS, Horizons assumed the 0.5 inches per day of snow melt runoff referenced in the Loon EIS is an appropriate value for use in assessing snowmelt contribution for the Balsams project.

To complete this analysis Horizons used the New Hampshire StreamStats Internet-based regression analysis tool maintained by the United States Geological Survey to model 2-year through 500-year storm events at three locations in the Clear Stream watershed and one location in the Mohawk River watershed. An Excel spreadsheet was created for the analysis locations using the modeled storm event output from StreamStats, and the estimated acreage for ski trails at full build out in each watershed.

The spreadsheet was used to compare flows under three separate scenarios, including:

1. No snowmelt contribution;
2. Contribution from uniform snowmelt from a snowpack covering the entire drainage area; and
3. Contribution from melting of a residual snow pack of man-made snow covering only the ski trails.

The third scenario assumes that the additional depth of manmade snow on the ski trails will take longer to melt than the natural snow pack, and therefore will contribute to runoff after the surrounding natural snowpack has completely melted. For the purposes of this exercise it was assumed that man-made snow would cover a total of 800 acres of ski terrain in the Clear Stream watershed, and 400 acres in the Mohawk River watershed. This is likely a conservatively high estimate of snowmaking coverage.

Snowmelt Analysis
The results of the four analyses are summarized as follows:

Location 1 - Clear Stream at the Dixville / Millsfield Boundary
This location was chosen to represent the highest point within the Clear Stream drainage basin that would receive runoff from all ski trails within the Clear Stream watershed. The point is also approximately concurrent with the easterly down-stream limit of the project area.

Results indicate that for a 5 year storm event StreamStats estimates a flow of 710 cubic feet per second (cfs) at the analysis point. If one were to assume that snowmelt occurred during this 5 year flow event, adding 0.5 inches of runoff resulting from the melting natural snowpack from the entire drainage basin above the analysis point adds an estimated 146.54 cfs to this flow (~21% increase). Melting of man-made snowpack on only the ~800 acres of ski trail within this watershed adds an estimated 16.81 cfs. If this melting of man-made snow were to occur during a 5 year flow event the analysis predicts a 2.37% increase in flow at the analysis point.

Location 2 - Clear Stream/West Branch Junction
This location was chosen to represent a point in the watershed where developed property was in the vicinity of Clear Stream.

Results indicate that for a 5 year storm event, StreamStats estimates a flow of 1,250 cubic feet per second at the Clear Stream/West Branch junction. If one were to assume that snowmelt occurred during this 5 year flow event, adding 0.5 inches of runoff resulting from the melting natural snowpack from the entire drainage basin above the analysis point adds an estimated 258.13 cfs to this flow (~21% increase). Melting of man-made snowpack on only the ~800 acres of ski trail within this watershed adds an estimated 16.81 cfs. If this melting of man-made snow were to occur during a 5 year flow event the analysis predicts a 1.34% increase in flow at the Clear Stream/West Branch Junction.

Location 3 - Clear Stream/Millsfield Pond Brook Junction
This location was chosen to represent a point farther down in the watershed where Clear Stream flows are significantly higher than at the project boundary.

At the Clear Stream/Millsfield Pond Brook junction, StreamStats estimates a 5 year storm event flow of 2,090 cfs. Basin-wide snow melt would be expected to result in an estimated

549.88 cfs addition to this flow (~26% increase). Melting of man-made snowpack on only the ~800 acres of ski trail within this watershed adds an estimated 16.81 cfs. If this melting of man-made snow were to occur during a 5 year flow event the analysis predicts an increase in flow of 0.8% at the analysis point.

Location 4 – Mohawk River/Hodge Brook Intersection
This location was chosen to represent the highest point within the Mohawk River drainage basin that would receive runoff from all ski trails within the Mohawk River watershed. The point is also approximately concurrent with the westerly down-stream limit of the project area.

At the Mohawk River/Hodge Brook junction, StreamStats estimates a 5 year storm event flow of 442 cfs just downstream of the junction. Basin-wide snow melt would be expected to result in an estimated 549.88 cfs addition to this flow (~25% increase) if the melting occurred during the 5 year event predicted by Stream Stats. Melting of man-made snowpack on just the ~400 acres of ski trail within this watershed adds an estimated 8.40 cfs, resulting in an increase in flow of 1.9% at the analysis point.

Flow comparisons for all four locations for 2-year through 500-year storm events are summarized on the attached table. Output tables and watershed delineations for each StreamStats analysis point are also attached for reference.

Conclusions
Results of the snowmelt runoff analysis completed by Horizons indicate that the runoff contribution from melting of man-made snow on the ski trails during storm events is a minor contribution to overall storm flows, and likely well within the margin of error of flow analysis. Modeled snowmelt from the ski trails had an increase of 2.37% of the modeled 5-year storm event in the Clear Stream drainage basin at the project boundary, and a modeled increase of 1.9% in the Mohawk drainage basin at the project boundary.

These findings are consistent with those of a similar assessment for the Loon Mountain Ski Area completed in 1998 by Carlson and Fay (Internal US Forest Service Document, Carlson and Fay, 1998). A copy of the Carlson and Fay study was provided to the New Hampshire Department of Environmental Services by Horizons under a separate cover. It should be noted that this analysis does not include assessment of flows resulting from changes in land cover type. These flows will be assessed as part of the Alteration of Terrain permitting process.

Thank you for your assistance and please do not hesitate to contact me at (603) 444-4111 if you have any questions or require additional information.

Jon L. Warzocha, P.G.
CEO
Horizons Engineering, Inc.

Att.

Cc (via email); B. Mills, E. Brisson, S. LaFrance, file

BALSAMS SNOW MELT CONTRIBUTION ANALYSIS

Location 1: Clear Stream at Dixville/Millsfield Line

Storm Event (yr interval)	StreamStats Modeled Flow (cfs)	Snow Pack Melt Contribution* (cfs)	Trail Melt Contribution* (cfs)	Snow Pack Melt % of Modeled Flow (percent)	Trail Melt % of Modeled Flow (percent)	Flow with Snow Pack Melt (cfs)	Flow with Trail Melt Only (cfs)
2.00	448.00	146.54	16.81	32.71%	3.75%	594.54	464.81
5.00	710.00	146.54	16.81	20.64%	2.37%	856.54	726.81
10.00	925.00	146.54	16.81	15.84%	1.82%	1071.54	941.81
25.00	1210.00	146.54	16.81	12.11%	1.39%	1356.54	1226.81
50.00	1440.00	146.54	16.81	10.18%	1.17%	1586.54	1456.81
100.00	1710.00	146.54	16.81	8.57%	0.98%	1856.54	1726.81
500.00	2340.00	146.54	16.81	6.26%	0.72%	2486.54	2356.81

Location 2: Clear Stream / West Branch Junction

Storm Event (yr interval)	StreamStats Modeled Flow (cfs)	Snow Pack Melt Contribution* (cfs)	Trail Melt Contribution* (cfs)	Snow Pack Melt % of Modeled Flow (percent)	Trail Melt % of Modeled Flow (percent)	Flow with Snow Pack Melt (cfs)	Flow with Trail Melt Only (cfs)
2.00	800.00	258.13	16.81	32.27%	2.10%	1058.13	816.81
5.00	1250.00	258.13	16.81	20.65%	1.34%	1508.13	1266.81
10.00	1620.00	258.13	16.81	15.93%	1.04%	1878.13	1636.81
25.00	2090.00	258.13	16.81	12.35%	0.80%	2348.13	2106.81
50.00	2470.00	258.13	16.81	10.45%	0.68%	2728.13	2486.81
100.00	2920.00	258.13	16.81	8.84%	0.58%	3178.13	2936.81
500.00	3940.00	258.13	16.81	6.55%	0.43%	4198.13	3956.81

