Final Report on Snowmaking Pilot Plant Using Treated Wastewater

December 2012

DOWL HKM

1. Introduction

The Big Sky County Water and Sewer District currently disposes of 120 to 150 million gallons per year of its treated wastewater by irrigation on two local golf courses, the Big Sky Meadow Village course and the Yellowstone Mountain Club course. In addition, the District has a legal obligation to provide wastewater service, in the future, to lots within the District that are currently not developed. As development continues, eventually the effluent flow from the District will exceed the irrigation capacity of these golf courses and the storage capacity of the ponds. Because of this capacity limitation and an ongoing commitment to wastewater reuse, the District is interested in evaluating snowmaking as a disposal option for treated effluent.

In addition, during the past few years a citizen's group of conservationists, developers, representatives from the three ski areas (Big Sky, Moonlight Basin and Yellowstone Club), and the District, collectively known as the Wastewater Solutions Forum, have been evaluating the feasibility of providing sewage collection and treatment for the Gallatin River corridor (Figure 1). Development in the corridor currently uses septic tanks and drainfields that have a hydraulic connection to the Gallatin River. Expansion of the District's wastewater service area to include the Gallatin River corridor would place additional irrigation demands for effluent disposal on the already overcommitted golf courses. A key element in being able to service full build-out demand of the current water and sewer district, or to expand the District, and to protect the water quality of the Gallatin River involves reusing the treated wastewater for snowmaking. The ability to use treated effluent in a snowmaking operation would reduce the winter time storage needs and the land required for irrigation. A feasibility study completed in November of 2008 concluded that snowmaking was the most cost effective and environmentally safe reuse alternative (DOWL HKM, 2008).

In December of 2001, the Montana Board of Environmental Review (BER) received a petition to designate the Gallatin River as an Outstand Resource Water (ORW) from the Yellowstone National Park boundary to Spanish Creek, a river reach that would include the Canyon Study area shown in Figure 1. The BER ordered the Montana Department of Environmental Quality to prepare an Environmental Impact Statement (EIS) to disclose the potential impacts of the ORW designation. The Final EIS published in 2007 found that under the proposed action approximately 67 Single Family Equivalent (SFE's) could be built before impacts to water quality from nutrients would be observed (Montana Department of Environmental Quality, 2007). The problem was, and continues to be, that the existing development already exceeds the 67 SFE allowable under the ORW designation.

Figure 1
Canyon Study Area

2. Background

In September 2010, the Montana Department of Environmental Quality published the final Total Maximum Daily Load (TMDL) study for the West Fork Gallatin River Watershed (Figure 2) (Montana Department of Environmental Quality, 2010). Three stream segments on the 2008 303(d) list (list of impaired waters), were listed as impaired in the West Fork Gallatin River watershed.

As shown in Table 1, nutrients are listed as one of the causes of impairment in all three stream segments.

Figure 2 West Fork Gallatin River Watershed for TMDL Study and the snowmaking study site.

Table 1
2008 303(d) Listed Waterbodies, Impairment Causes, and Impaired Beneficial Uses in the West Fork Gallatin River Watershed. (Montana Department of Environmental Quality, 2010)

Waterbody & Location Description	Waterbody ID	Impairment Cause	Pollutant Category	Impaired Uses
MIDDLE FORK OF WEST FORK GALLATIN RIVER, headwaters to mouth (West Fork Gallatin River)	MT41H005_050	Solids (Suspended/Bedload)	**Sediment***	Aquatic Life, Cold Water Fishery
		Alteration in stream-side or littoral vegetative covers	Not a Pollutant	Aquatic Life Cold Water Fishery
		Nitrate/Nitrite	**Nutrients***	Aquatic Life Cold Water Fishery Primary Contact Recreation
		Fecal Coliform	**Pathogens***	Aquatic Life Cold Water Fishery Primary Contact Recreation
SOUTH FORK OF WEST FORK GALLATIN RIVER, headwaters to mouth (West Fork Gallatin River)	MT41H005_060	Siltation, Sedimentation	**Sediment***	Aquatic Life, Cold Water Fishery
		Alteration in stream-side or littoral vegetative covers	Not a Pollutant	Aquatic Life Cold Water Fishery
		Physical substrate habitat alterations	Not a Pollutant	Aquatic Life Cold Water Fishery
		Nitrate/Nitrite, Total Phosphorus, Chlorophyll-*a*	**Nutrients***	Aquatic Life Cold Water Fishery Primary Contact Recreation
WEST FORK GALLATIN RIVER, Confluence Mid & N Forks West Gallatin to mouth (Gallatin River)	MT41H005_040	Siltation, Sedimentation	**Sediment***	Aquatic Life, Cold Water Fishery
		Nitrate/Nitrite, Total Phosphorus, Chlorophyll-*a*	**Nutrients***	Aquatic Life Cold Water Fishery Primary Contact Recreation

The TMDL study listed nutrient target values (Table 2) for the Upper Gallatin Planning area that are believed to prevent the growth and proliferation of excess or undesirable algae growth. It is important to note that these target values apply only during the summer months, July1st through Sept 30th, when algae growth has the highest potential to affect beneficial uses. Historical records from the weather stations on Lone Mountain and the Mountain Village show the snowpack is gone be mid-June and consequently runoff from a snowmaking operation using effluent should not be impacted by the nutrient targets.

Table 2
Nutrient Targets in the Upper Gallatin (Source: (Montana Department of Environmental Quality, 2010)

Parameter	Target Value
Nitrate +Nitrite	≤0.100 mg/l
Total Nitrogen	≤0.320 mg/l
Total Phosphorous	≤0.030 mg/l
Chlorophyll-*a*	≤129mg/m^2

Several studies have demonstrated that 50% to 80% of the contaminants in snowpack can be contained in the first 20% to 30% of the melt water (Johannessen, 1978) (Cadle, 1984) (Akan, 1994) (Meyer, 2008). There is also evidence that microbial action in the initial meltwater may result in a significant decrease in inorganic nitrogen ($NH_4 + NO_3$) (Semkin R.G, 2002). A pilot test conducted by the District in 1997 of a snowmaking process showed a reduction in ammonia from 43 mg/l-N in the applied snow to 20.6 mg/l N in aged snowpack and to 1.12 mg/l-N in the melt water, an ammonia reduction of 97.4%. In the 1997 test, Total Kjedkahl Nitrogen (TKN) was not measured in the pond or sprayed snow but was measured in the aging snowpack. The measured TKN and ammonia values allow the Total Nitrogen removal to be calculated. The calculations indicated a 74.1% removal of Total Nitrogen. Table 3 shows a summary of the 1997 test results.

Table 3
Summary of 1997 Pilot Test Results

	Fecal Coliforms cfu/100ml	Total Suspended Solids mg/l	BOD_5 mg/l	Total Phosphorus mg/l	Nitrate + nitrite as N mg/l	pH	Ammonia as N mg/l	Total Kjedahl Nitrogen mg/l
Applied Water	7167	21	32	6.0	0.00	7.53	43	—
Fresh snowpack	ND	58	30	7.0	0.11	9.3	24	—
Aged snowpack	ND	74	27	5.6	0.03	9.2	8.37	5.92
Snowmelt	ND	23	9	3.7	0.02	8.0	1.12	2.62

A new snowmaking pilot project was conducted in the winter of 2011-2012 where approximately 980,000 gallons of treated wastewater was sprayed onto a slope typical of what could be used for an expanded snowmaking operation. Seven bucket lysimeters where installed across the snowmaking site to measure the concentration of contaminants that percolate through various lengths of soil profile. Samples were collected from the aging snowpack and the melt water to measure the concentration of contaminants and to quantify any reduction of key contaminants that occur during the snowmaking and snow aging processes when treated wastewater is used in the snowmaking process.

3. Site Information

The snowmaking site was located at an elevation of 8270 feet above sea level, on a cut slope created when the effluent storage pond was constructed at the Yellowstone Club. The site slope and vegetation is similar to what would be expected in any future large scale snowmaking operation. Waterbars were constructed at the toe of the snowmaking area to direct any runoff into the storage pond. Figure 3 is an aerial view of the site showing the site modifications that were made to direct runoff to the storage pond and Figure 4 shows the slope and vegetation present.

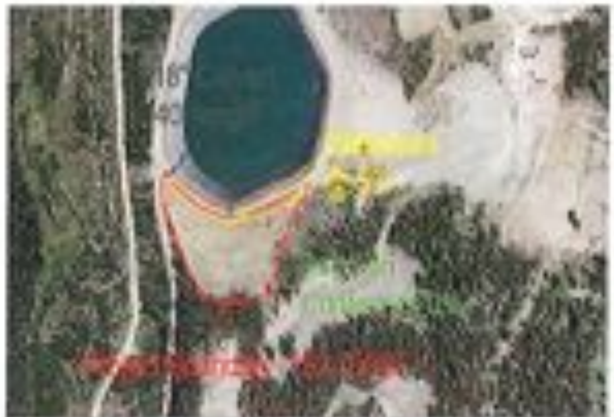


Figure 3 Aerial view of snowmaking disposal site showing runoff protection

Seven bucket-lysimeters (See attachment 1) were installed along the hillside to collect snowmelt water percolating through the soil (Figure 5). The lysimeters were installed at depths ranging from 2-3 feet below the ground surface.

Figure 4 Snowmaking Site showing the general vegetation and slope.

Soil excavated during the installation was placed inside the lysimeter so snowmelt would percolate through soil layers similar to natural conditions.

Approximately 980,000 gallons of treated wastewater from the effluent storage pond was sprayed onto the site from November 14 through December 5, 2011. Snow pit profiles dug in January show a manmade snow depth ranging from 32.5 cm (12.8 inches) to 57 cm (22.4

Figure 5- Lysimeter locations

inches) with an average of 43.7 cm (17.21inches) in the six pits dug in January (Appendix A). The spraying operation used a Techno Alpin T-40 snowmaking gun (Figure 6). The snow pile created during the spraying operation was spread over a 3 acres site with a snowcat.

Figure 6 – Snowmaking Gun

4. Sampling Methods

Samples were collected by Yellowstone Club and Blue Water Task Force personnel during the snowmaking process and then on a monthly basis as the snowpack aged. Each sampling of fresh snowpack was accomplished using a shovel to collect the top 1-2 inches of freshly made snow. The samples were placed in 30-gallon plastic bags and taken to the Water and Sewer District laboratory where the bags were placed in a warm water bath to melt the snow. The melted samples were transferred to sample bottles and then shipped overnight to Energy Laboratories in Billings. A sulfuric acid preservative was added to one bottle for nitrogen testing.

