APPENDIX M

TECHNICAL MEMORANDUM
INFILTRATION ANALYSIS - SKI LANE RAVINE

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TECHNICAL MEMORANDUM

TO:	Brian Sandberg, Sarah Illi	REF. NO.:	002012
FROM:	Brian Verspagen / Mark Sullivan/pw/1 BV M.S.	DATE:	February 19, 2007
C.C.:	Filing		
RE:	**Infiltration Analysis - Ski Lane Ravine North Oaks, Minnesota**		

INTRODUCTION

This memorandum was prepared as an appendix to CRA's "Groundwater and Residential Well Evaluation Report (February 2006 - January 2007)" (Report) for North Oaks, Minnesota. This memorandum presents the infiltration analysis for the Ski Lane Ravine (Site).

BACKGROUND

The Site is located in the City of North Oaks, Minnesota. The ravine is bounded by East Oaks Road to the south, Ski Lane to the northwest and Buffalo Road to the northeast. Surface runoff from a small contributing drainage area comprising residential property and light brush currently drains to the ravine. All surface runoff from the small drainage area ultimately infiltrates into the ground at the bottom of the ravine. An infiltration analysis was completed to determine if the existing surface runoff, and additional flow from a proposed groundwater extraction system could be infiltrated into the existing soils via discharge to the ground surface without prolonged surface ponding.

HYDROLOGIC ANALYSIS

The contributing drainage area to the ravine was determined from USGS topographical maps and is presented in Figure 1. The contributing drainage area to the ravine is approximately 12.2 acres. The catchment parameters representative of the contributing drainage area are presented in Table 1.

Hydrologic modeling of the catchment area was completed using the US Army Corps of Engineers Hydrologic engineering Center's Hydrologic Modeling System (HEC-HMS). Rainfall data for 2005 and 2006 was obtained from the Mounds Park, East Metro, Saint Paul, Minnesota weather station. Using the rainfall data, particular storm events were chosen to represent a certain amount of rainfall for a given day. Five storm events were modeled to represent daily rainfall totals of 0.5 in., 1.0 in., 1.5 in., 2.0 in., and larger than 2.0 in. The storm events were modeled using HEC-HMS and the corresponding runoff coefficients for each storm were calculated. These runoff coefficients were used to compute the runoff from the daily

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rainfall values for the weather station. The annual surface runoff into the ravine was then calculated. The daily rainfall and runoff values are presented in Table 2. The average annual runoff from the contributing drainage area is 231,000 ft^3/year. This represents the volume of water that is conveyed to the ravine, and infiltrates into the existing soils.

A similar analysis was completed using long-term monthly average rainfall data. The runoff coefficient from the 1.5 in. rainfall was used for the analysis. The results of the analysis are presented in Table 3. The annual runoff from the contributing drainage area using the long-term monthly rainfall data was 338,000 ft^3/year.

It should be noted that the calculated runoff values do not account for additional losses such as evapo-transpiration, which occur during the growing season and when water is ponded in the ravine during the summer months.

A constant groundwater extraction rate of 30 gpm equates to approximately 2,108,000 ft^3/year of additional flow which would need to infiltrate into the existing soil. A total volume of approximately 2,340,000 ft^3/year would be discharged to the ravine from the proposed groundwater extraction system and surface runoff. This represents a eight-fold increase in the volume of water that must be infiltrated into the existing soils.

GEOTECHNICAL ANALYSIS

As part of the infiltration analysis, geotechnical soil sampling was conducted in the northern portion of the Ski Lane Ravine. A detailed presentation of the soil sampling activities and geotechnical analysis is provided in the Report. Based on field observations, the stratigraphy of the site was assumed to be a topsoil/clay layer from the ground surface to 5 feet below the ground surface, and then a sand layer down to the water table (approximately 40 feet below ground surface). Soil boring SB-1 was most representative of the existing soils, therefore the grain size distribution associated with SB-1 was used to determine the hydraulic conductivity of the existing soils. Hydraulic conductivity calculations are presented in Table 4. The hydraulic conductivity of the clay layer was estimated at 1.0×10^{-6} cm/s and 5×10^{-3} cm/s for the sand layer.

INFILTRATION ANALYSIS

As part of the infiltration analysis, a licensed topographic and property line survey was completed in the northern portion of the Ski Lane Ravine. The topographic survey was used to create a stage-storage relationship, representative of the ravine. The stage discharge relationship is presented in Table 5. Based on the drawdown times from the stage discharge relationship, water which ponds to an elevation of 906 ft. (approximately 1 ft above the bottom of the ravine) would take approximately 436 days to infiltrate. The calculated drawdown time is conservative, as there is not standing water in the ravine year round.