Location 3: Clear Stream / Millsfield Pond Brook Junction

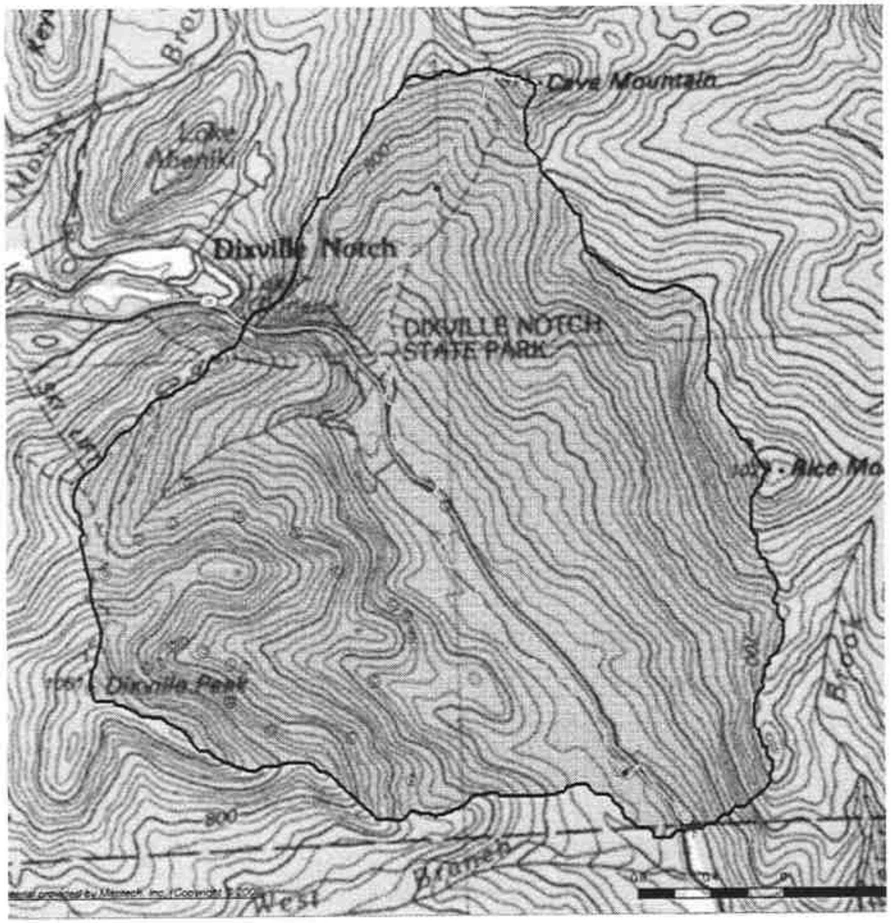
Storm Event (yr interval)	StreamStats Modeled Flow (cfs)	Snow Pack Melt Contribution* (cfs)	Trail Melt Contribution* (cfs)	Snow Pack Melt % of Modeled Flow (percent)	Trail Melt % of Modeled Flow (percent)	Flow with Snow Pack Melt (cfs)	Flow with Trail Melt Only (cfs)
2.00	1370.00	549.88	16.81	40.14%	1.23%	1919.88	1386.81
5.00	2090.00	549.88	16.81	26.31%	0.80%	2639.88	2106.81
10.00	2660.00	549.88	16.81	20.67%	0.63%	3209.88	2676.81
25.00	3390.00	549.88	16.81	16.22%	0.50%	3939.88	3406.81
50.00	3970.00	549.88	16.81	13.85%	0.42%	4519.88	3986.81
100.00	4640.00	549.88	16.81	11.85%	0.36%	5189.88	4656.81
500.00	6160.00	549.88	16.81	8.93%	0.27%	6709.88	6176.81

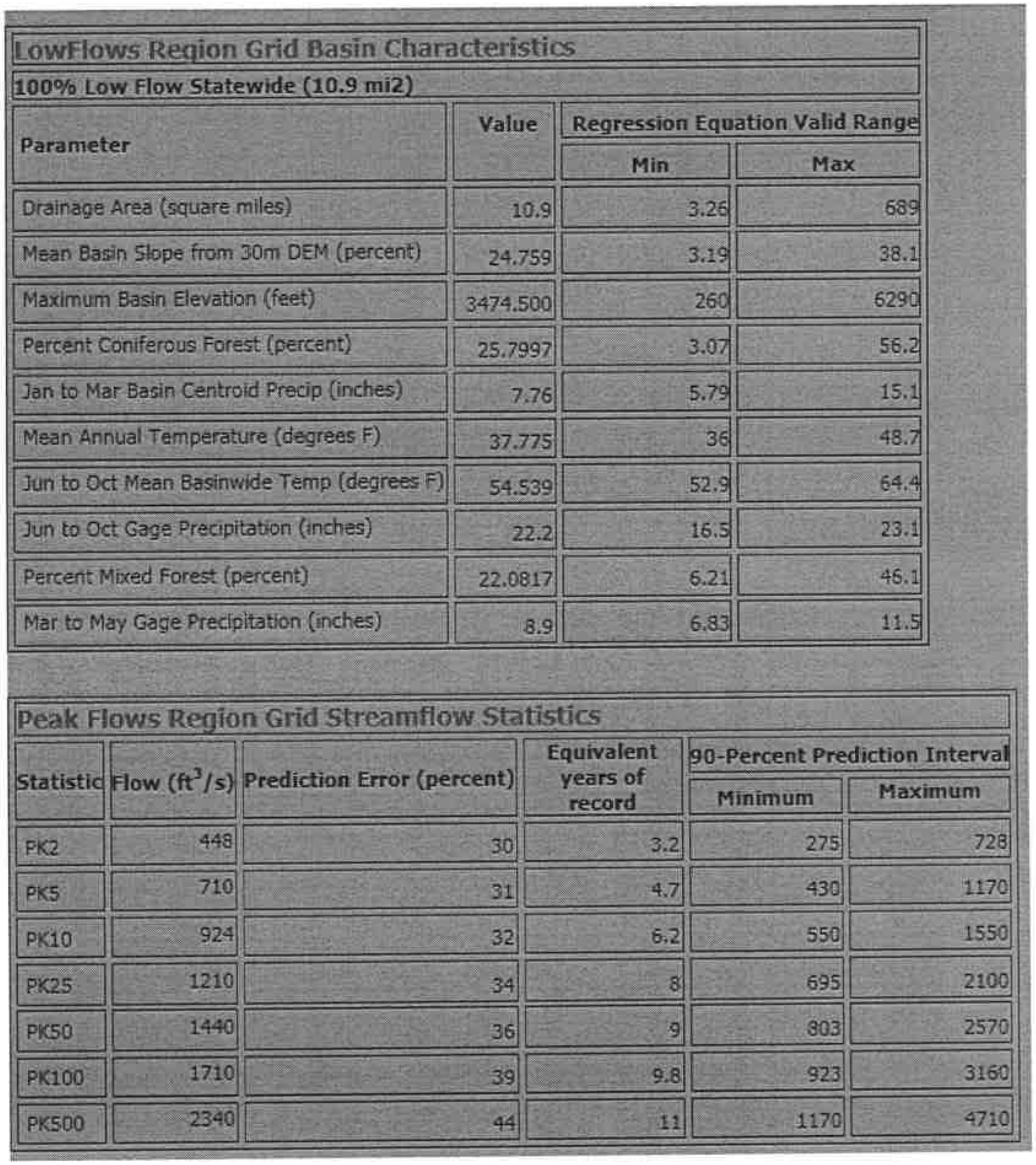
Location 4: Mohawk River at Hodge Brook Junction

Storm Event (yr interval)	StreamStats Modeled Flow (cfs)	Snow Pack Melt Contribution* (cfs)	Trail Melt Contribution* (cfs)	Snow Pack Melt % of Modeled Flow (percent)	Trail Melt % of Modeled Flow (percent)	Flow with Snow Pack Melt (cfs)	Flow with Trail Melt Only (cfs)
2.00	280.00	108.63	8.40	38.80%	3.00%	388.63	288.40
5.00	442.00	108.63	8.40	24.58%	1.90%	550.63	450.40
10.00	576.00	108.63	8.40	18.86%	1.46%	684.63	584.40
25.00	755.00	108.63	8.40	14.39%	1.11%	863.63	763.40
50.00	900.00	108.63	8.40	12.07%	0.93%	1008.63	908.40
100.00	1070.00	108.63	8.40	10.15%	0.79%	1178.63	1078.40
500.00	1480.00	108.63	8.40	7.34%	0.57%	1588.63	1488.40

* assumes melt contribution to runoff of 0.5" per day as presented in 2002 Loon Mountain EIS

Balsams Snowmelt Runoff Assessment – Location 1: Clear Stream Watershed Millsfield/Dixville Town Line