Figure 7 Snow pack sampling pit. Photo of 30 cm x 30 cm excavated column for snowpack sampling. Photo taken by Rich Chandler on 12/20/11

After the snowmaking process was completed, snow pack samples were taken monthly. One control sample was taken of natural snow at the same location as the control lysimeter, the western most site. Three separate samples were taken at the same elevation across the slope within the testing boundary. The test elevation was mid slope at locations where the depth of the manmade snow best represented the coverage goal of 45-60 cm. A snow pit (Figure 7) was excavated and a 30 cm by 30 cm snow column was carefully removed and transferred into a plastic bag. Snow density and depth were then recorded. During the December sampling the depth of the control was 25 cm, the first site had a depth of 45 cm, and the second and third sites had depths of 70 & 80 cm respectively. The samples were then taken back to the BSWS laboratory for melting. Using a hot water bath, the columns were entirely melted before being transferred to bottles. Sulfuric acid was added to one sample bottle for each site to preserve the sample for nitrogen testing. Samples were then shipped overnight to Energy Laboratories in Billings, MT to meet the 24 hour holding time for the Total Coliform/E. Coli parameters.

5. Effluent Water Characteristics

Water used in the snowmaking operation consisted of treated wastewater stored in a pond located adjacent to the snowmaking operation. A portion of treated wastewater from the District's wastewater plant and all of the Yellowstone Club's treated wastewater is typically pumped to the storage pond. Table 4 shows the average of test results from the pond collected at the time water was being pumped to the snowmaking operation.

Table 4
Effluent Pond Water Quality

Total Nitrogen = 3.2 mg/l	Total Phosphorous = 1.74 mg/l	Turbidity = 7.0 NTU
Ammonia = 0.87 mg/l	pH = 7.63 s.u.	Total Coliforms = 10.5 #/100ml
TKN = 2.27 mg/l	Conductivity = 550 umhos/cm	*E. Coli* = <1 #/100ml
NO_3+NO_2 = 0.91 mg/l	TSS = 26 mg/l	

The total nitrogen concentration from the District's plant averages around 7.5 mg/l and sample results from the Yellowstone Club plant indicate a total nitrogen concentration of approximately 9 mg/l. As shown above, the total nitrogen in the pond used for snowmaking was only 3.2 mg/l well below the effluent nitrogen concentration from either of the treatment plants. It is not known if the low nitrogen levels in the storage pond were a result of dilution from past snowmelt or possibly from algae assimilation of nitrogen in the pond and subsequent settling of the algae in the fall. While the pond nitrogen levels are less than expected, as shown later in the results discussion, the percent nitrogen removal was still high and comparable to the 1997 test results even though in 1997 the starting nitrogen concentration was much greater, 43 mg/l versus 3.2 mg/l. In 1997, there was an 82% removal of total nitrogen in the ageing snowpack compared to a greater than 85 % removal in the current pilot test.

6. Regulatory Requirements

The Montana Department of Environmental Quality has recently published a draft of revised design standards for public sewage systems. The draft standards include a new section specifically addressing water reclamation and reuse and includes snowmaking as an allowable use of reclaimed water. For a restricted access site designed to discharge to groundwater the treatment must meet a B-1 classification. For unrestricted access such as ski slopes the treatment must meet A-1 standards. A summary of the treatment standards are shown in Table 5

Table 5
Summary of A-1 and B-1 Treatment Standards

Class	TREATMENT STANDARDS SUMMARY
A-1	Class A-1 reclaimed wastewater must, at all times, be oxidized, coagulated, filtered and disinfected, as described below. Class A-1 reclaimed wastewater effluent quality should have approximately 10 mg/l or less of BOD and TSS Class A-1 reclaimed wastewater must be disinfected such that the median number of total coliforms does not exceed 2.2 CFU/ 100 ml and the number of total coliform organisms does not exceed 23 CFU/ 100 mls. Total nitrogen must not exceed 5.0 mg/l at any time. For aquifer recharge proposals, the effluent quality

	must meet either primary drinking water standards or non-degradation requirements at the point of discharge
B-1	Class B-1 reclaimed wastewater must, at all times, be oxidized, settled and disinfected. Class B-1 reclaimed wastewater must be disinfected such that the median number of total coliform organisms does not exceed 2.2 CFU/ 100ml and the number of total coliforms does not exceed 23 CFU/100 ml. Total nitrogen must not exceed 5.0 mg/l at any time. For aquifer recharge or injection the water must meet at a minimum, secondary treatment standards.

The reclaimed wastewater from the District's and Yellowstone Club's treatment plant will meet the A-1 reclaim standard with the exception of the nitrogen concentration.

Unless the runoff from the snowmaking site is contained, during snowmelt, a portion of the applied effluent would percolate into the soils and a portion would run-off into surface streams. Both components of the effluent would have to meet non-degradation criteria and Water Quality Based Effluent Limits (WQBEL's). As indicated previously the TMDL's established for the West Gallatin Watershed apply only during the summer months and would not apply to runoff that occurs prior to July 1st. A discharge to groundwater is considered non-significant if the nitrate level at the boundary of the mixing zone does not exceed 7.5 mg/l. The treatment processes used in conjunction with snowmaking would have a nitrate level below 7.5 mg/l so the portion of effluent percolating to groundwater would be non-significant. The portion of effluent running off as snowmelt would be considered non-significant if the runoff results in an in-stream change in concentration that is less than the trigger value specified in Circular DEQ7 or the change is less than 15% of the lowest applicable standard. The contaminants of most concern in runoff would be total inorganic nitrogen, nitrate + nitrate, and inorganic phosphorous which have trigger values of 0.01 mg/l-N, 0.01 mg/l-N and 0.001 mg/l-P respectively. The lowest applicable standard will be the numeric acute and chronic aquatic life standards for total ammonia (DEQ-7). In addition, to be considered non-significant, the increase in monthly flow must be less than 15 % and the increase in the 7Q10 flow must be less than 10% (ARM 17.30.715a).

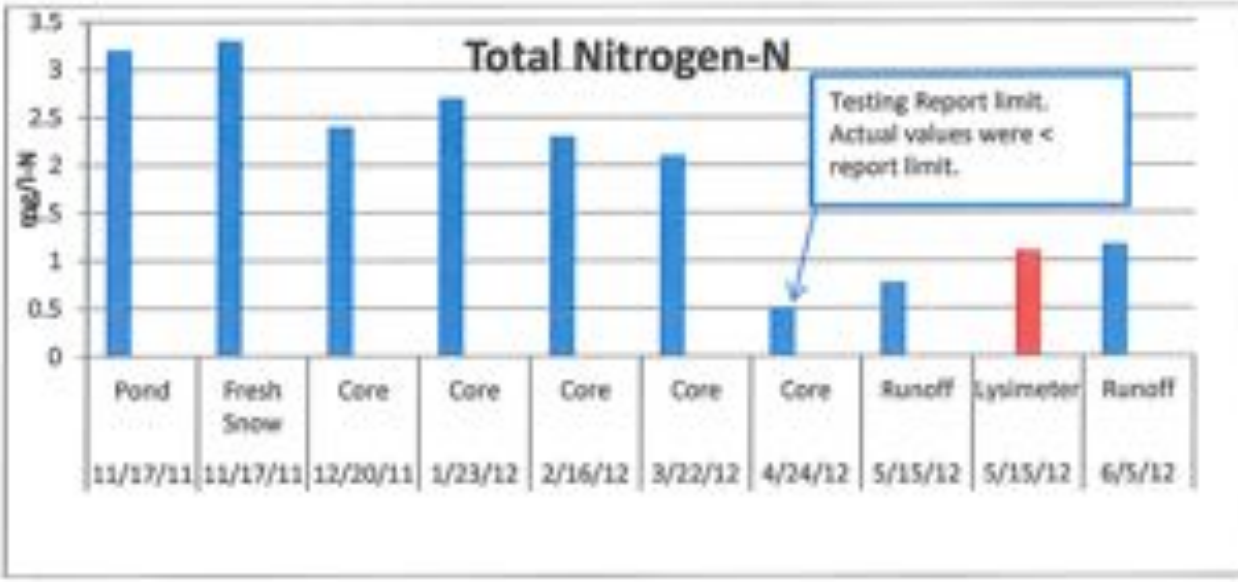
7. Results

During each sampling period, three replicate samples were taken from each sampling site. The data was analyzed using a statistical test, Q-test at a 90 percent confidence level, to identify outlying results and whether to accept or reject the outlying value.

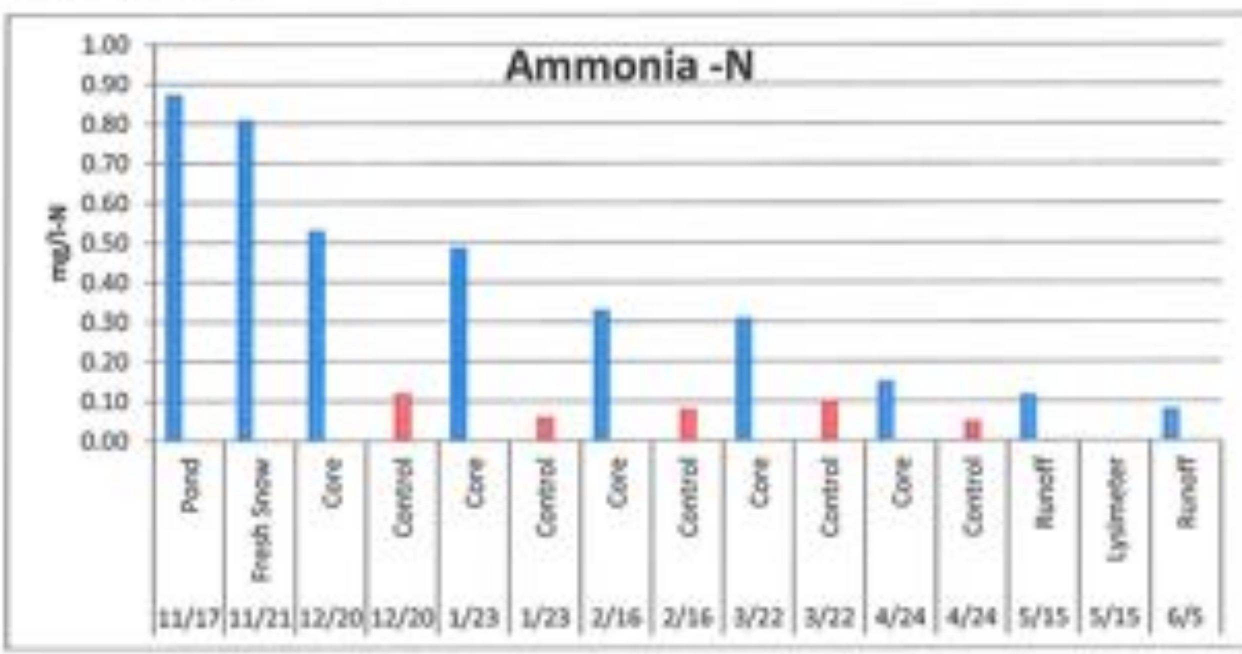
Of the 7 lysimeters installed, only 1 collected water during the spring melt which suggests the primary hydrologic pathway during snowmelt is surface runoff.