HEC-HMS was used to route the surface runoff from the catchment area to the ravine. The rainfall data from 2005 was used in the analysis and the ravine filled to a stage elevation of approximately 915 feet by the end of the year. Again this is a conservative estimate, as the ravine does not contain standing water year round. When 30 gpm was added to the runoff and simulated through the existing ravine, surface water ponded above the maximum entered stage elevation of 920 feet over the course of a year.

The infiltration analysis indicates that the low hydraulic conductivity of the clay layer significantly restricts the amount of water that can infiltrate into the existing soils without prolonged surface ponding. Therefore, infiltration of extracted groundwater from the proposed extraction system is only feasible via an engineered infiltration gallery.

INFILTRATION GALLERY

Since the hydraulic conductivity of the sand layer is significantly greater than the hydraulic conductivity of the clay layer, discharging directly to the sand layer (approximately 5 ft. below the ground surface) significantly increases the capacity of ravine to handle discharge of the extracted groundwater. Extracted groundwater can be discharged directly into the existing sand layer via construction of an infiltration gallery within the Ski Lane Ravine.

Table 6 presents the infiltration gallery sizing for a groundwater extraction rate of 30 gpm. An area of approximately 1020 ft^2 is required to accommodate a groundwater extraction rate of 30 gpm. Table 7 presents the infiltration gallery sizing for a groundwater extraction rate of 50 gpm. An area of approximately 1700 ft^2 is required to accommodate a groundwater extraction rate of 50 gpm. An infiltration gallery of this size can readily fit within the northern portion of the Ski Lane Ravine.