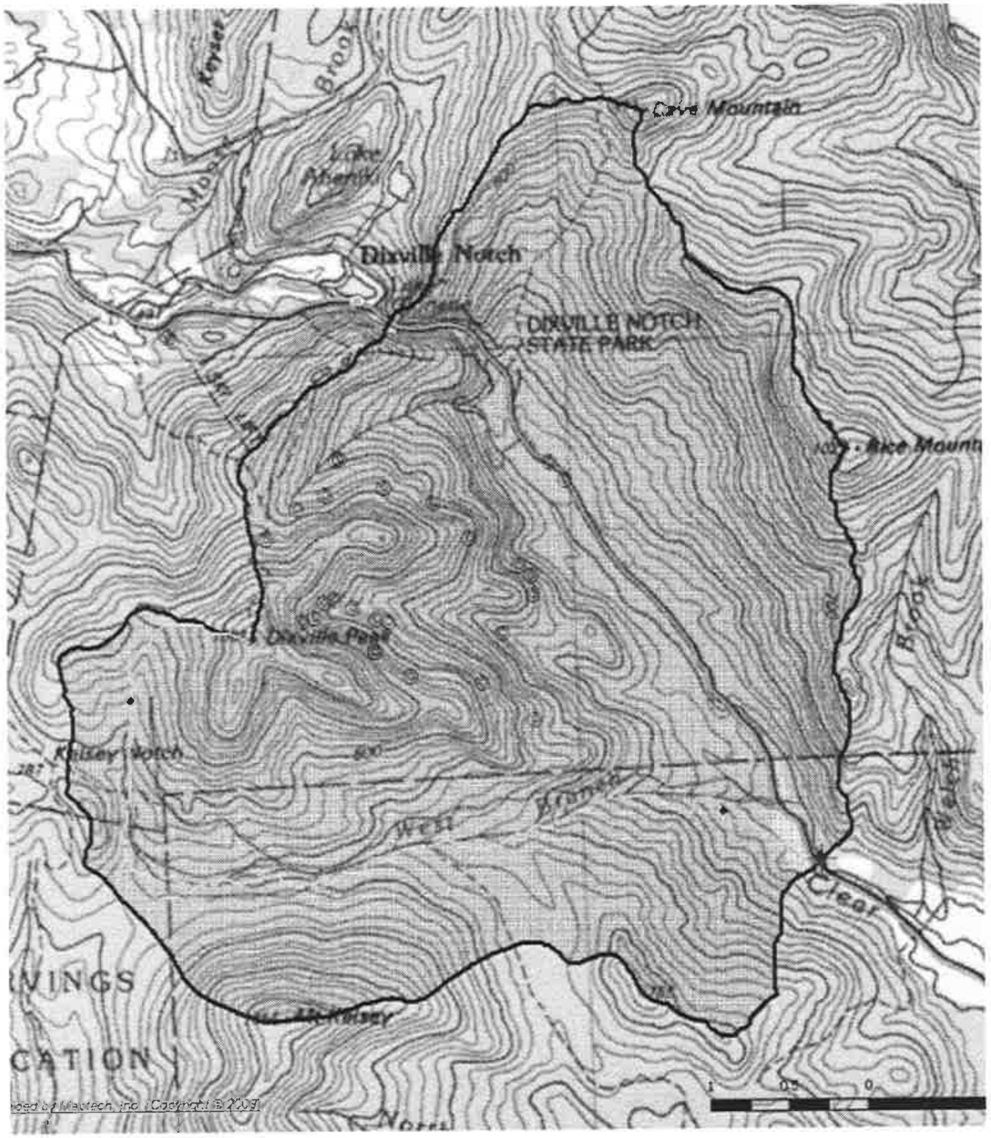


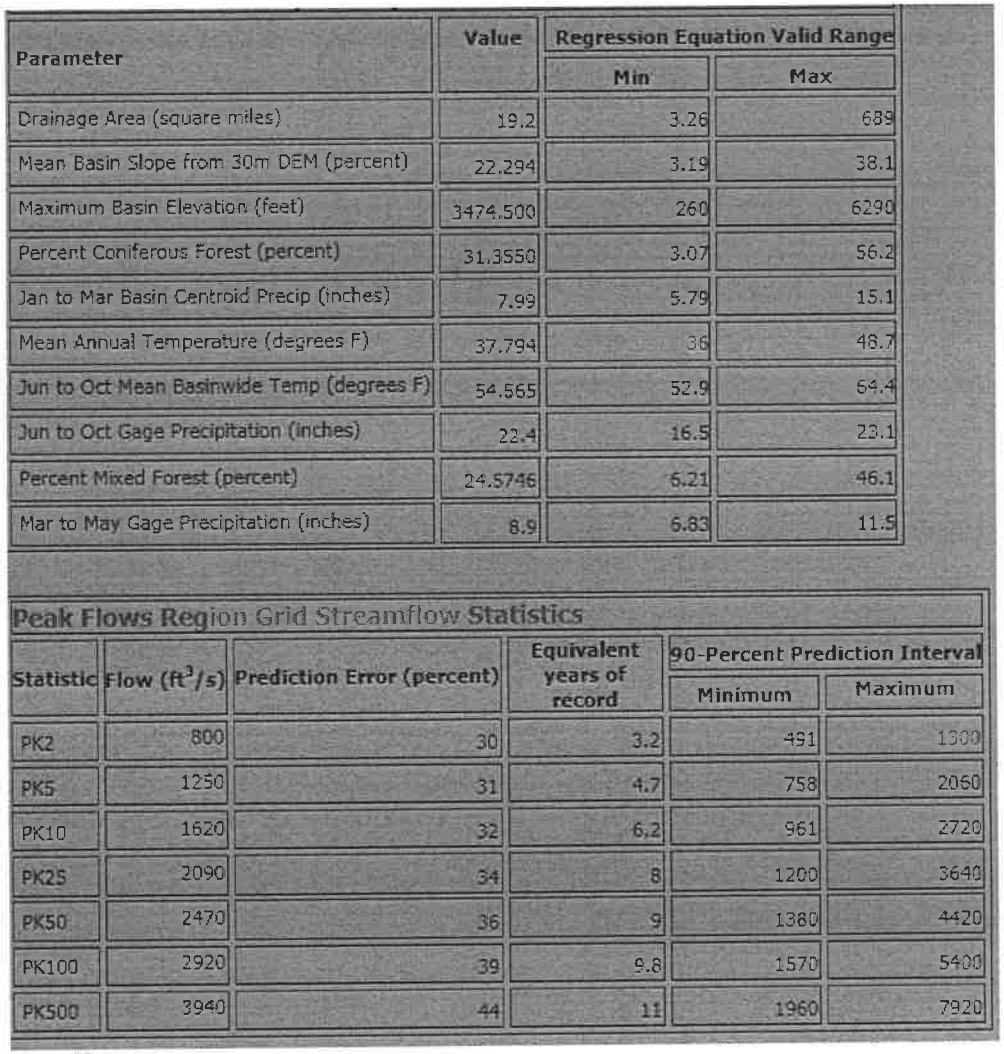


LowFlows Region Grid Basin Characteristics			
100% Low Flow Statewide (10.9 mi2)			
Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	10.9	3.26	689
Mean Basin Slope from 30m DEM (percent)	24.759	3.19	38.1
Maximum Basin Elevation (feet)	3474.500	260	6290
Percent Coniferous Forest (percent)	25.7997	3.07	56.2
Jan to Mar Basin Centroid Precip (inches)	7.76	5.79	15.1
Mean Annual Temperature (degrees F)	37.775	36	48.7
Jun to Oct Mean Basinwide Temp (degrees F)	54.539	52.9	64.4
Jun to Oct Gage Precipitation (inches)	22.2	16.5	23.1
Percent Mixed Forest (percent)	22.0817	6.21	46.1
Mar to May Gage Precipitation (inches)	8.9	6.83	11.5

Peak Flows Region Grid Streamflow Statistics					
Statistic	Flow (ft^3/s)	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
				Minimum	Maximum
PK2	448	30	3.2	275	728
PK5	710	31	4.7	430	1170
PK10	924	32	6.2	550	1550
PK25	1210	34	8	695	2100
PK50	1440	36	9	803	2570
PK100	1710	39	9.8	923	3160
PK500	2340	44	11	1170	4710

Balsams Snowmelt Runoff Assessment– Location 2: Clear Stream Watershed Junction Clear Stream and West Branch