Nitrogen

During the winter, total nitrogen levels decreased in the snowpack approximately 69%, from a concentration of 3.2 mg/l in the effluent storage pond and 3.3 mg/l in the sprayed snow to approximately 1.0 mg/l in the runoff water measured in May and June. The core samples collected in April were below the testing report limit of 0.5 mg/l which is at a concentration similar to the control samples. The control samples and samples collected on Pioneer Mountain were below the reporting limits (0.5 mg/l) of the testing method.

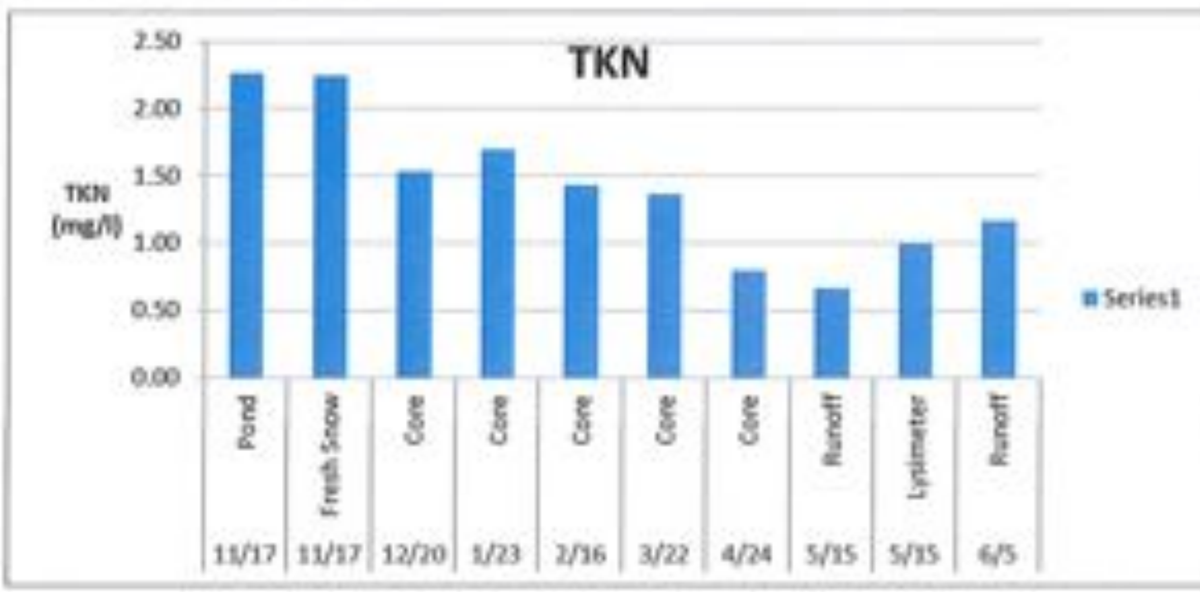


Ammonia (NH_3-N) also showed a significant decreased during the snowpack aging process. The ammonia concentration in the pond was 0.87 mg/l, which was reduced to 0.1 mg/l in the runoff water. Ammonia was not detected in the water collected in the lysimeter. Ammonium (NH_4-N) in the fresh snow had an average concentration of 0.43 mg/l which decreased to an average of 0.25 mg/l NH_4-N in the March core sample and to non-detect levels in the April core samples and runoff samples.



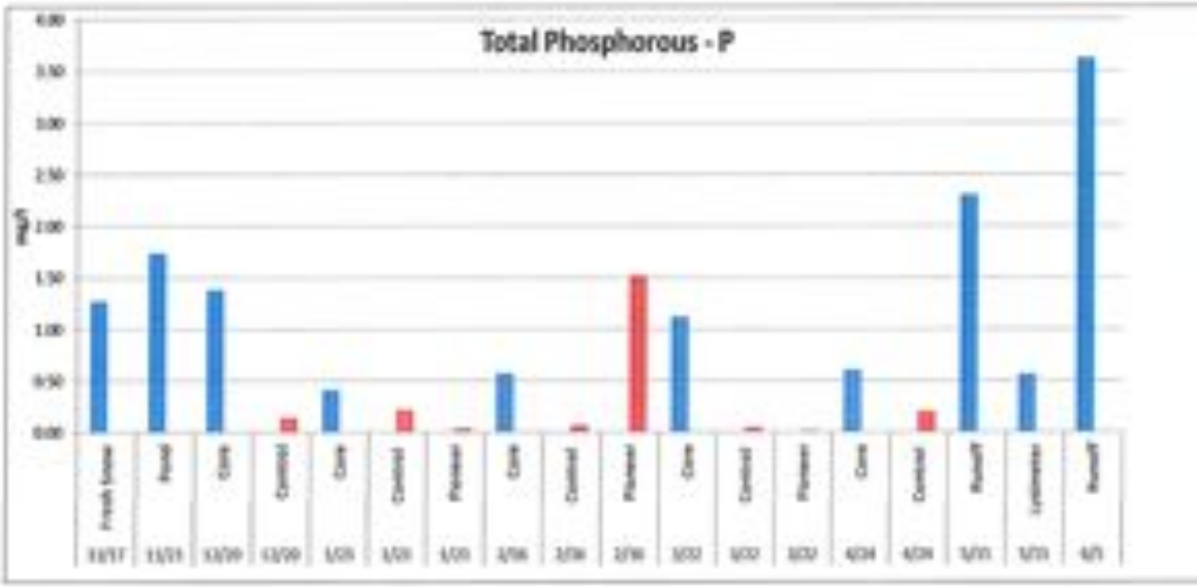
The concentration of nitrate + nitrite increased slightly after the snow was originally applied and then decreased to background / control levels during the runoff period.

Total Kjeldahl Nitrogen (TKN), which is the sum of the organic nitrogen, ammonia, and ammonium, also decreased in concentration through the snow aging process from concentration of 2.3 mg/l in the pond to 0.67 mg/l in May. The concentration increased slightly in the lysimeter and the June runoff.



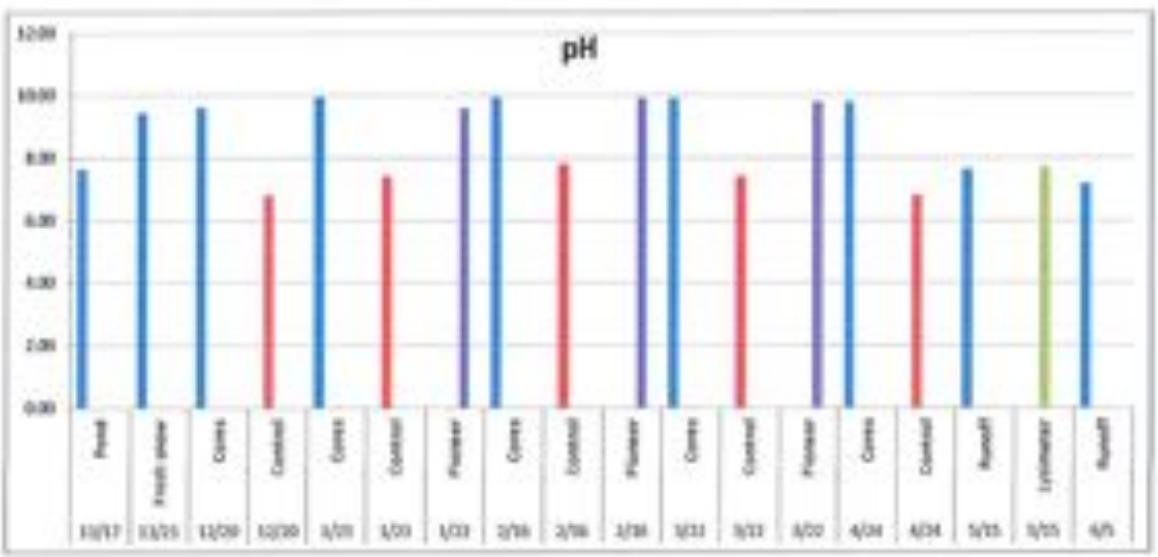
Phosphorous

The phosphorous concentrations in the samples showed variations in both the control and snow samples throughout the testing period. It is likely that the spike in phosphorous during the runoff is due to release of solids and sediment from the snowpack and sediment from erosion of soil in the runoff water.



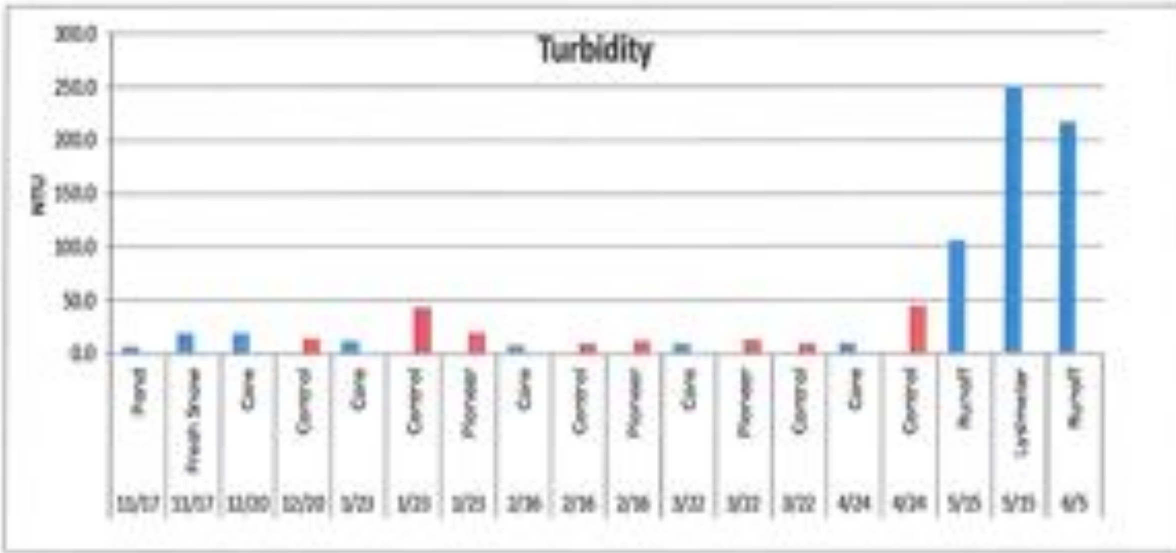
pH

The pH of the water used in the snowmaking operation increased from 7.63 to 9.45 in the fresh snow and then remained in a range of 9.5 to 9.93 until May when the pH of the runoff was measured between 7.17 and 7.63. It is important to note that the shift in pH from 7.63 to 9.45 also drives the form of ammonia present to a higher percentage of gaseous NH_3 from the ammonium ion NH_4 which exists in aqueous solution. At a pH of 7.1 and a temperature of 1°C the percentage of total ammonia present in the NH3 form is 0.113% whereas at a pH of 9.5 and 1°C the percentage of NH3 is 22.1% (EPA, 1979)



Turbidity

Turbidity levels were consistent with control values observed at the snowmaking site and on Pioneer Mountain. During spring runoff turbidity levels spiked as would be expected. The high turbidity observed in the lysimeter sample was most likely caused by washing fines out of the soil in the lysimeter.