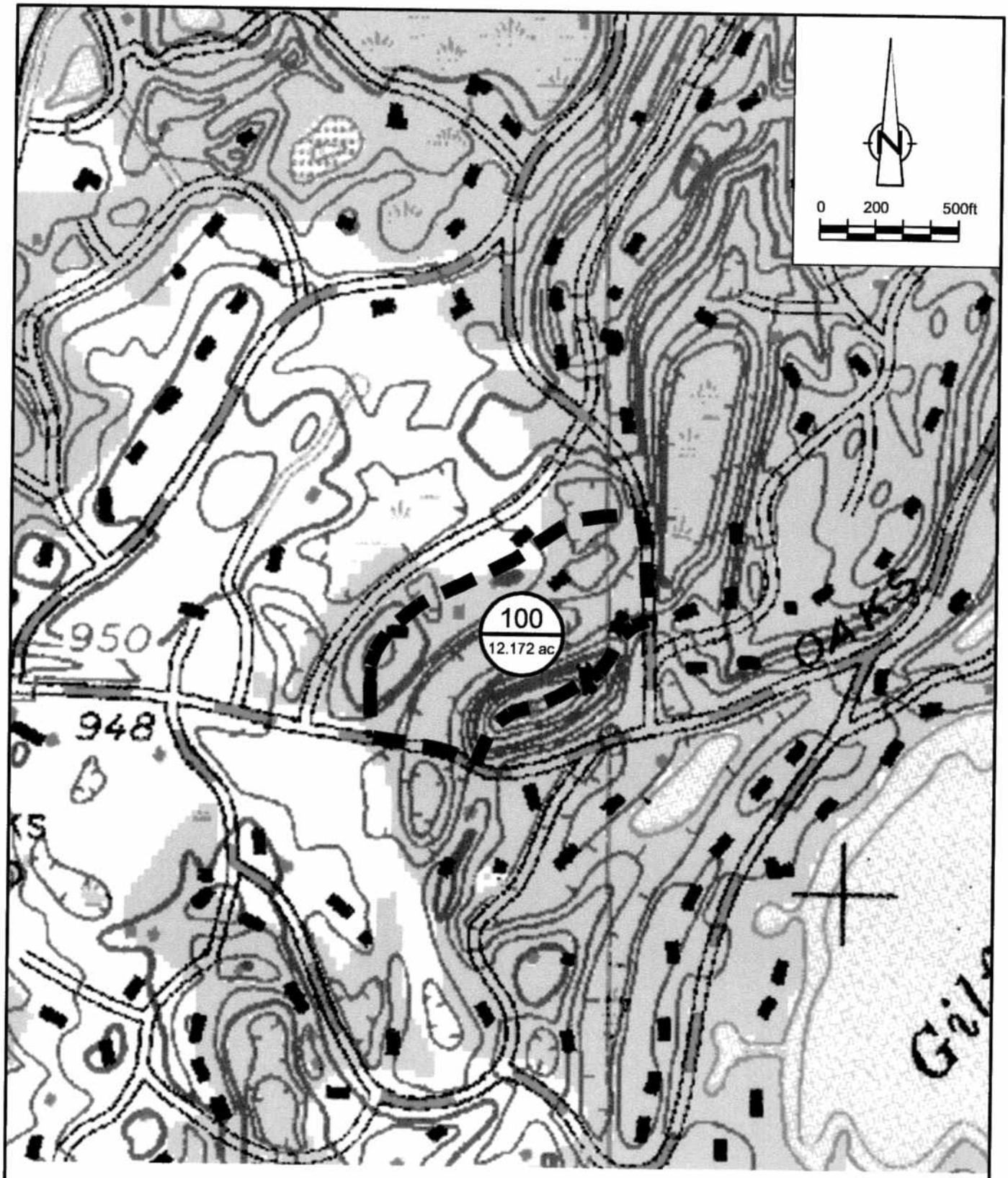

figure 1

CONTRIBUTING DRAINAGE AREA
SKI LANE RAVINE
North Oaks, Minnesota

02012-00(MEMO001-WA)GN-WA004 FEB 19/2007

TABLE 1

EXISTING CONDITIONS SUBCATCHMENT PARAMETERS
INFILTRATION ANALYSIS
SKI LANE RAVINE
NORTH OAKS, MINNESOTA

Subcatchment	*Area (acres)*	*Flow Length (feet)*	*Slope (%)*	*Soil Group*	*CN1*	*Initial Abstraction 2 (in.)*	*Manning's kinematic solution (tc) (min)*	*Time to Peak 3 (min)*
100	12.17	270	16.7	C	70	0.43	64.2	*38.5*
Total	*12.17*							

Notes:

1. Soil Conservation Service (SCS) Curve Number.
2. Assumes Ia = 0.1S
3. Time to Peak = 0.6 x tc

TABLE 2

2005 AND 2006 RAINFALL AND RUNOFF SUMMARY
INFILTRATION ANALYSIS
SKI LANE RAVINE
NORTH OAKS, MINNESOTA

Summary of Runoff Coefficients

Daily Rainfall	Runoff Coefficient
0-0.5 in.	0.1506
0.5-1.0 in.	0.1815
1.0-1.5 in.	0.2614
1.5-2.0 in.	0.3137
>2.0 in.	0.4020

2005 Daily Rainfall Data
from Mounds Park, East Metro, Saint Paul, MN

Date	Rainfall (in.)	Runoff (in.)	Loss (in.)
1-Jan-05	0.00	0.00	0.00
2-Jan-05	0.00	0.00	0.00
3-Jan-05	0.00	0.00	0.00
4-Jan-05	0.00	0.00	0.00
5-Jan-05	0.00	0.00	0.00
6-Jan-05	0.00	0.00	0.00
7-Jan-05	0.00	0.00	0.00
8-Jan-05	0.00	0.00	0.00
9-Jan-05	0.00	0.00	0.00
10-Jan-05	0.00	0.00	0.00
11-Jan-05	0.00	0.00	0.00
12-Jan-05	0.00	0.00	0.00
13-Jan-05	0.00	0.00	0.00
14-Jan-05	0.00	0.00	0.00
15-Jan-05	0.00	0.00	0.00
16-Jan-05	0.00	0.00	0.00
17-Jan-05	0.00	0.00	0.00
18-Jan-05	0.00	0.00	0.00
19-Jan-05	0.00	0.00	0.00
20-Jan-05	0.00	0.00	0.00
21-Jan-05	0.00	0.00	0.00
22-Jan-05	0.00	0.00	0.00
23-Jan-05	0.00	0.00	0.00
24-Jan-05	0.12	0.02	0.10
25-Jan-05	0.38	0.06	0.32
26-Jan-05	0.01	0.00	0.01
27-Jan-05	0.00	0.00	0.00
28-Jan-05	0.00	0.00	0.00
29-Jan-05	0.00	0.00	0.00
30-Jan-05	0.01	0.00	0.01
31-Jan-05	0.04	0.01	0.03
1-Feb-05	0.00	0.00	0.00
2-Feb-05	0.02	0.00	0.02
3-Feb-05	0.00	0.00	0.00
4-Feb-05	0.00	0.00	0.00
5-Feb-05	0.00	0.00	0.00
6-Feb-05	0.00	0.00	0.00
7-Feb-05	0.00	0.00	0.00
8-Feb-05	0.00	0.00	0.00
9-Feb-05	0.00	0.00	0.00
10-Feb-05	0.00	0.00	0.00
11-Feb-05	0.00	0.00	0.00
12-Feb-05	0.00	0.00	0.00
13-Feb-05	0.27	0.04	0.23