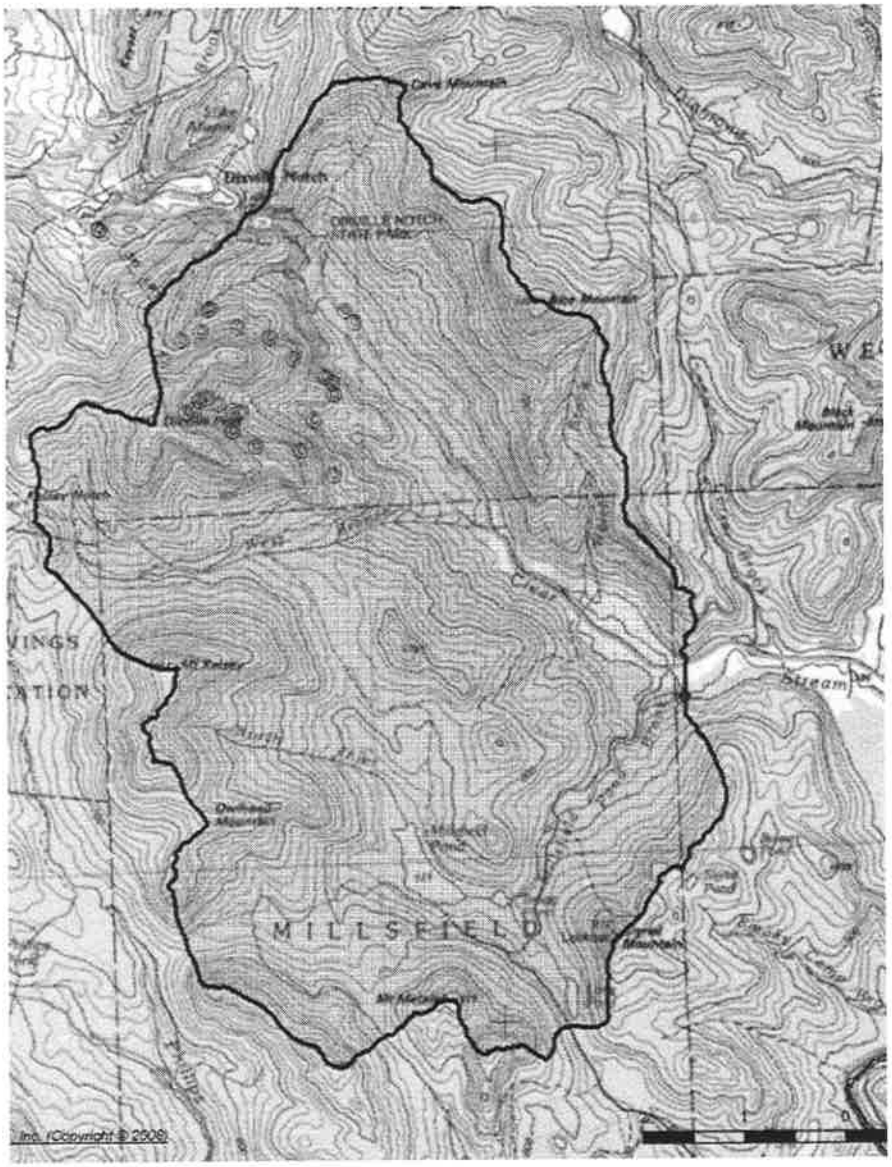


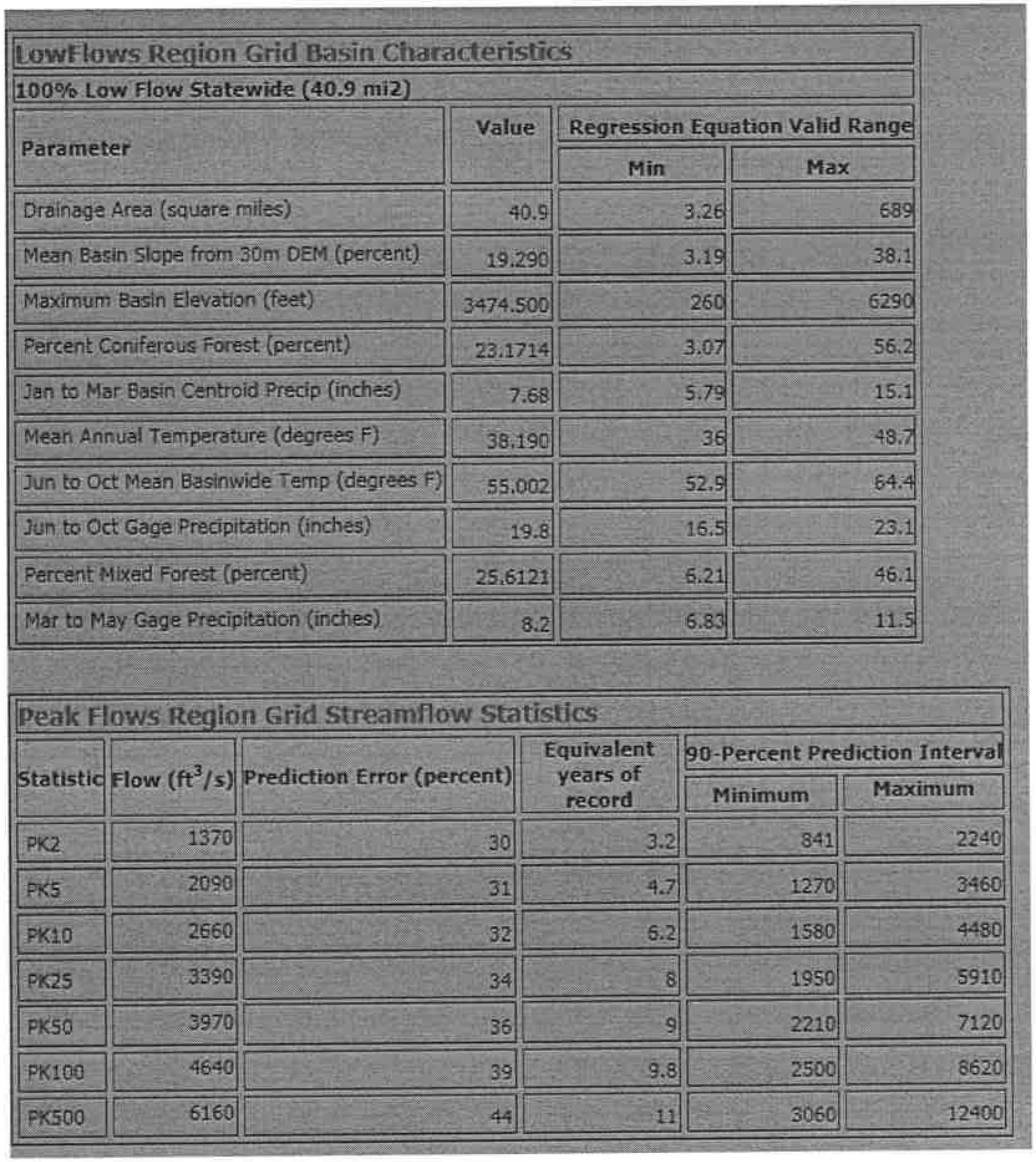
Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	19.2	3.26	689
Mean Basin Slope from 30m DEM (percent)	22.294	3.19	38.1
Maximum Basin Elevation (feet)	3474.500	260	6290
Percent Coniferous Forest (percent)	31.3550	3.07	56.2
Jan to Mar Basin Centroid Precip (inches)	7.99	5.79	15.1
Mean Annual Temperature (degrees F)	37.794	36	48.7
Jun to Oct Mean Basinwide Temp (degrees F)	54.565	52.9	64.4
Jun to Oct Gage Precipitation (inches)	22.4	16.5	23.1
Percent Mixed Forest (percent)	24.5746	6.21	46.1
Mar to May Gage Precipitation (inches)	8.9	6.83	11.5

Peak Flows Region Grid Streamflow Statistics

Statistic	Flow (ft^3/s)	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
				Minimum	Maximum
PK2	800	30	3.2	491	1300
PK5	1250	31	4.7	758	2060
PK10	1620	32	6.2	961	2720
PK25	2090	34	8	1200	3640
PK50	2470	36	9	1380	4420
PK100	2920	39	9.8	1570	5400
PK500	3940	44	11	1960	7920

Balsams Snowmelt Runoff Assessment – Location 3: Clear Stream Watershed Junction Clear Stream and Millsfield Pond Brook





LowFlows Region Grid Basin Characteristics

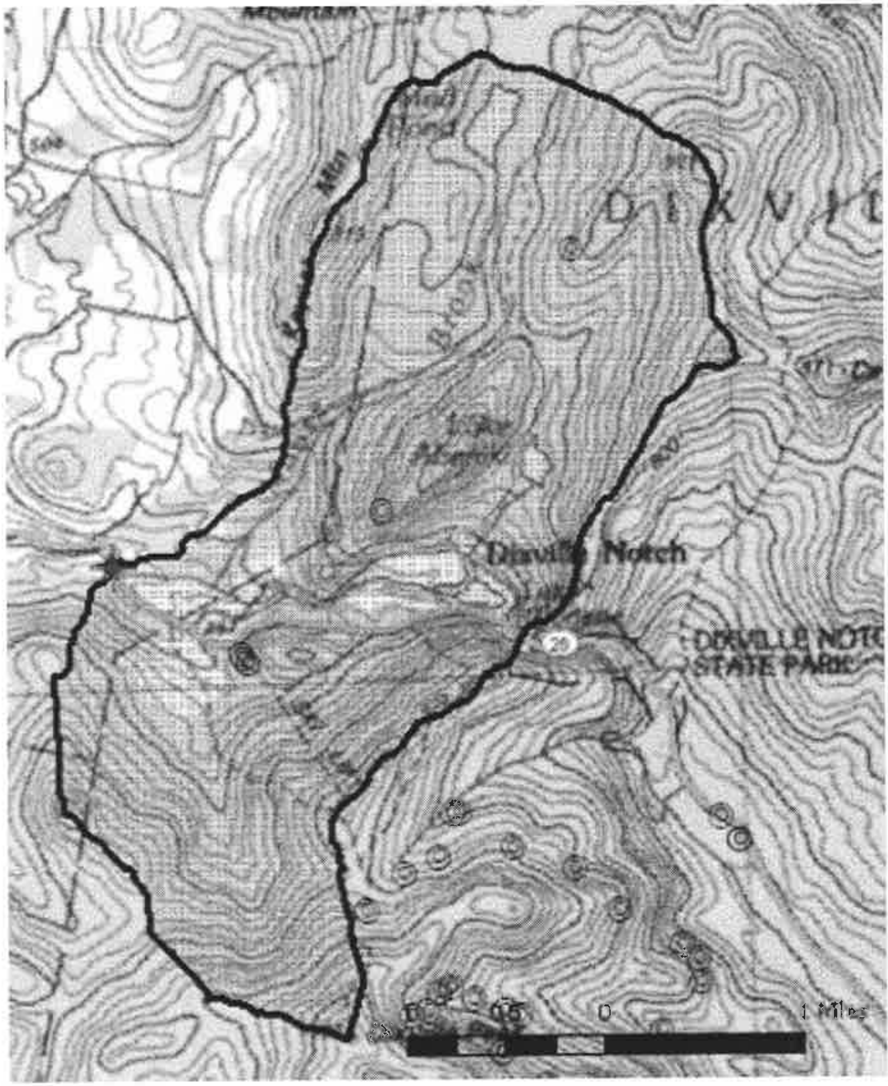
100% Low Flow Statewide (40.9 mi2)