Total Suspended Solids

Total Suspended Solids concentrations in the pond and snowpack were consistent with the control site and the site on Pioneer Mountain. A spike was observed during spring runoff which is most likely caused by sediments picked-up from the soil during runoff.

Biochemical Oxygen Demand (BOD_5)

The BOD_5 concentrations remained relatively unchanged and very low during the pilot test with all results being less than 4 mg/l. The samples collected from the pond on two separate days had results of less than 4 mg/l and less than 3 mg/l. The core samples collected had BOD_5 concentrations ranging from non-detect to less than 4 mg/l. The runoff samples were all less than 4 mg/l and the water collected in the lysimeter had a BOD_5 concentration of less than 6 mg/l. All of the results meet the BOD_5 requirements for class A-1 reuse water.

Total Coliforms and *E. Coli*

Total coliform counts and *E. Coli* counts are shown in Table 6. The snowmaking operation appears to be effective in reducing total coliform bacteria with no regrowth of total coliforms in the snowpack during the season. Total coliforms were present in the runoff samples but *E. Coli* were absent with the exception of one sample collected on 5/15/2012. Of the three samples tested for *E. Coli* on 5/15/2012 two showed no evidence of E. Coli and one sample result was 10.9 mpn/100 ml. While the presence of *E. Coli* in the snowpack cannot be ruled out conclusively, the one positive test appears to be an anomaly possibly from contamination during the sampling process or testing. The higher total coliform counts in the runoff samples were probably due to the sediments picked up during the runoff.

Table 6
Total Coliform and *E. Coli* Values

Total Coliforms

		mpn/100ml
Pond 1	11/17/2011	11
Pond 2	11/17/2011	9.8
Pond 3	11/17/2011	10.8
Pond 1	11/21/2011	11.9
Pond 2	11/21/2011	15.5
Pond 3	11/21/2011	7.4
Fresh Snow 1	11/17/2011	1
Fresh Snow 2	11/17/2011	<1
Fresh Snow 3	11/17/2011	3.1
Fresh Snow 2	11/21/2011	<1
Fresh Snow 3	11/21/2011	<1
Core 1	12/20/2011	7.4
Core 2	12/20/2011	9
Core 3	12/20/2011	<1
Core 1	1/23/2012	<1
Core 2	1/23/2012	<1
Core 3	1/23/2012	1
Core 1	2/16/2012	<1
Core 2	2/16/2012	<1
Core3	2/16/2012	<1
Core 1	3/22/2012	<1
Core 2	3/22/2012	<1
Core 3	3/22/2012	<1
Core 1	4/24/2012	<1
Core 2	4/24/2012	<1
Core 3	4/24/2012	<1
Lysimeter 6	5/15/2012	325.5
Runoff 1	5/15/2012	8.5
Runoff 2	5/15/2012	<1
Runoff 1 Dup	5/15/2012	16.1
Runoff 1	6/5/2012	120
Runoff 2	6/5/2012	280
Runoff 1 Dup	6/5/2012	62
Control	12/20/2011	75.9
Control	1/23/2012	<1
Pioneer	1/23/2012	1
Control	2/16/2012	<1
Pioneer	2/16/2012	<1
Pioneer	3/22/2012	ND
Control	3/22/2012	ND
Control	4/24/2012	2

E. Coli

		mpn/100ml
Pond 1	11/17/2011	<1
Pond 2	11/17/2011	<1
Pond 3	11/21/2011	<1
Pond 2	11/21/2011	<1
Pond 3	11/21/2011	<1
Fresh Snow 1	11/17/2011	<1
Fresh Snow 2	11/17/2011	<1
Fresh Snow 3	11/17/2011	<1
Fresh Snow 2	11/21/2011	<1
Fresh Snow 3	11/21/2011	<1
Core 1	12/20/2011	<1
Core 2	12/20/2011	<1
Core 3	12/20/2011	<1
Core 1	1/23/2012	<1
Core 2	1/23/2012	<1
Core 3	1/23/2012	<1
Core 1	2/16/2012	<1
Core2	2/16/2012	<1
Core 3	2/16/2012	<1
Core 1	3/22/2012	ND
Core 2	3/22/2012	ND
Core 3	3/22/2012	ND
Core 1	4/24/2012	<1
Core 2	4/24/2012	<1
Core 3	4/24/2012	<1
Lysimeter 6	5/15/2012	<1
Runoff 1	5/15/2012	<1
Runoff 2	5/15/2012	10.9
Runoff 1 Dup	5/15/2012	<1
Runoff 1	6/5/2012	<1
Runoff 2	6/5/2012	<1
Runoff 1 Dup	6/5/2012	<1
Control	12/20/2011	<1
Control	1/23/2012	<1
Pioneer	1/23/2012	<1
Control	2/16/2012	<1
Pioneer	2/16/2012	<1
Pioneer	3/22/2012	ND
Control	3/22/2012	ND
Control	4/24/2012	<1

8. Discussion

As discussed in the 2008 Preliminary Engineering Report (DOWL HKM, 2008), runoff from a snowmaking operation would have to meet non-degradation criteria and Water Quality Based Effluent Limits (WQBEL's) and would require a Montana Pollution Discharge Elimination System (MPDES) permit. Nitrogen TMDL's contained in the West Fork Gallatin River TMDL study only apply from July 1 through September 30th and therefore are unlikely to come into play during snowmelt conditions. The ability of a snowmaking site to meet non-degradation criteria will be site specific and will depend on the volume of effluent applied, the stream flow rate, and how well runoff from the snowmaking site can be controlled. The test results show that a discharge to groundwater through infiltration would meet non-degradation criteria as the meltwater concentration for nitrate is well below the 7.5mg/l NO_3-N trigger value. As mentioned previously, it appears that at this site and in this meltwater cycle, the primary hydrologic pathway was surface runoff rather than infiltration. It is expected that the distribution of surface runoff and infiltration of meltwater will be site specific and possible vary by year due to changes in the snowpack characteristics.

The results clearly show that there is a reduction in nitrogen concentration in the ageing snowpack but it is difficult to determine with any accuracy how much of the reduction was due to dilution from natural snowfall or from biological/chemical processes within the snowpack. Water collected in the lysimeter on May 15th had a higher total nitrogen concentration than the runoff sample and core sample collected on April 24th which would be consistent with a slug of nutrients being washed out in the initial meltwater. The ammonia concentration in the runoff, 0.12 mg/l NH_3–N, was higher but consistent with average concentrations measured for the control samples (0.082 mg/l NH_3-N).

9. Recommendation

One of the drivers necessitating alternative disposal methods, such as snowmaking, is the potential for significant wastewater flow originating from the lower canyon area if the area is served with a sewer system. The current zoning classification includes provisions for issuing conditional use permits that allow increased development density and higher wastewater flows. The 2008 Preliminary Engineering Report (DOWL HKM, 2008) estimated the lower canyon area had the potential to generate wastewater flows of over 1 million gallons per day, which is roughly 3 times the current flow at the wastewater treatment plant. It is recommended that the Wastewater Solutions Forum work with the County and other local stakeholders to review the current zoning with a goal of limiting wastewater flows.

In oeder to gain approval from the MDEQ for disposal through snowmaking, runoff from the snowmaking application site will have to be contained and percolate into the ground. It is recommended that the topography of the mountain area be evaluated for larger sites where snowmaking could be implemented on a permanent basis with runoff being controlled either by the natural topography or by site grading.

10. Works Cited

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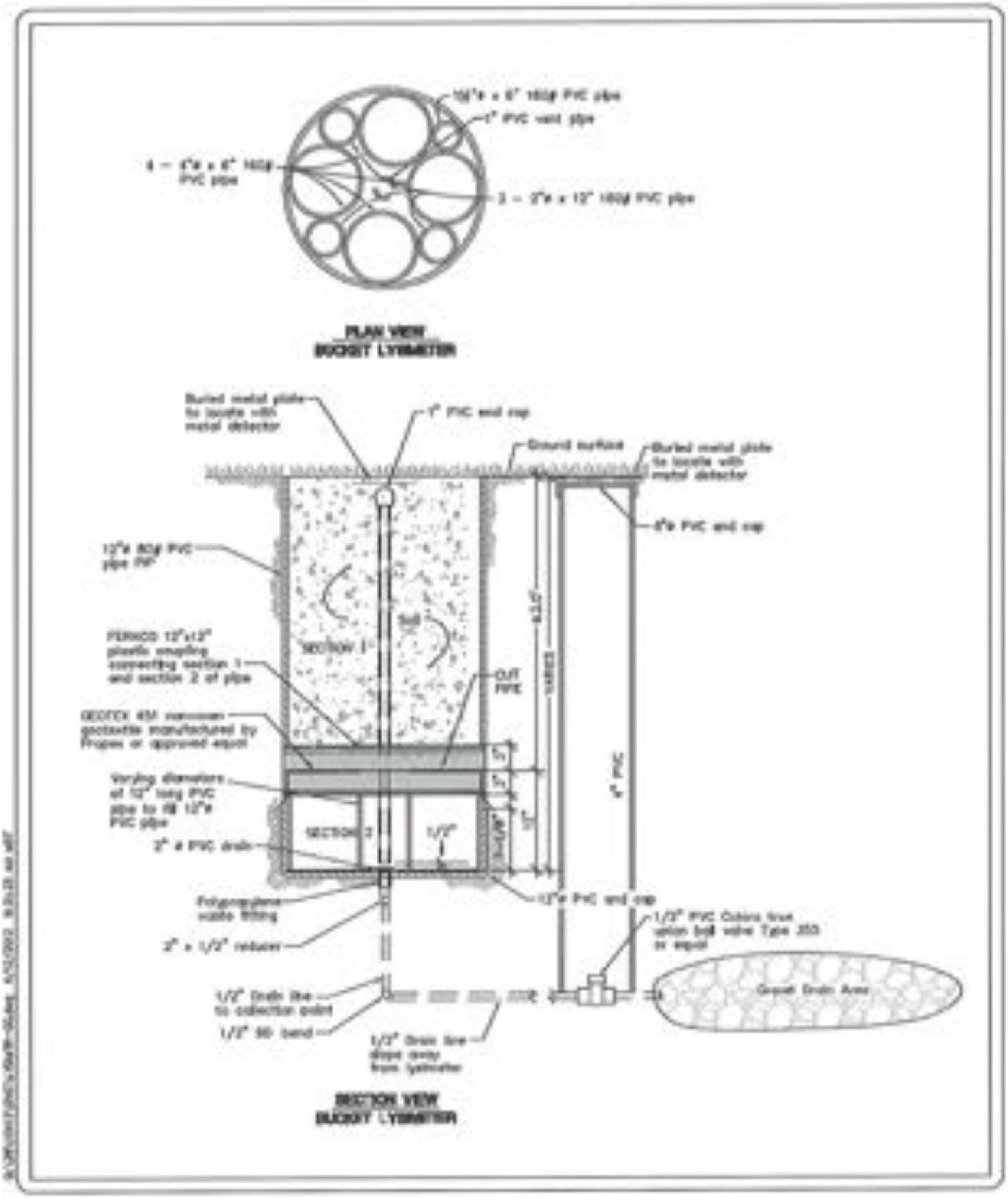
Attachment 1