2006 Daily Rainfall Data
from Mounds Park, East Metro, Saint Paul, MN

Date	Rainfall (in.)	Runoff (in.)	Loss (in.)
1-Jan-06	0.04	0.01	0.03
2-Jan-06	0.04	0.01	0.03
3-Jan-06	0.13	0.02	0.11
4-Jan-06	0.08	0.01	0.07
5-Jan-06	0.00	0.00	0.00
6-Jan-06	0.00	0.00	0.00
7-Jan-06	0.00	0.00	0.00
8-Jan-06	0.00	0.00	0.00
9-Jan-06	0.00	0.00	0.00
10-Jan-06	0.00	0.00	0.00
11-Jan-06	0.00	0.00	0.00
12-Jan-06	0.00	0.00	0.00
13-Jan-06	0.00	0.00	0.00
14-Jan-06	0.00	0.00	0.00
15-Jan-06	0.00	0.00	0.00
16-Jan-06	0.00	0.00	0.00
17-Jan-06	0.00	0.00	0.00
18-Jan-06	0.00	0.00	0.00
19-Jan-06	0.00	0.00	0.00
20-Jan-06	0.00	0.00	0.00
21-Jan-06	0.01	0.00	0.01
22-Jan-06	0.00	0.00	0.00
23-Jan-06	0.00	0.00	0.00
24-Jan-06	0.03	0.00	0.03
25-Jan-06	0.00	0.00	0.00
26-Jan-06	0.04	0.01	0.03
27-Jan-06	0.00	0.00	0.00
28-Jan-06	0.10	0.02	0.08
29-Jan-06	0.07	0.01	0.06
30-Jan-06	0.02	0.00	0.02
31-Jan-06	0.00	0.00	0.00
1-Feb-06	0.01	0.00	0.01
2-Feb-06	0.10	0.02	0.08
3-Feb-06	0.00	0.00	0.00
4-Feb-06	0.00	0.00	0.00
5-Feb-06	0.00	0.00	0.00
6-Feb-06	0.00	0.00	0.00
7-Feb-06	0.00	0.00	0.00
8-Feb-06	0.00	0.00	0.00
9-Feb-06	0.00	0.00	0.00
10-Feb-06	0.01	0.00	0.01
11-Feb-06	0.00	0.00	0.00
12-Feb-06	0.00	0.00	0.00
13-Feb-06	0.00	0.00	0.00