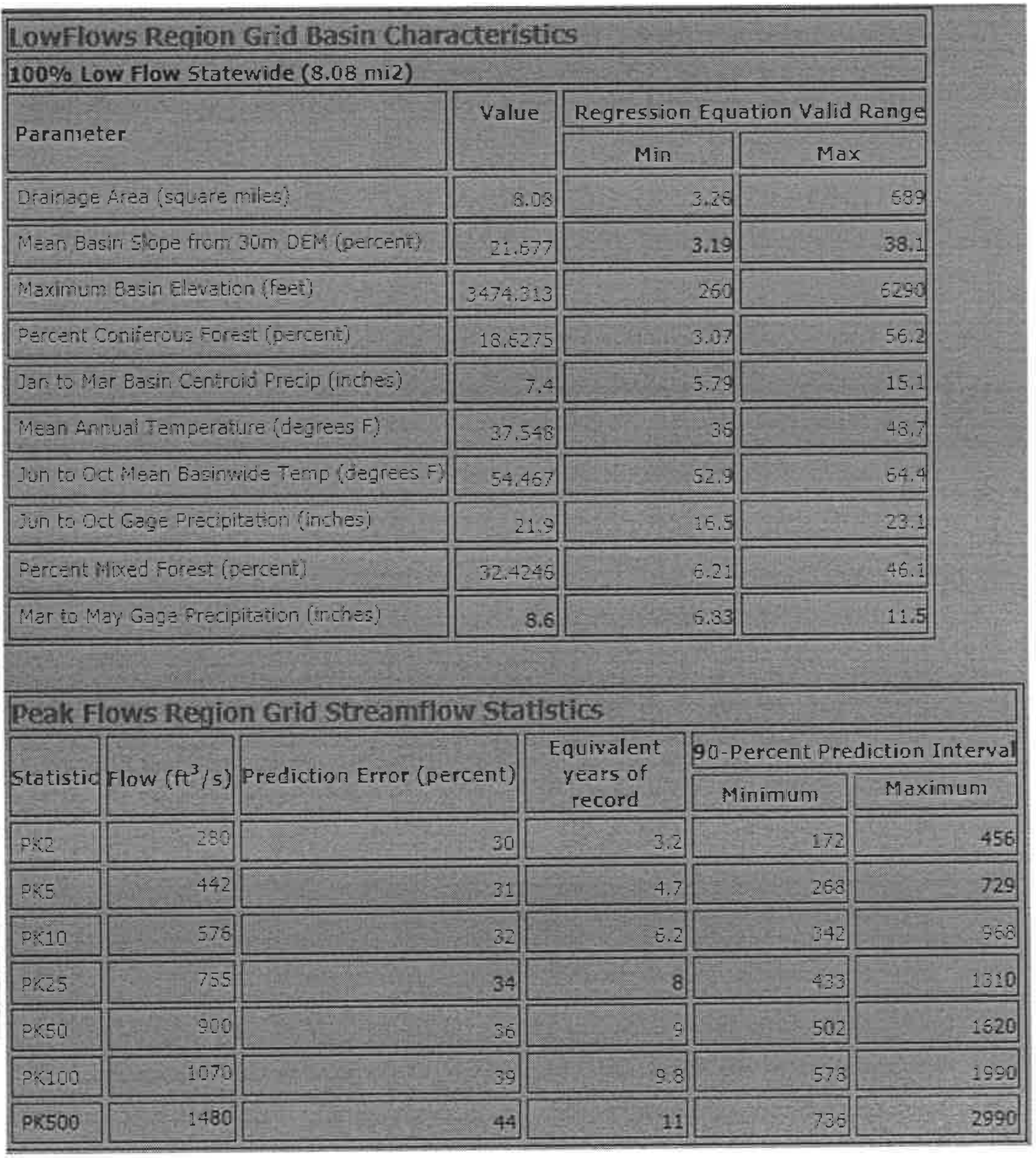
Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	40.9	3.26	689
Mean Basin Slope from 30m DEM (percent)	19.290	3.19	38.1
Maximum Basin Elevation (feet)	3474.500	260	6290
Percent Coniferous Forest (percent)	23.1714	3.07	56.2
Jan to Mar Basin Centroid Precip (inches)	7.68	5.79	15.1
Mean Annual Temperature (degrees F)	38.190	36	48.7
Jun to Oct Mean Basinwide Temp (degrees F)	55.002	52.9	64.4
Jun to Oct Gage Precipitation (inches)	19.8	16.5	23.1
Percent Mixed Forest (percent)	25.6121	6.21	46.1
Mar to May Gage Precipitation (inches)	8.2	6.83	11.5

Peak Flows Region Grid Streamflow Statistics

Statistic	Flow (ft^3/s)	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
				Minimum	Maximum
PK2	1370	30	3.2	841	2240
PK5	2090	31	4.7	1270	3460
PK10	2660	32	6.2	1580	4480
PK25	3390	34	8	1950	5910
PK50	3970	36	9	2210	7120
PK100	4640	39	9.8	2500	8620
PK500	6160	44	11	3060	12400

Balsams Snowmelt Runoff Assessment – Location 4: Mohawk River Watershed
Mohawk River at Convergence with Hodge Brook





LowFlows Region Grid Basin Characteristics

100% Low Flow Statewide (8.08 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	8.08	3.26	689
Mean Basin Slope from 30m DEM (percent)	21.677	3.19	38.1
Maximum Basin Elevation (feet)	3474.313	260	6290
Percent Coniferous Forest (percent)	18.6275	3.07	56.2
Jan to Mar Basin Centroid Precip (inches)	7.4	5.79	15.1
Mean Annual Temperature (degrees F)	37.548	36	48.7
Jun to Oct Mean Basinwide Temp (degrees F)	54.467	52.9	64.4
Jun to Oct Gage Precipitation (inches)	21.9	16.5	23.1
Percent Mixed Forest (percent)	32.4246	6.21	46.1
Mar to May Gage Precipitation (inches)	8.6	6.33	11.5

Peak Flows Region Grid Streamflow Statistics

Statistic	Flow (ft^3/s)	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
				Minimum	Maximum
PK2	280	30	3.2	172	456
PK5	442	31	4.7	268	729
PK10	576	32	6.2	342	968
PK25	755	34	8	433	1310
PK50	900	36	9	502	1620
PK100	1070	39	9.8	578	1990
PK500	1480	44	11	736	2990

Forest Service
Document - add as
reference

The Snowmelt Report
(6/23/98)

Joan Carlson, Hydrologist and Stephen Fay, Soil Scientist
White Mountain National Forest
Laconia, NH

Introduction.

The Court presented the Forest Service with two, soil and water problems related to the snowmaking pipeline at Loon Mountain Ski Area:

1/ Analyze the impacts of greater amounts of snowmaking on runoff, soil erosion, and water quality.

2/ Are the impacts likely to be significant?

This report is the Forest Service's analysis of these two issues. It is based on scientific literature, ski area studies, and site conditions, mitigation measures and monitoring results at Loon Mountain Ski Area.

The principal difference with greater amounts of snow, or water content to be discharged, is the duration of the snowmelt period. Or, put another way, the mere fact you must dispose of more water does not mean that the rate at which it is dispersed is any different. The significant factors governing the likelihood of impacts, e.g. frozen soil, grass cover, soil infiltration and watershed size, remain essentially the same during snowmelt regardless of snow quantity.

Water Quantity:

The amount of water available to make snow at Loon Mountain Ski Area is limited by the restrictions in the May 5, 1997 Court Order and the minimum flow requirements attached to the State wetlands permit for the new pumphouse. With these restrictions, the water sources available to Loon are the top 4 feet of Loon Pond (without refill from the East Branch), East Branch Pemigewasset River when flows are above 62 cfs, and Boyle Brook.

A water demand and addendum study were completed recently for the snowmaking system (1). This study used industry standards to determine the desired capacity of the snowmaking system based on the area of ski terrain (220.1 acres), depth of snow (2.16 feet), number of coverages (three) and conversion rate (175,000 gallons of water per acre-ft. of snow). This conversion rate is an efficiency of approximately 80 percent (2). This study concludes that the desired design target for the snowmaking system at Loon is to have the capacity to pump at least 250.4 million gallons (MGAL) in 85 percent of the years.

A model was used to determine the quantity of snow likely to be on the ski slopes based on different snowmaking systems. This model used historic river flow and temperature data, the water source restrictions listed above and the physical snowmaking infrastructure at the ski area. The initial water demand study analyzed three snowmaking configurations: "Baseline", "Pipeline" and "Existing". Baseline and Existing scenarios are of interest here since they represent the low and high ends, respectively, of snowmaking capacity. The Baseline scenario includes the old pumphouse and the old piping on the ski slopes. The Existing scenario includes the Baseline plus the new pumphouse and North Star/Upper Bear new pipeline.

The attached figure shows the results of the model contained in the water demand study addendum. The study concluded that the Baseline system has the capacity to pump at least 250.4 MGAL by the end of the snowmaking season (March 15) in about 74 percent of the years and the Existing system has the capacity to pump at least 250.4 MGAL by March 15 in about 89 percent of the years. Under ideal snowmaking/river flow conditions, the Baseline system has a maximum capacity, constrained only by physical parameters of infrastructure, to pump 369.6 MGAL. The Existing system has a maximum capacity of 559.1 MGAL. Statistically, this volume could only be pumped in 4 percent of the years. In terms of water depth, 369.6 MGAL and 559 MGAL over 220.1 acres equate to 61.8 and 93.5 inches of water respectively.

In addition to water from artificial snow, the ski area can expect to receive natural precipitation in the form of rain and snow during the snowmaking season (November - March). In order to determine what this potential contribution could be, precipitation records for Lincoln (3) were examined to find the maximum and average total precipitation for these months. The maximum November through March precipitation on record for Lincoln is 26.52 inches. This occurred November, 1935 to March, 1936, and was primarily the result of a very wet March (11.27 inches). Statistically, this value would be equalled or exceeded only 3 percent of the time. The average November through March precipitation at Lincoln is 18.10 inches. The period of record for Lincoln is 1931 - 1965. Climate data representative of conditions at Lincoln are currently collected at Benton, NH, which is approximately 14 miles west of Lincoln and 400 feet higher in elevation. The period of record for Benton is 1940 - 1996. The maximum November through March precipitation on record for Benton is 20.98 inches in 1957-58, and the average is 13.53 inches.