APPENDIX A
SNOW PITS

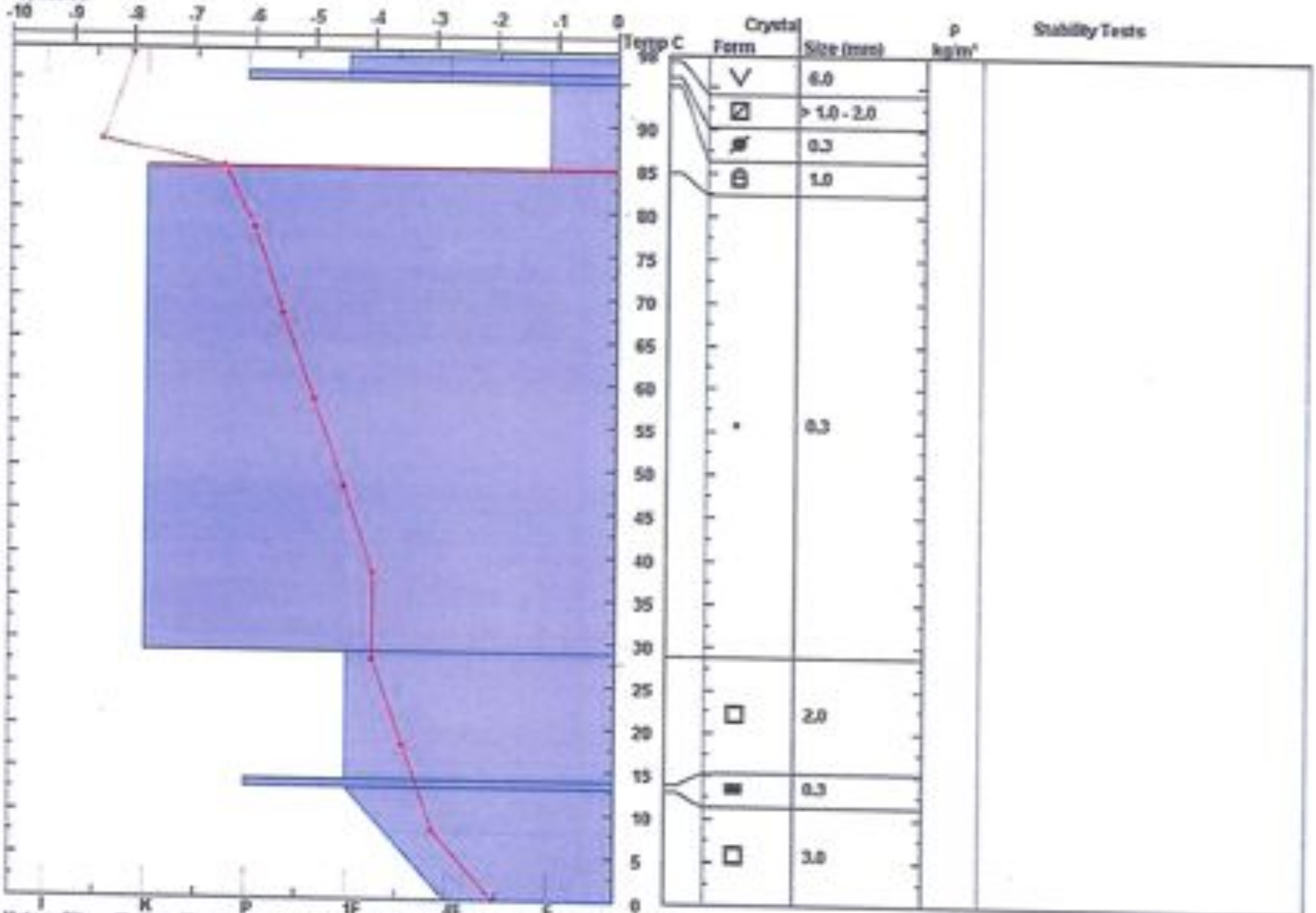
YC collection site 1
Madison, MT
Elevation (ft) 8270
Aspect 95
Specifics:

Mon Jan 09 13:30:00 MST 2012
Co-ord: N W
Slope: 30
Wind loading: previous

Air Temperature: -2.7 C
Sky Cover: Clear
Precipitation: None
Wind: Calm

Stability Test Notes:

29-85: Problematic Layer
Man Made Layer



Notes: Pit profile for effluent snowmaking pilot test. This is not a natural snowpack.

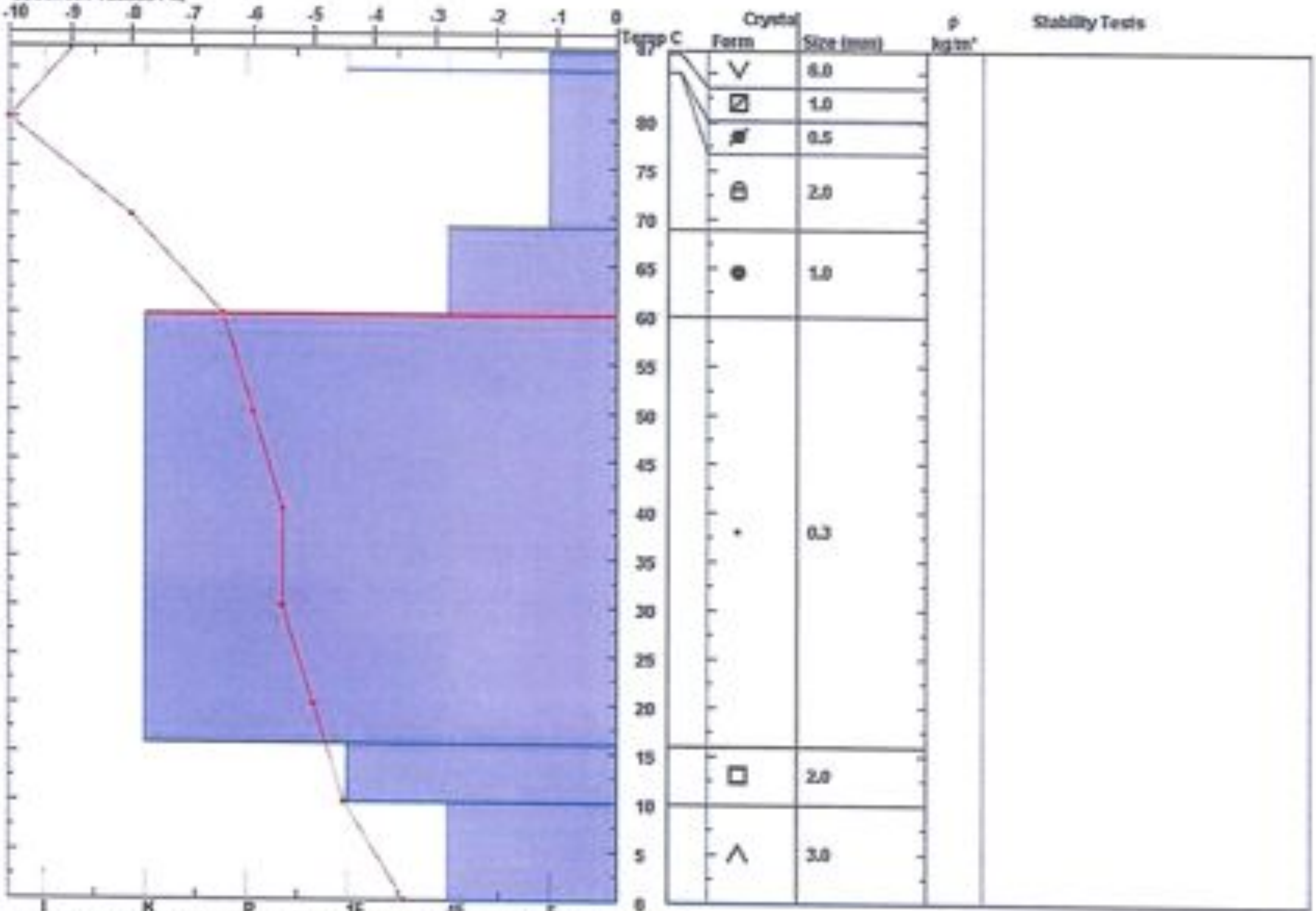
YC Collection site 2
Madison, MT
Elevation (ft) 8270
Aspect: 15
Specifics: Practice Pit;

Mon Jan 09 02:00:00 MST 2012
Co-ord: N W
Slope: 20
Wind loading:

Air Temperature: -3.8 C
Sky Cover: Clear
Precipitation: None
Wind: Calm

Stability Test Notes:

Layer notes:
16-60: Problematic Layer



Notes: Pit Profile for effluent snowmaking pilot test. This is not a natural snowpack.

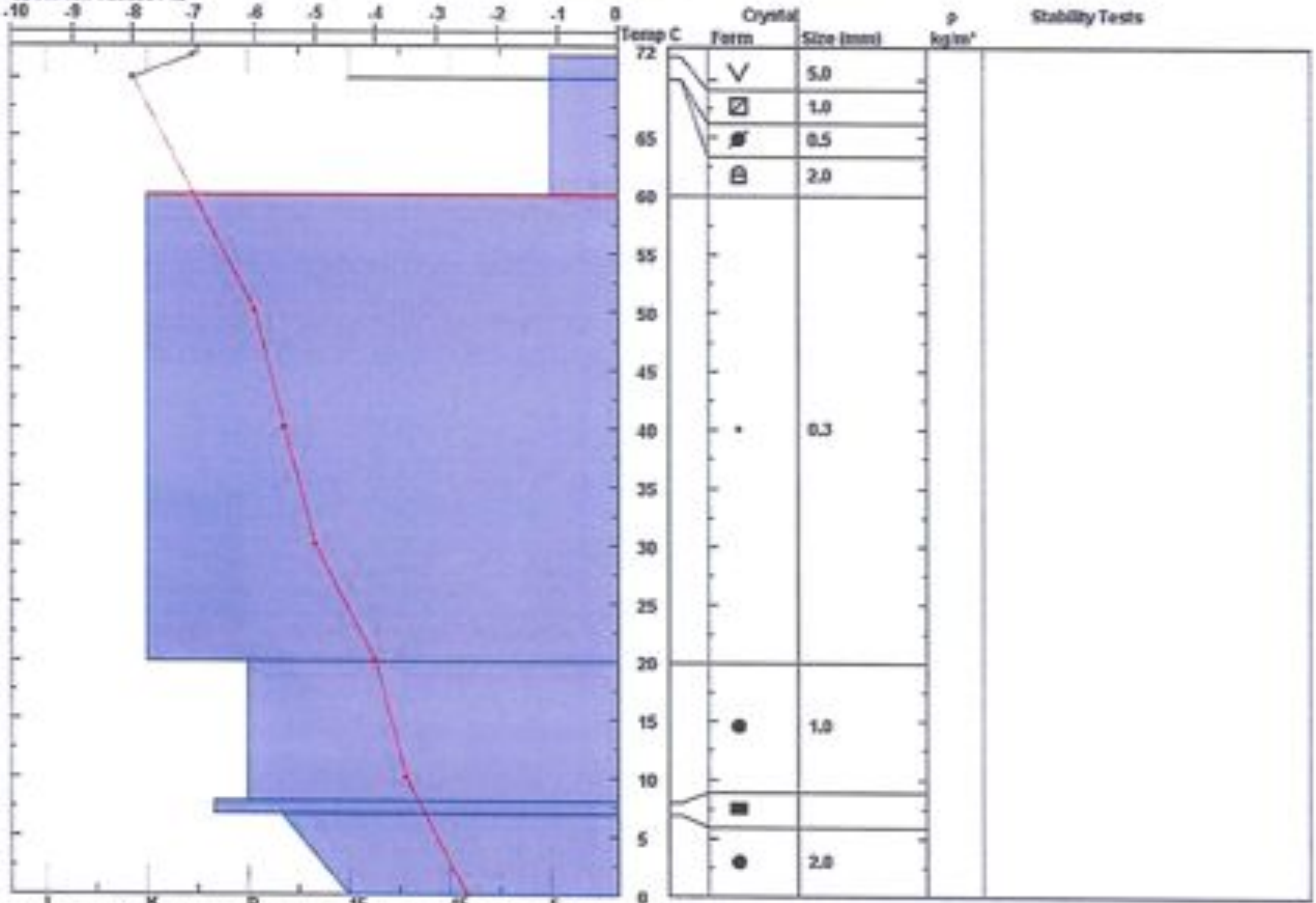
YC Collection site 3
Madison, MT
Elevation (ft) 8270
Aspect: 12
Specifics: Practice Pit:

Mon Jan 09 14:35:00 MST 2012
Co-ord: N W
Slope: 20
Wind loading:

Air Temperature: -2 C
Sky Cover: Clear
Precipitation: None
Wind: Calm

Stability Test Notes:

20-60: Problematic Layer



Notes: Pit profile for effluent snowmaking pilot test. This is not a natural snowpack.

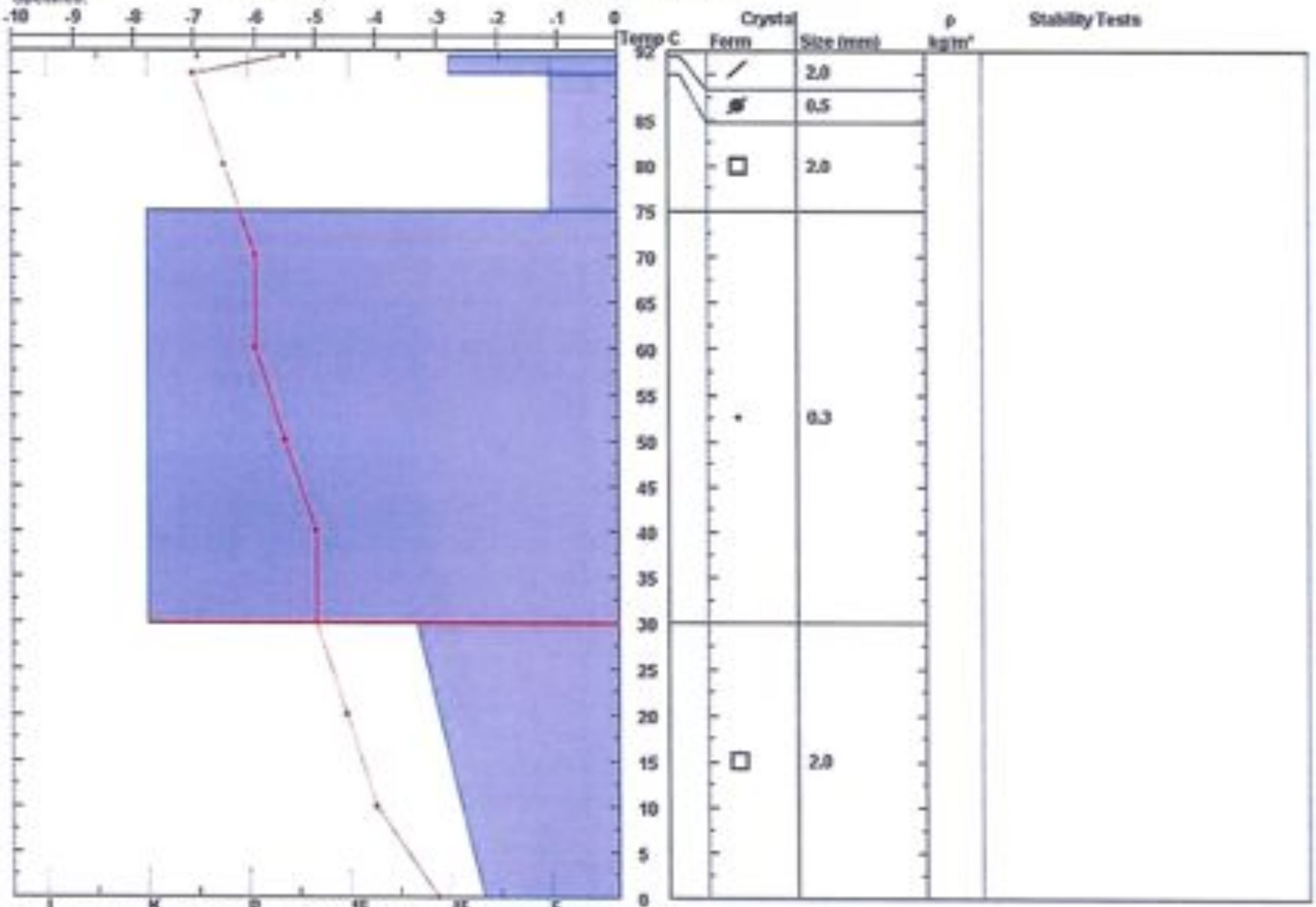
Snow Profile
YC Collection 1
Madison, MT
Elevation (ft) 8270
Aspect: 15
Specifics:

Observer:
Thu Jan 19 13:45:00 MST 2012
Co-ord: N W
Slope: 28
Wind loading:

Stability on similar slopes: Poor
Air Temperature: -2.9 C
Sky Cover: sky 4/8 to 8/8 covered
Precipitation:
Wind: W Light Breeze

Stability Test Notes:

Layer notes:
30-75: Problematic Layer



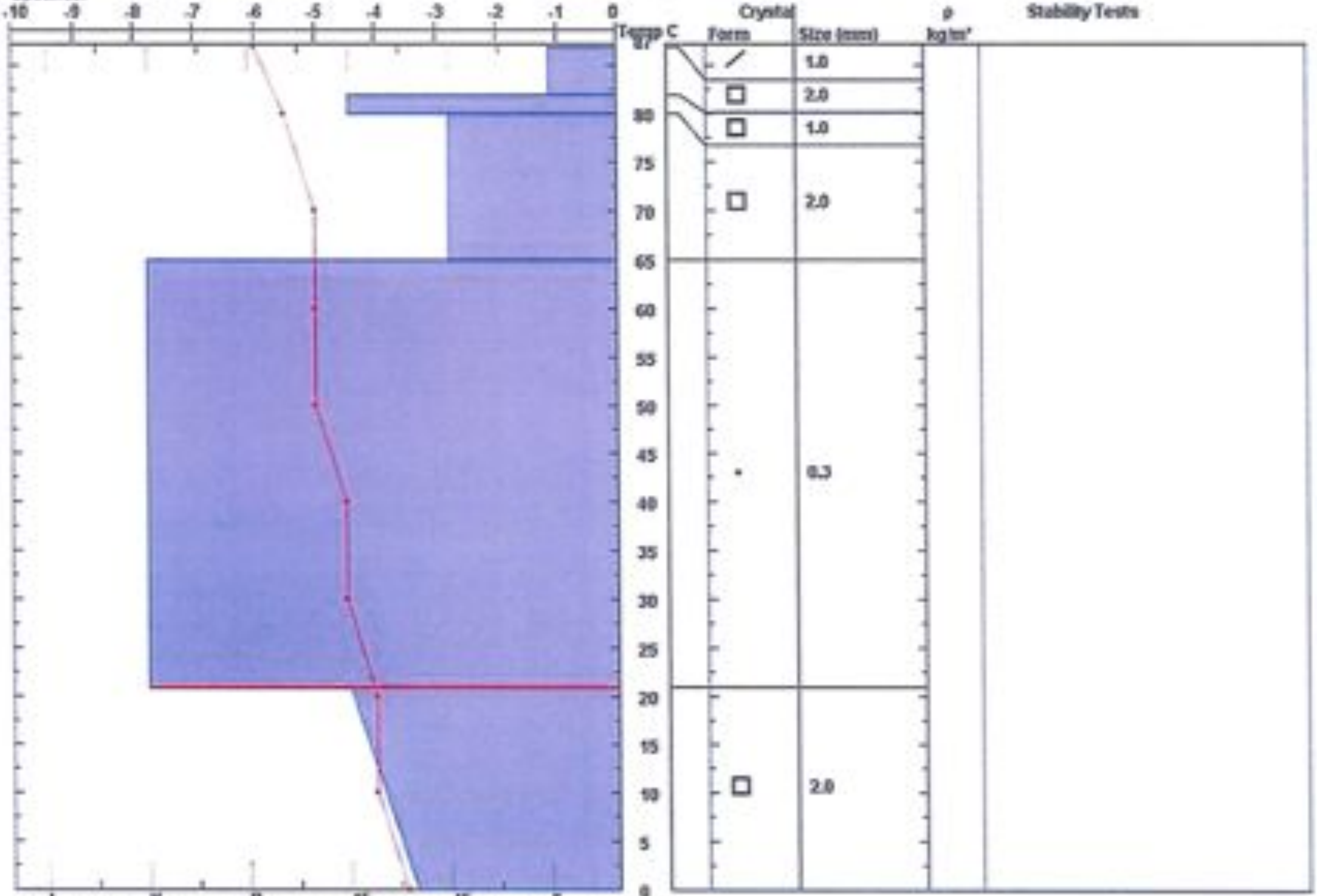
Notes: Pit profile for effluent snowmaking pilot test. This is not a natural snowpack.

YC Collection 2
Madison, MT
Elevation (ft) 8270
Aspect: 15
Specifics:

Thu Jan 19 13:30:00 MST 2012
Co-ord: N W
Slope: 20
Wind loading:

Air Temperature: -2.0 C
Sky Cover: sky 4/8 to 8/8 covered
Precipitation: None
Wind: W Light Breeze

Stability Test Notes:
21-65: Problematic Layer



Notes: Pit profile for effluent snowmaking pilot test. This is not a natural snowpack.