TABLE 2

2005 AND 2006 RAINFALL AND RUNOFF SUMMARY
INFILTRATION ANALYSIS
SKI LANE RAVINE
NORTH OAKS, MINNESOTA

2005 Daily Rainfall Data
from Mounds Park, East Metro, Saint Paul, MN

Date	Rainfall (in.)	Runoff (in.)	Loss (in.)
14-Feb-05	0.29	0.04	0.25
15-Feb-05	0.00	0.00	0.00
16-Feb-05	0.00	0.00	0.00
17-Feb-05	0.00	0.00	0.00
18-Feb-05	0.00	0.00	0.00
19-Feb-05	0.00	0.00	0.00
20-Feb-05	0.11	0.02	0.09
21-Feb-05	0.00	0.00	0.00
22-Feb-05	0.00	0.00	0.00
23-Feb-05	0.02	0.00	0.02
24-Feb-05	0.00	0.00	0.00
25-Feb-05	0.00	0.00	0.00
26-Feb-05	0.00	0.00	0.00
27-Feb-05	0.02	0.00	0.02
28-Feb-05	0.00	0.00	0.00
1-Mar-05	0.00	0.00	0.00
2-Mar-05	0.00	0.00	0.00
3-Mar-05	0.02	0.00	0.02
4-Mar-05	0.02	0.00	0.02
5-Mar-05	0.00	0.00	0.00
6-Mar-05	0.00	0.00	0.00
7-Mar-05	0.00	0.00	0.00
8-Mar-05	0.00	0.00	0.00
9-Mar-05	0.00	0.00	0.00
10-Mar-05	0.21	0.03	0.18
11-Mar-05	0.00	0.00	0.00
12-Mar-05	0.00	0.00	0.00
13-Mar-05	0.00	0.00	0.00
14-Mar-05	0.00	0.00	0.00
15-Mar-05	0.00	0.00	0.00
16-Mar-05	0.00	0.00	0.00
17-Mar-05	0.00	0.00	0.00
18-Mar-05	0.00	0.00	0.00
19-Mar-05	0.12	0.02	0.10
20-Mar-05	0.00	0.00	0.00
21-Mar-05	0.00	0.00	0.00
22-Mar-05	0.00	0.00	0.00
23-Mar-05	0.00	0.00	0.00
24-Mar-05	0.00	0.00	0.00
25-Mar-05	0.00	0.00	0.00
26-Mar-05	0.00	0.00	0.00
27-Mar-05	0.00	0.00	0.00
28-Mar-05	0.00	0.00	0.00
29-Mar-05	0.00	0.00	0.00
30-Mar-05	0.82	0.15	0.67
31-Mar-05	0.04	0.01	0.03
1-Apr-05	0.02	0.00	0.02
2-Apr-05	0.00	0.00	0.00
3-Apr-05	0.00	0.00	0.00
4-Apr-05	0.00	0.00	0.00
5-Apr-05	0.00	0.00	0.00
6-Apr-05	0.00	0.00	0.00
7-Apr-05	0.00	0.00	0.00

2006 Daily Rainfall Data
from Mounds Park, East Metro, Saint Paul, MN

Date	Rainfall (in.)	Runoff (in.)	Loss (in.)
14-Feb-06	0.04	0.01	0.03
15-Feb-06	0.00	0.00	0.00
16-Feb-06	0.00	0.00	0.00
17-Feb-06	0.03	0.00	0.03
18-Feb-06	0.00	0.00	0.00
19-Feb-06	0.00	0.00	0.00
20-Feb-06	0.00	0.00	0.00
21-Feb-06	0.00	0.00	0.00
22-Feb-06	0.00	0.00	0.00
23-Feb-06	0.00	0.00	0.00
24-Feb-06	0.00	0.00	0.00
25-Feb-06	0.00	0.00	0.00
26-Feb-06	0.00	0.00	0.00
27-Feb-06	0.00	0.00	0.00
28-Feb-06	0.00	0.00	0.00
1-Mar-06	0.00	0.00	0.00
2-Mar-06	0.00	0.00	0.00
3-Mar-06	0.00	0.00	0.00
4-Mar-06	0.00	0.00	0.00
5-Mar-06	0.03	0.00	0.03
6-Mar-06	0.06	0.01	0.05
7-Mar-06	0.08	0.01	0.07
8-Mar-06	0.00	0.00	0.00
9-Mar-06	0.01	0.00	0.01
10-Mar-06	0.00	0.00	0.00
11-Mar-06	0.00	0.00	0.00
12-Mar-06	0.03	0.00	0.03
13-Mar-06	0.04	0.01	0.03
14-Mar-06	0.01	0.00	0.01
15-Mar-06	0.02	0.00	0.02
16-Mar-06	0.04	0.01	0.03
17-Mar-06	0.13	0.02	0.11
18-Mar-06	0.03	0.00	0.03
19-Mar-06	0.01	0.00	0.01
20-Mar-06	0.00	0.00	0.00
21-Mar-06	0.00	0.00	0.00
22-Mar-06	0.00	0.00	0.00
23-Mar-06	0.02	0.00	0.02
24-Mar-06	0.00	0.00	0.00
25-Mar-06	0.00	0.00	0.00
26-Mar-06	0.00	0.00	0.00
27-Mar-06	0.00	0.00	0.00
28-Mar-06	0.00	0.00	0.00
29-Mar-06	0.00	0.00	0.00
30-Mar-06	0.21	0.03	0.18
31-Mar-06	0.12	0.02	0.10
1-Apr-06	0.00	0.00	0.00
2-Apr-06	0.76	0.14	0.62
3-Apr-06	0.00	0.00	0.00
4-Apr-06	0.00	0.00	0.00
5-Apr-06	0.00	0.00	0.00
6-Apr-06	0.37	0.06	0.31
7-Apr-06	0.00	0.00	0.00