When this total of natural precipitation is added to the maximum capacities, the maximum total potential amount of water that could occur would be 88.32 inches (61.8 + 26.52) under the Baseline scenario and [illegible].02 inches (93.5 + 26.52) under the Existing scenario. It is these possible scenario's which were taken into account in the following analysis.

Physics of snowmelt:

The "Handbook of Snow" describes the basic science of snowmelt (4). Snowmelt originates primarily at the top of the snowpack from direct and diffuse solar radiation. It is this energy exchange at the snow-air interface which dominates the melt process. Other minor sources of energy for snowmelt come from sensible heat (evaporation and sublimation), condensation, conduction from underlying soil and heat supplied by incident rainfall. There is little snowmelt at the soil/snow interface, though some thawing and re-freezing may occur forming a frozen ice layer at the soil surface. Some water content is lost over the course of the winter through evaporation (and sublimation). Under ideal conditions, as much as 0.2 inches of water equivalent per day can evaporate from a snow surface (5).

The remainder of the snowpack is primed to melt when it is at a temperature throughout of 0 degrees Centigrade, and the individual crystals are coated with a thin film of water. Liquid water in the upper portions of the snowpack generally percolates very slowly to the ground surface under the influence of gravity and other pressure gradients. Movement of water through the snowpack is similar to the movement of water through the soil. The permeability of the snowpack, which affects water flow, is a function of many physical properties of the snowcover, including density and grain size; distribution, continuity, size, shapes and number of pores; and the development of ice layers within the snowpack. A snowpack resulting from a series of individual snowfalls (both natural and artificial) is usually heavily stratified into layers. These layers are frequently separated by buried crusts or ice layers which originate as an old snow surface which has experienced freezing rain, wind packing, refreezing of diurnal snowmelt, and, at ski areas, compaction from snow groomers. Dye studies suggest ice layers in the snowpack are not impermeable, but rather are characterized by variable permeability which forces the melt water to take numerous sideways steps on its route to the ground. The maximum flow rate decreases with depth below the snow surface. Lateral flow within the snowpack has been observed.

Once the liquid water moving through the snowpack reaches the ground surface, one of two things happens: 1) if the ground is unfrozen, snowmelt water will infiltrate into the ground similar to water generated by rainfall or ponded on the soil surface, or 2) if the infiltration capacity is exceeded or if the soil is frozen preventing infiltration, snowmelt will flow overland in a saturated slush layer in the lower portion of the snowpack near the snow-ground interface (4).

Under natural conditions, the soil is usually frozen during the snowmelt period (4). Various forms of frost have been identified in soils, including concrete frost, honeycomb frost, granular frost, and stalactite frost (6). Soil frost in grassy openings has been characterized as concrete frost (7). It is an extremely dense structure of many thin ice lenses and ice crystals in the top 0.20-0.83 foot of surface soil (7). Studies in open, grassy pasture confirm low permeability of soil when concrete frost is present (7). While this may increase the likelihood of runoff, soil detachment contributing to erosion and sedimentation is probably less likely. It is reported that even one inch of snow is capable of shielding the ground sufficiently to keep the soil frozen (7), which indicates this condition will persist until nearly the end of the melt season. Exposed soil remains frozen for about one day after snowmelt is complete, and the soil is exposed to solar radiation (7). Experience indicates the soil under snow at ski area's is usually frozen; however, substantial, early snowfall, or substantial artificial snowmaking on a few selected trails, may in some years prevent, or minimize, freezing on some slopes because of its insulating properties.

Effects:

The principal difference with greater amounts of snow, or water content to be discharged, is the duration of the melt period. For example, a study of snowmelt and soil erosion potential done at Sugerbush Ski Area in Vermont determined that the melt rate, or day to day reduction in the snowpack water content was 0.83 inches per day (8). This study also found no difference in melt rate between artificial snow and natural snow on the ski trails. Or, put another way, the mere fact that you must dispose of more water does not mean that the rate at which it is dispensed is any different, it only means more time will elapse. The fact that Loon Mountain Ski Area is a north facing slope may also contribute to a longer snow melt period It is well known that snow melts slower on north facing slopes because orientation affects the amount of direct beam solar radiation received per unit area (4).

Erosion

Soil erosion means the movement of soil particles. It may be either surface or rainfall erosion, or mass movement of soil particles. Surface erosion is initiated by raindrop splash, then the soil is transported downslope by further raindrop splash or carried in suspension by flowing water. Of the four main factors governing surface soil erosion, plant and litter cover is the greatest deterrent (9). In the presence of adequate vegetation cover, both the detaching and transporting power of rainfall is minimized (9). Other factors affecting soil erosion may include rainfall intensity, topography, and soil infiltration or percolation rates. Mass movement involves simultaneous movement of large quantities of soil under the influence of gravity, and is often lubricated by large amounts of water.

il in the permit area is generally sandy loams with a high coarse fragment content consisting of vel.cobbles, and boulders (19). Soils vary from shallow to greater than 10 feet deep over boulders, with the vast majority of soil greater than 10 feet deep based on site inspection (19). ELT Maps and tabular descriptions are available containing extensive information about soils (11,26). Most soils in the permit area have moderate to high surface soil erosion hazard, estimated on an unmitigated, bare soil surface condition (21). Reconnaissance of the existing ski area indicated few, if any, erosion or revegetation problems (19). More recent reconnaissance on those places where trail widening was done makes a similar observation (20). This is not a surprise given the grass cover, berms and waterbars on the slopes whose effectiveness was analyzed previously (19), but also based on the moderate to high soil permeability (21) and absence of stream turbidity (See Water Quality Section). Evidence of the good grass cover, and its effectiveness, is shown in photo's taken after intense rainfall the week of June 19, 1998 at numerous locations from the base to the summit where ski trails are intersected by the service road (27); no surface water was evident this day supporting the moderate to high soil permeability findings. Further, as reported by a Forest Service Permit Administrator, meltwater was evident everywhere on this sunny day with temperatures over 50 degrees; the water bars, berms and other erosion control measures that I saw were handling water runoff well (22). This should not be construed to mean there is no soil erosion, as isolated, on-site soil erosion has been observed over the years and routinely dealt with on a case by case basis. An example is the need for re-seeding of some of the lower portions of the pipeline installed late last fall (28).

Soil particle detachment from raindrop impact does not occur during snowmelt because the snowpack acts as a buffer preventing it. This buffer exists regardless of the duration of the snowmelt period. Therefore, the initiation of soil erosion does not occur. Any possibility of such initiation toward the completion of snowmelt is mitigated by the grass cover on the ski slopes, the importance of which is already described, or zen soils or soil infiltration. This helps explains why snowmaking, even in the last few years, has not ulted in any widespread evidence of surface soil erosion on the ski trails or roads at Loon Mountain Ski Area (10).

Meltwater from the bottom of the snowpack leaves the ski slope as runoff or infiltrates into the soil. To the extent it is runoff, the frozen soil surface and grass cover mitigates against soil particle detachment. To the extent some areas are not frozen because of substantial early snowfall, soils at Loon Mountain are moderately to well drained indicating infiltration into the soil will occur. Recent monitoring at Loon this spring indicates isolated evidence of on-site soil erosion as the snow melts (10). Previous monitoring in the summer and fall showed that while there are some small areas of limited, on-site soil erosion, the ski slopes are generally well covered with grass. This reflects routine maintenance, and the benefits of well distributed rainfall in New England.

The service road to the summit of the ski area is an exception to the above description to the extent it does not have a grass cover. Instead, it is a gravel road with numerous broad-based dips, culverts, and a road prism with a high crown in the center. This road is about a mile and one-half long. While this surface is not grassed, it is designed and maintained to shed water into the nearby grass cover, or forest. The fact there is a road prism means any surface flow remains on the road for only short distances thereby leading to little chance of accelerated soil erosion. In addition, it is well known that the most erosion from a road occurs in the first year after construction, which in this case was probably 10-15 years ago, or more (18).

Taking all the factors which might affect surface soil erosion during snowmelt into consideration, it is expected at both "baseline" and "existing" snowmaking regimes, soil erosion will be small, on-site and lated amounts of soil movement including some erosion behind waterbars. The difference in snowmelt gth makes no difference between "baseline" and "existing". Greater amounts of water dispensed at the e average daily rate with the same physical and biological governing factors in place will not translate significant soil erosion, especially when the same surface soil erosion control devices including waterbars, culverts and grass cover are in place. The indirect effect of limited soil erosion is the potential for stream sedimentation (turbidity); however, as described in detail in the water quality section of this report, turbidity is barely present at the sampling stations monitored. Cumulative soil erosion impacts are not anticipated to be significant. Loon Mountain Ski Area is surrounded by complete forest cover, no past actions within the original permit area are contributing substantial soil erosion during the snowmelt period, and while future actions may include further slope development, the same soil erosion control measures will be applied to minimize or eliminate soil erosion.