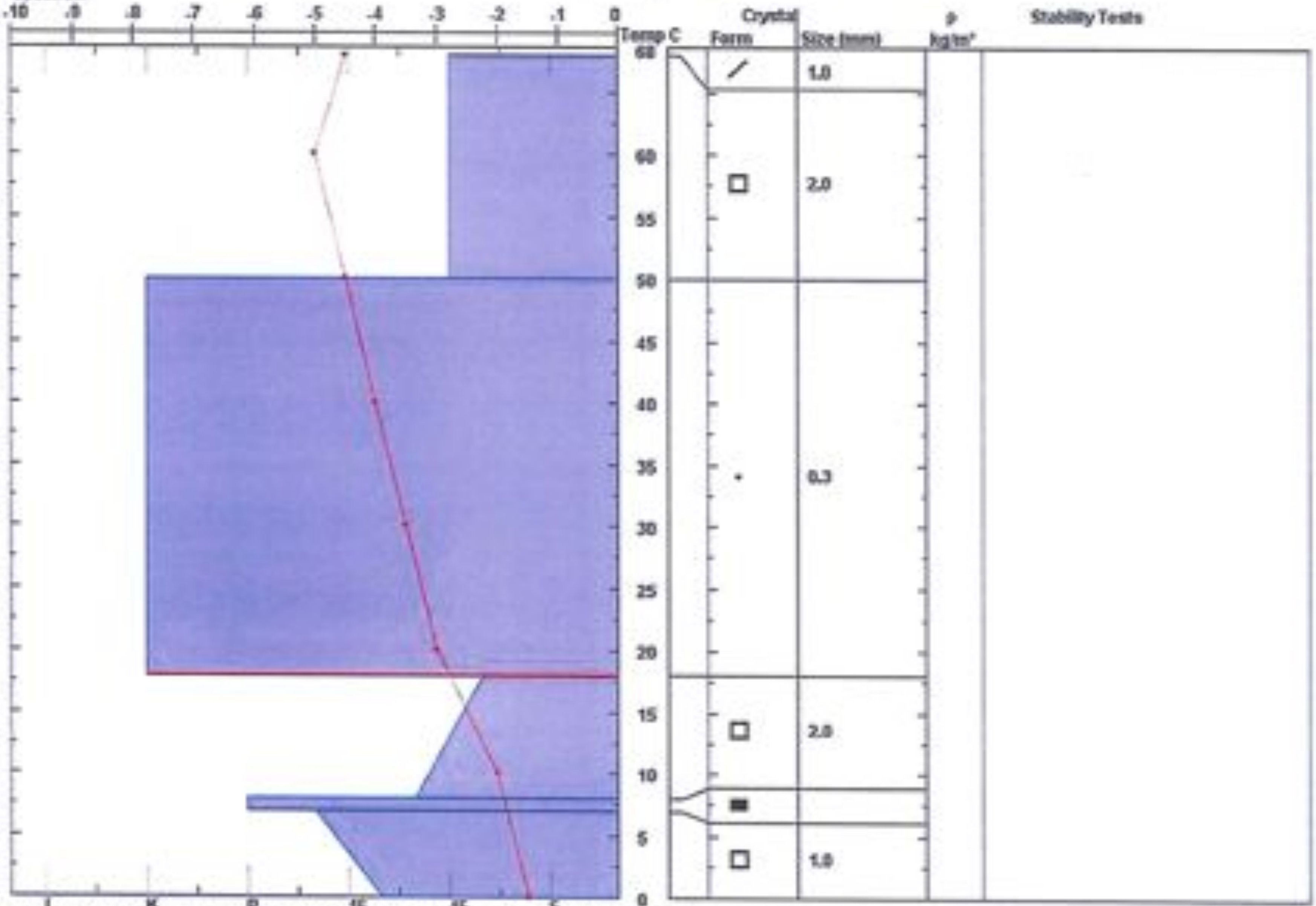
Snow Pit Profile
YC Collection 3
Madison, MT
Elevation (ft) **8270**
Aspect **15**
Specifics:

Observer:
Thu Jan 19 13:00:00 MST 2012
Co-ord: **N W**
Slope: **20**
Wind loading: **no**

Stability on similar slopes:
Air Temperature: **-2.3 C**
Sky Cover: **sky 4/8 to 8/8 covered**
Precipitation: **None**
Wind: **W Light Breeze**

Stability Test Notes:

Layer notes:
18-50: Problematic Layer



Notes: Pit profile for effluent snowmaking pilot test. This is not a natural snowpack.

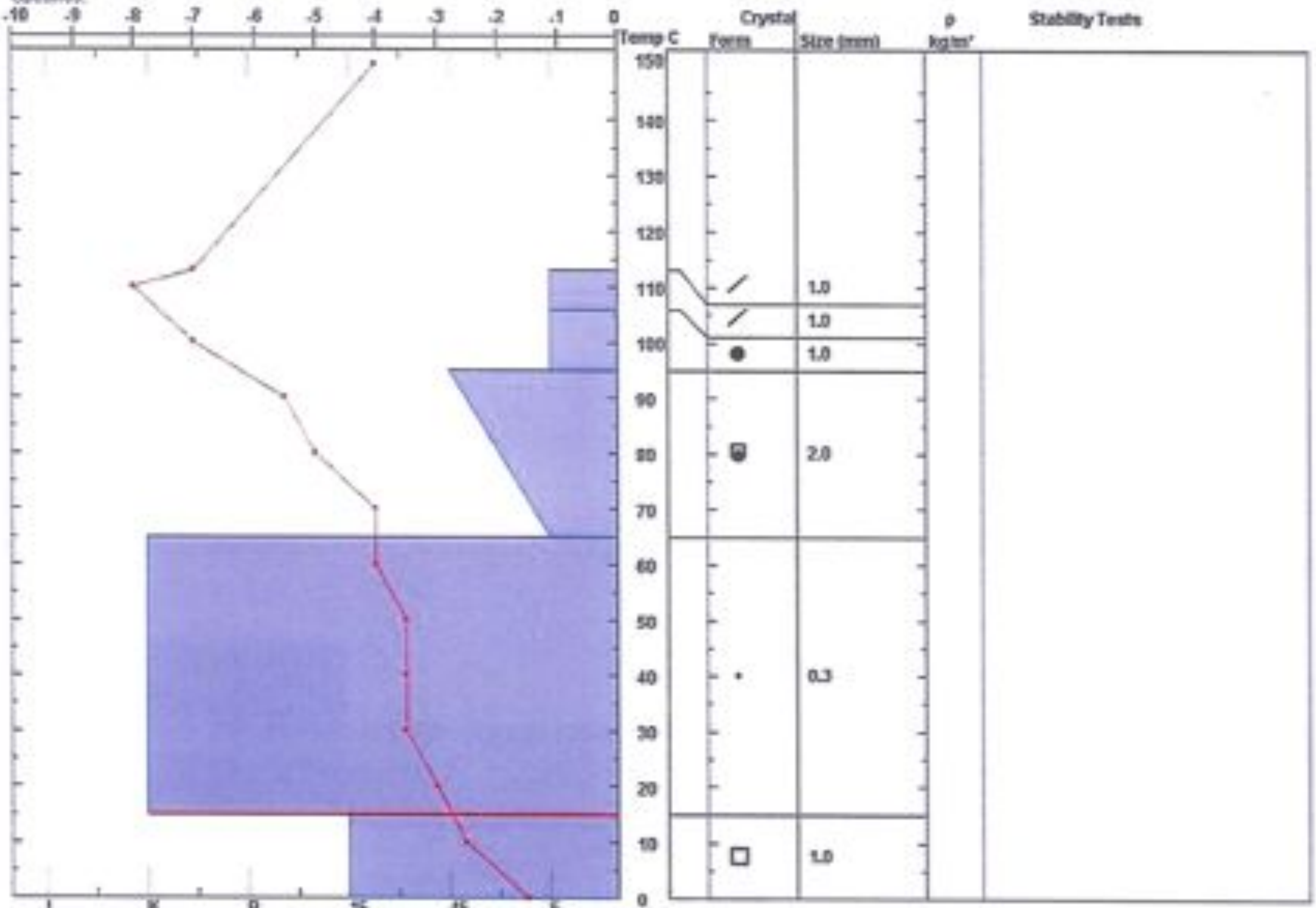
Snow Pit Profile
YC collection site 1
Madison, MT
Elevation (ft) **8270**
Aspect: **15**
Specifics:

Observer: **Rich Chandler**
Thu Feb 16 13:00:00 MST 2012
Co-ord: **N W**
Slope: **30**
Wind loading:

Stability on similar slopes:
Air Temperature: **-4.1 C**
Sky Cover: **Clear**
Precipitation:
Wind:

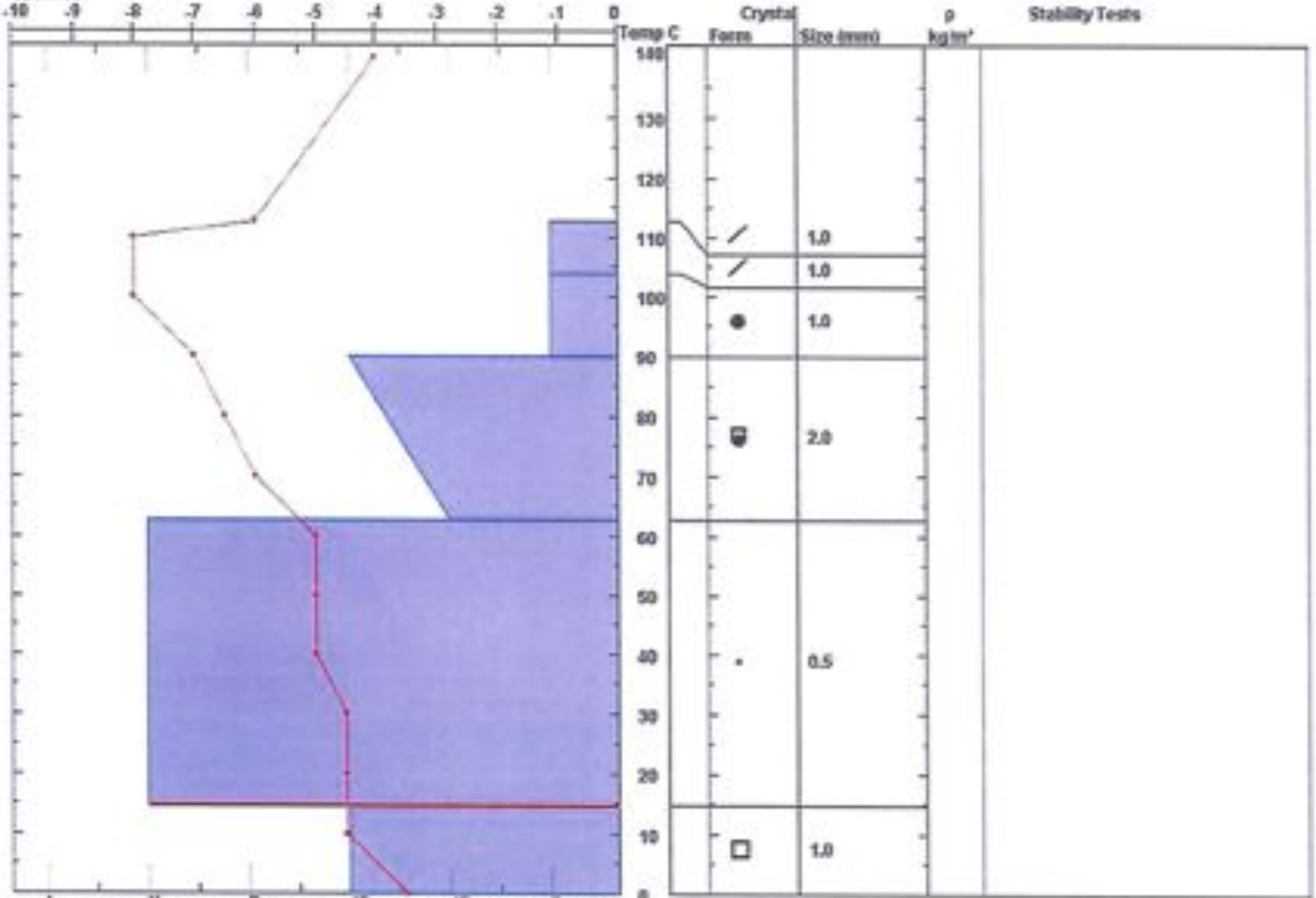
PF40 HS113
Stability Test Notes:

Layer notes:
15-65: Problematic Layer



Notes: Pit profile for effluent snowmaking pilot test. This is not a natural snowpack.

Snow Pit Profile	Observer: Rich [illegible]	Stability on similar slopes:	[illegible]
YC collection 2	Thu Feb 16 13:58:00 MST 2012	Air Temperature: -4.1 C	Stability Test Notes:
Madison, MT	Co-ord: N W	Sky Cover: Clear	Layer Notes: 15-63: Problematic Layer
Elevation (ft) 8270	Slope: 30	Precipitation:	
Aspect: 15	Wind loading:	Wind: Calm	
Specifics:			



Notes: Pit profile for effluent snowmaking pilot test. This is not a natural snowpack.

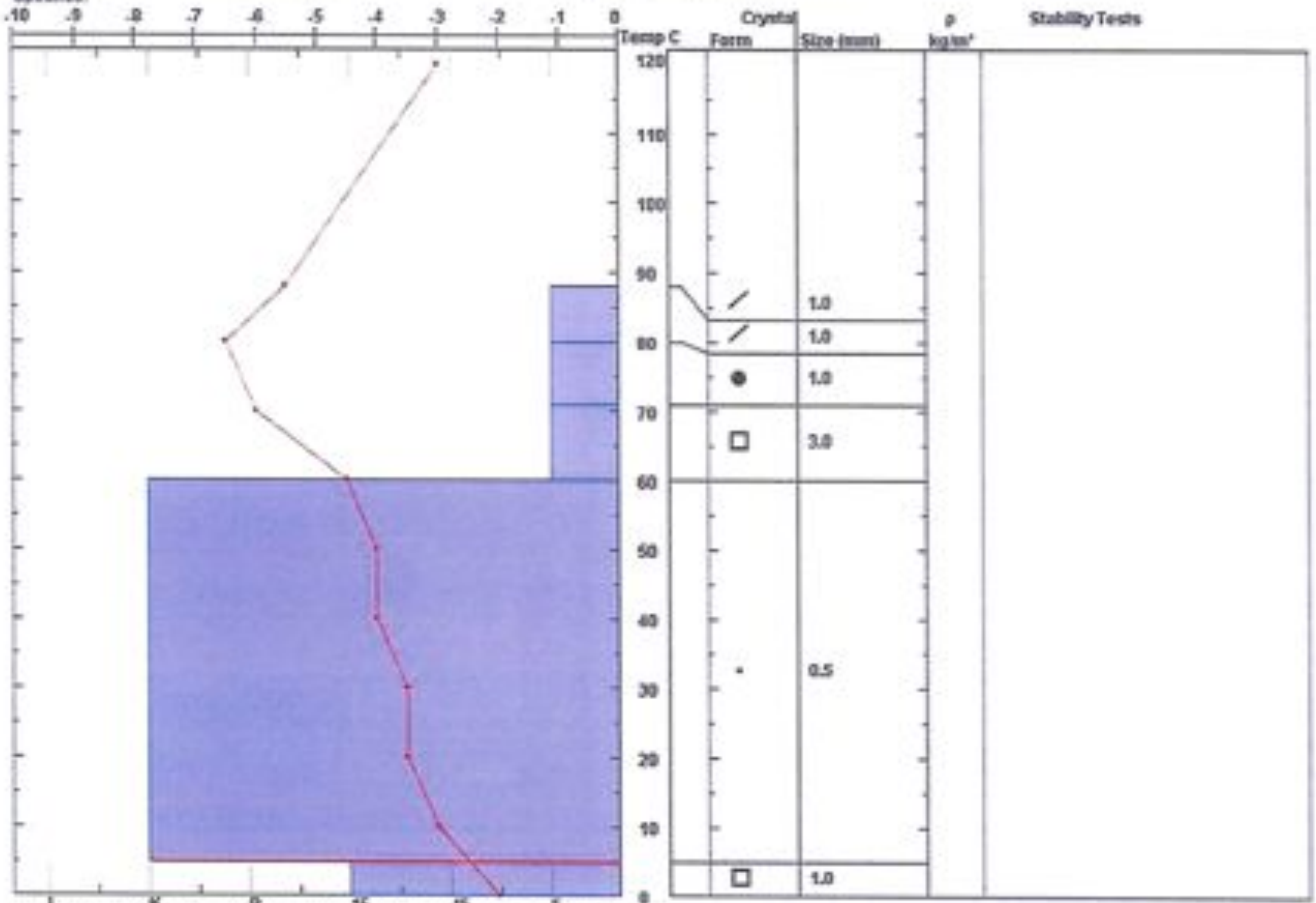
Snow Pit Profile
YC collection 3
Madison, MT
Elevation (ft) **8270**
Aspect: **15**
Specifics:

Observer: **Zach Chandler**
Thu Feb 16 14:05:00 MST 2012
Co-ord: **N W**
Slope: **30**
Wind loading: **no**

Stability on similar slopes:
Air Temperature: **-3.2 C**
Sky Cover: **Clear**
Precipitation:
Wind: **SW Light Breeze**

PF3d1fbd0
Stability Test Notes:

Layer notes:
5-60: Problematic Layer



Notes: Pit profile for effluent snowmaking pilot test. This is not a natural snowpack.

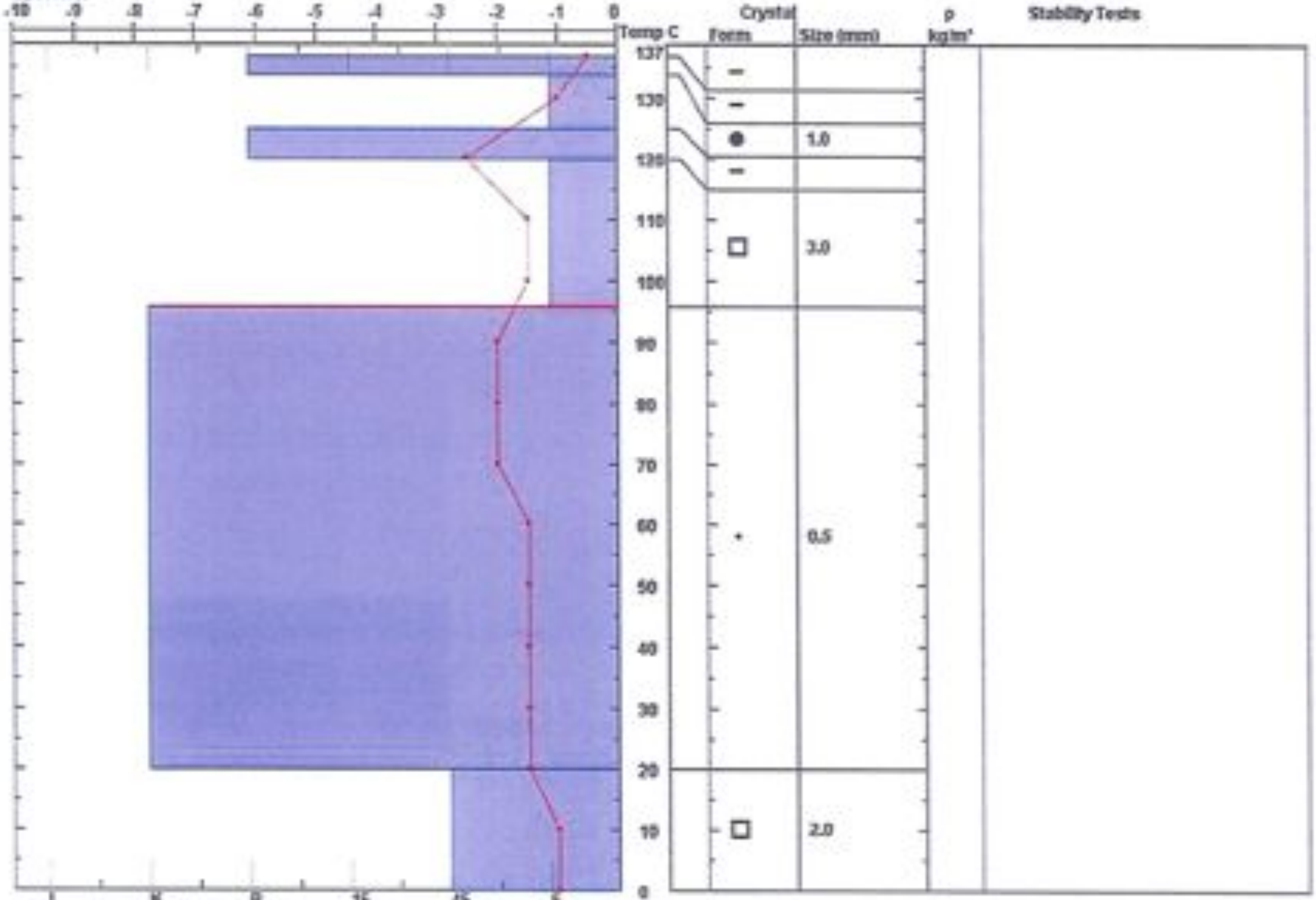
Snow Pit Profile
YC Collect 1 3.22.12
Madison, MT
Elevation (ft)
Aspect: 15
Specifics:

Observer: Rich Chandler
Thu Mar 22 12:20:00 MDT 2012
Co-ord: N W
Slope: 20
Wind loading:

Stability on similar slopes:
Air Temperature: 8.8 C
Sky Cover: Clear
Precipitation:
Wind:

PFO HS137
Stability Test Notes:

Layer notes:
20-96: Problematic Layer



Notes: Pit profile is for effluent snowmaking pilot test. This is not a natural snowpack.