Mass movement of soil occurs in two situations on the White Mountain National Forest (21). First, there are dry debris slides on extremely steep, very thin gravelly soils on long slopes related to cirque headwalls at high elevations which are those areas described as Ecological Land Type (ELT) 8. This ELT does not occur where there are ski trails or lift lines or other facilities at Loon Mountain Ski Area based on a comparison of the ELT photo's and the more recent air photo's showing the location of the ski area facilities (23,24). Dry debris slides may also occur where conditions for ELT 2 include similarly extremely steep, long slopes with very thin till soils. While ELT 2 exists where there are ski trails at Loon Mountain, this combination of conditions does not occur based on on-site inspection. The lack of a dry debris slide hazard is bolstered by the following: on-the-ground evidence of dry debris slides has not been observed by the Forest Service or others (19); there is no aerial photo evidence of historic dry debris slides as occur elsewhere on the WMNF (23,24); and finally, even if there were evidence, a tabulation of 127 dry debris slides shows they occur exclusively in the months of June-November, associated with heavy rains, so they are not even affiliated with snowmelt (25).

ond, sometimes there are deep soil slumps on oversteepened slopes along major rivers and streams. These are called breakland 15's in the ELT descriptions. This condition, too, does not occur at Loon Mountain (11). It was neither mapped (11), nor is it observable on aerial photo's (23). Breaklands appear as very steep, cliff-like features which sometime show evidence of previous slumps. This is bolstered by unpublished soil survey reports which indicate soil conditions along the river is generally flat with sandy outwash soils or ablation tills. Mass movement, therefore, is not a hazard at Loon Mountain regardless of the amount of snow made.

Runoff

Peak runoff and streamflow during snowmelt events are primarily controlled by climatic conditions affecting the rate of melting. More snow does not usually mean faster melting or increased runoff rates. The net effect of an increased snowpack caused by snowmaking generally is one of a longer snowmelt season and a greater duration of seasonal high stream flow period rather than an increase in peak runoff quantities. In addition, not all of the water put on the slopes (i.e. is available) comes off as runoff. A study of snowmelt and soil erosion potential done at Sugarbush Ski Area in Vermont found that only 300 million gallons of the total 534 million gallons of water available for runoff (artificial snow and natural precipitation) came off as runoff measured in the stream (8). The remaining 234 million gallons was lost to evaporation, replenished soil moisture storage capacity, percolated to deep groundwater, or was used by vegetation (evapotranspiration) as it begins to emerge from the dormant winter state.

As part of the snowmaking expansion project at Mount Snow/Haystack Ski Area near Wilmington, VT, a snowmelt runoff analysis was completed by Pioneer Environmental Associates, Inc. (12). A model was eloped for the North Branch Deerfield River to evaluate the potential for flooding from increased [illegible]owmaking at the ski area. Ski trails with no artificial snow were compared to ski trails with 100 % [illegible]owmaking coverage. Results of the analysis indicated extremely minor impacts of snowmaking on peak runoff quantities in all receiving waters, even those closest to trails covered with artificial snow. Streamflow was predicted to increase by 0.23 % to 0.38 % for a 10-year storm and only 0.12 % to 0.21 % for a 100-year storm. These quantities are well below the limits of quantification or measurement and are therefore insignificant. The area of the North Branch Deerfield River watershed at the junction with Harriman Reservoir near Wilmington, VT is 57.94 square miles (personal communication, Jeff Nelson, Pioneer Environmental Associates, Inc). The area of ski trails at Mount Snow/Haystack in the North Branch Deerfield River watershed is 577.7 acres or 1.6 percent of the watershed area.

Loon is similar to Mount Snow/Haystack in that the area of watershed in ski trails is only a small proportion of the entire watershed area. In fact, Mount Snow/Haystack represents a more extreme case than Loon, as Loon is less than half the size of Mount Snow/Haystack and the East Branch Pemigewasset River watershed is nearly twice as large as the North Branch Deerfield River. The area of the East Branch Pemigewasset River watershed above the USGS stream gage in Lincoln is 115 square miles (13). The permit area at Loon Mountain Ski Area, of which the ski trails comprise one-third, is 785 acres or 1.1 percent of the watershed area. In addition, Loon is located low in the watershed, near the junction of the East Branch with the main stem Pemigewasset River, so the majority of the watershed area, i.e. runoff source area, is upstream of Loon. The contribution of runoff from Loon to the East Branch Pemigewasset River is small in proportion to the whole. And, like at Mount Snow/Haystack, the "additional" runoff from increased snowmaking would cause an immeasurable increase in streamflow and is, therefore, insignificant.

Water Quality

[illegible]ter quality impacts from soil erosion occur when soil particles reach water bodies, such as streams and lakes, in sufficient quantities to cause impaired turbidity or sediment accumulation to streambeds. Best Management Practices (BMP's) are used to control soil erosion and protect water quality. These practices include providing buffer/filter strips along water courses, vegetating disturbed areas, proper placement of water bars and diversion ditches to control surface water flow, and use of silt fences or sediment detention basins to remove sediment particles before they reach the water body.

Loon Mountain has a network of waterbars, culverts and diversion ditches which serve to divert surface flow from ski trails to safe outlets in the forest. These features, plus the grassed slopes, are constructed in accord with the standards and guidelines in White Mountain National Forest Land and Resource Management Plan which generally reflect, or exceed, the Best Management Practices (BMP's) in the State of New Hampshire. An examination of these drainage features during this spring indicate they were successfully diverting surface runoff (10).

Daily turbidity measurements were taken at Loon during the snowmelt season (mid-April through mid-May) in 1996 and again in 1998 (14). Sampling points included the East Branch Pemigewasset River above and below Loon, Loon Pond Brook (at the road crossing), and three smaller drainages: "WWB" which drains the lower slopes and maintenance shed area, and "GG1" and "GG2" which drain the South Mountain area. The attached charts summarizes the results of this monitoring. In general, turbidity readings in the East Branch Pemigewasset River and Loon Pond Brook were less than 1 NTU a majority of the time. There were no turbidity readings in these streams greater than 10 NTU, the Class B water quality standard for turbidity. On those occasions when turbidity in the East Branch Pemigewasset River was greater than 1, the upstream station (EBA) had equal or greater turbidity than the downstream station (EBB), which indicates [illegible]t Loon was not the source of the turbidity.

[illegible] majority of the turbidity readings in "WWB" were less than 10 NTU. "WWB" had several readings above 10 NTU, primarily in 1996. This stream has known turbidity problems, due to the disturbed area on private land near the Governor Adams Lodge (10, 15). Loon has been working on controlling this situation, through construction of settling basins and erosion control measures.. This turbidity is more a function of the disturbed nature of the area and not the volume of water passing through it

The following table shows the amount of water (snowmaking and natural precipitation) experienced by the ski trails at Loon over past winters (November through March) 1994 through 1997 (16, 17). The turbidity monitoring and on-site monitoring visits indicates that this volume of water does not cause an erosion or water quality concern.

Winter	Water Pumped (MGAL)	Water Pumped (inches)	Natural Precipitation (inches)	Total depth of water on ski slopes (inches)
1994 - 1995	201	27.84	11.11	38.95
1995 - 1996	200	27.70	14.44	42.14
1996 - 1997	221.5	30.68	15.00	45.68

These results at Loon are consistent with a similar study at Sugarbush Resort in Vermont (8). Turbidity monitoring at Sugarbush in the spring snowmelt period of 1993 found turbidity readings which were well below the 10 NTU Vermont water quality standard. This study concluded that this absence of turbidity indicates that little or no streambank or ski trail erosion was occurring during the spring snowmelt event.

[illegible]nclusion

An increase in snowmaking capacity at Loon Mountain Ski Area will lengthen the duration of the snowmelt period, but not the average daily melt. The factors which govern the likelihood of soil erosion, peak flow and water quality impacts remain unchanged when greater quantities of artificial snow and natural precipitation occur. No new risks were identified by this analysis which indicate new or greater hazards from greater amounts of snowmaking. Based on this analysis we conclude for both "baseline" and "existing" scenarios: soil erosion during snowmelt consists of isolated small amounts of on-site soil movement; no measurable impact to peak streamflows; and no increase in turbidity above water quality standards. No significant direct, indirect or cumulative effects on soil erosion, peak streamflow or water quality are expected.

Bibliography

1 Sno.matic Controls and Engineering, Inc. 1998 Amended Loon Pipeline Snowmaking Analysis.

2 Root Engineering, 1995. Sugarbush Resort Water Demand Study.

3 Precipitation record for Benton, Lincoln and Woodstock, NH. From Internet: (See #17) http://ftp.ncdc.noaa.gov/pub/data/coop-precip/new-hampshire.txt. (personal communication, Barry Kiem, NH State Climatologist).

Gray, D.M. and D.H. Male. 1981. Handbook of Snow. Principles, Processes, Management and Use pp.

5 Linsley, R.K., Kohler, M.A., and J.L. Paulhus. 1982. Hydrology for Engineers. Third Edition p.136.

6 Trimble, G.T. and Sartz, R.S. and R.S.Pierce. 1958. How Type of Soil Frost Affects Infiltration. Jor. Soil and Water Conservation Vol 13. No.2 81-82 pp.

7 Dunne, T. and R. Black. 1971. Runoff Processes During Snowmelt. Water Resources Research. Vol.7, No.5, 1160-1172.

8 Wagner, Heindel and Noyes, Inc. 1994. Evaluation of Actual and Potential Snowmelt Runoff at Sugarbush South. 25pp.

9 Dryness, C.T. 1965. Erodibility and Erosion Potential of Forest Watersheds. International Symposium on Forest Hydrology. Proc. of National Science Foundation Seminar at Penn. State University. August 29-Sept. 10, 599-609

10 1998 monitoring visits to Loon

· 11 ELT maps. (III - D - 2)

12 Nelson, J.A. memo to Mount Snow Snowmaking Expansion. March 17, 1998. Subject: Snowmelt Runoff Analysis.

Coakley, M.F; C. Keirstead; R.O. Brown; G.S. Hilgendorf, 1997. Water Resources Data, New Hampshire and Vermont Water Year 1996. US Geological Survey Water-Data Report NH-VT-96-1.

14 water quality data, 1996 and 1998

15 June 25, 1996 monitoring visit write-up

16 water use records at Loon, 1994-95 thru 1997-98

17 precipitation records for Benton, NH from NOAA

18 Stone, E. 1977. The Impact of Timber Harvest on Soils and Water. Reprinted from the Report of the President's Advisory on Timber and the Environment. pp. 427-454.

19 Loon Mountain Ski Area - South Mountain Expansion FEIS

20 6/27/97 Letter from Stephen Fay to District Ranger Anne Archie

21 Loon Mountain Ski Area - South Mountain Expansion FEIS - Appendix C

22 4/28/92 Letter from Permit Administrator Laura Falk to District Ranger Jim Dimaio

1958 ELT Aerial Photo depicting ELT's at Loon Mountain Ski Area

1966 Aerial Photo of Loon Mountain Ski Area

25 Flaccus, Edward. 1958. Landslides and their revegetation in the White Mountians of New Hampshire. PhD Dissertation. Duke University.

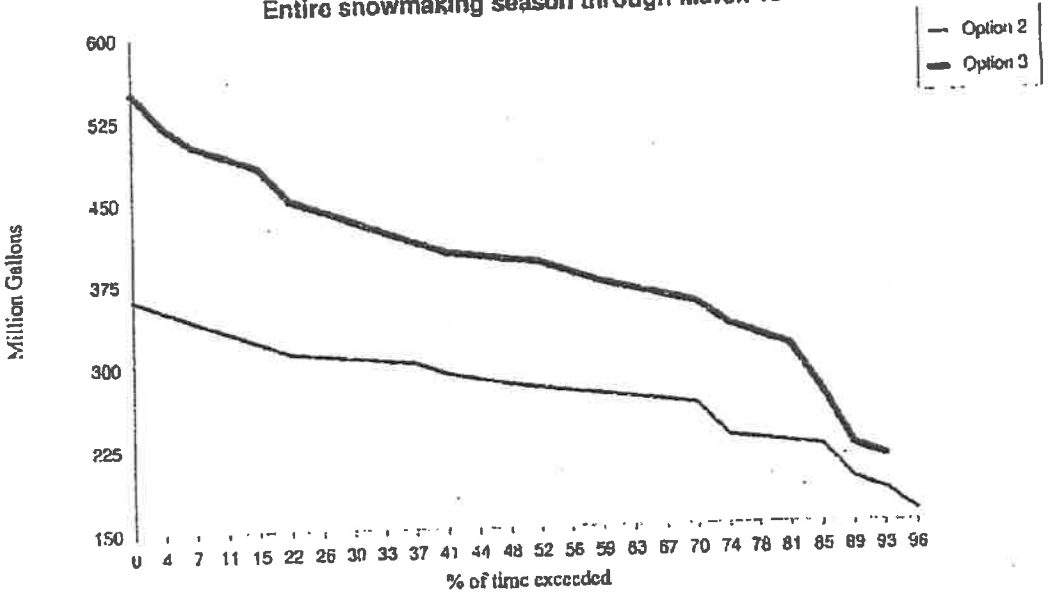
26 ELT Descriptive Tables for White Mountain National Forest (III - D - 3)

27 Photo's of Ski Trails at Loon Mountain Ski Area-June 19, 1998-Taken by S.Fay

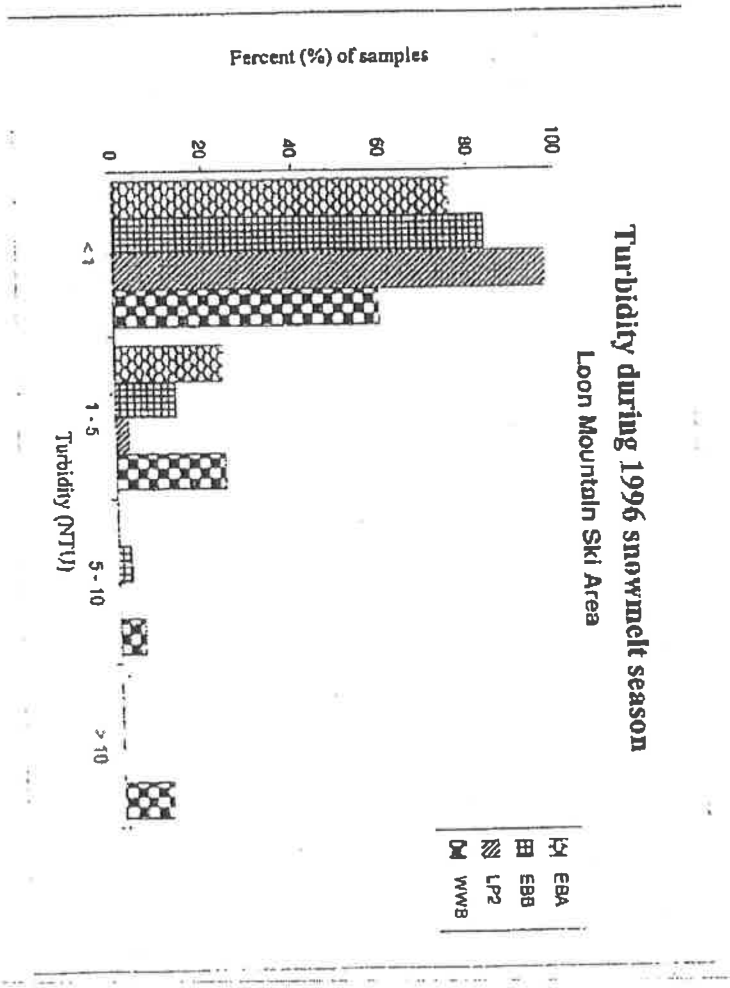
28 6/29/98 Letter from S.Fay to B.LeClair on pipeline inspection including photo's (II - F)

Capacity of Snowmaking System

Entire snowmaking season through March 15

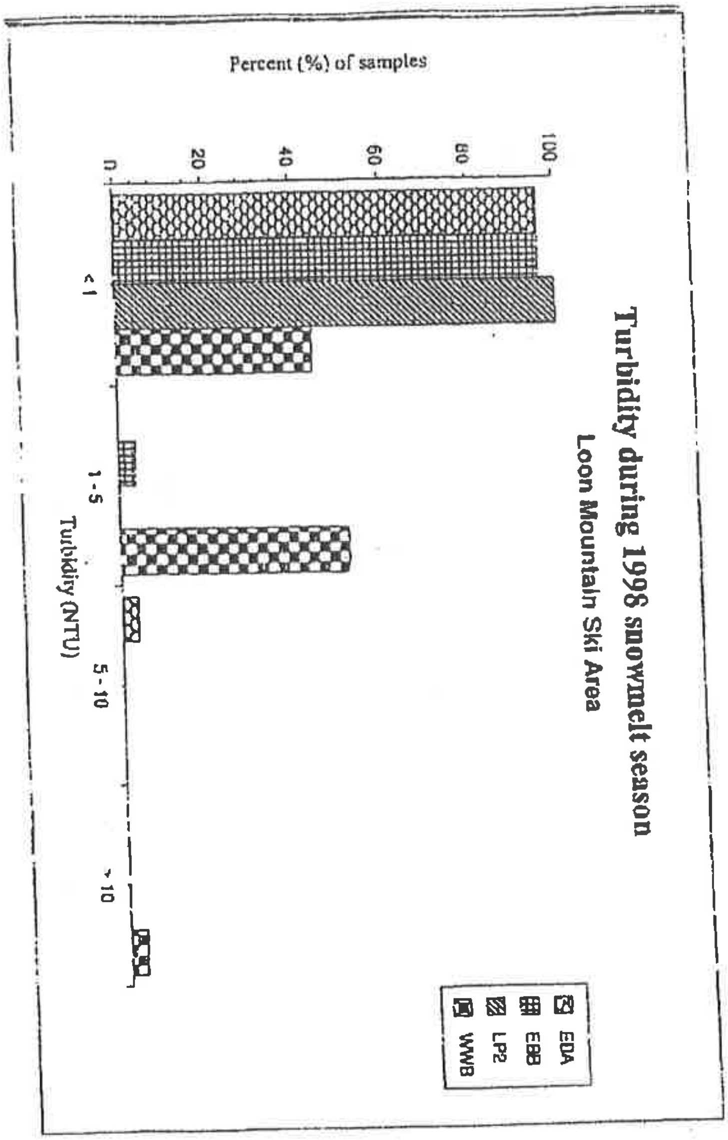


Data: Addendum Loon Pipeline Snowmaking Analysis, Sno.matic Controls and Eng., Inc



Turbidity during 1996 snowmelt season

Loon Mountain Ski Area


Turbidity during 1998 snowmelt season
Loon Mountain Ski Area
Percent (%) of samples
0
20
40
60
80
100
<1
1-5
5-10
>10
Turbidity (NTU)
EDA
EBB
LP2
WWB