TABLE 2

2005 AND 2006 RAINFALL AND RUNOFF SUMMARY
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SKI LANE RAVINE
NORTH OAKS, MINNESOTA

2005 Daily Rainfall Data
from Mounds Park, East Metro, Saint Paul, MN

Date	Rainfall (in.)	Runoff (in.)	Loss (in.)
8-Apr-05	0.00	0.00	0.00
9-Apr-05	0.00	0.00	0.00
10-Apr-05	0.00	0.00	0.00
11-Apr-05	0.18	0.03	0.15
12-Apr-05	0.21	0.03	0.18
13-Apr-05	0.00	0.00	0.00
14-Apr-05	0.00	0.00	0.00
15-Apr-05	0.03	0.00	0.03
16-Apr-05	0.90	0.16	0.74
17-Apr-05	0.00	0.00	0.00
18-Apr-05	0.05	0.01	0.04
19-Apr-05	0.23	0.03	0.20
20-Apr-05	0.00	0.00	0.00
21-Apr-05	0.00	0.00	0.00
22-Apr-05	0.01	0.00	0.01
23-Apr-05	0.00	0.00	0.00
24-Apr-05	0.00	0.00	0.00
25-Apr-05	0.04	0.01	0.03
26-Apr-05	0.11	0.02	0.09
27-Apr-05	0.00	0.00	0.00
28-Apr-05	0.00	0.00	0.00
29-Apr-05	0.00	0.00	0.00
30-Apr-05	0.00	0.00	0.00
1-May-05	0.02	0.00	0.02
2-May-05	0.00	0.00	0.00
3-May-05	0.00	0.00	0.00
4-May-05	0.00	0.00	0.00
5-May-05	0.00	0.00	0.00
6-May-05	0.01	0.00	0.01
7-May-05	0.00	0.00	0.00
8-May-05	0.09	0.01	0.08
9-May-05	0.05	0.01	0.04
10-May-05	0.15	0.02	0.13
11-May-05	0.00	0.00	0.00
12-May-05	0.57	0.10	0.47
13-May-05	0.38	0.06	0.32
14-May-05	0.06	0.01	0.05
15-May-05	0.00	0.00	0.00
16-May-05	0.40	0.06	0.34
17-May-05	0.07	0.01	0.06
18-May-05	0.64	0.12	0.52
19-May-05	0.01	0.00	0.01
20-May-05	0.00	0.00	0.00
21-May-05	0.05	0.01	0.04
22-May-05	0.00	0.00	0.00
23-May-05	0.00	0.00	0.00
24-May-05	0.00	0.00	0.00
25-May-05	0.21	0.03	0.18
26-May-05	0.24	0.04	0.20
27-May-05	0.02	0.00	0.02
28-May-05	0.00	0.00	0.00
29-May-05	0.01	0.00	0.01
30-May-05	0.00	0.00	0.00

2006 Daily Rainfall Data
from Mounds Park, East Metro, Saint Paul, MN

Date	Rainfall (in.)	Runoff (in.)	Loss (in.)
8-Apr-06	0.00	0.00	0.00
9-Apr-06	0.00	0.00	0.00
10-Apr-06	0.00	0.00	0.00
11-Apr-06	0.00	0.00	0.00
12-Apr-06	0.00	0.00	0.00
13-Apr-06	0.01	0.00	0.01
14-Apr-06	0.00	0.00	0.00
15-Apr-06	0.00	0.00	0.00
16-Apr-06	0.01	0.00	0.01
17-Apr-06	0.00	0.00	0.00
18-Apr-06	0.02	0.00	0.02
19-Apr-06	0.01	0.00	0.01
20-Apr-06	0.59	0.11	0.48
21-Apr-06	0.07	0.01	0.06
22-Apr-06	0.00	0.00	0.00
23-Apr-06	0.00	0.00	0.00
24-Apr-06	0.00	0.00	0.00
25-Apr-06	0.00	0.00	0.00
26-Apr-06	0.00	0.00	0.00
27-Apr-06	0.00	0.00	0.00
28-Apr-06	0.18	0.03	0.15
29-Apr-06	0.75	0.14	0.61
30-Apr-06	1.01	0.26	0.75
1-May-06	0.57	0.10	0.47
2-May-06	0.00	0.00	0.00
3-May-06	0.00	0.00	0.00
4-May-06	0.00	0.00	0.00
5-May-06	0.00	0.00	0.00
6-May-06	0.00	0.00	0.00
7-May-06	0.00	0.00	0.00
8-May-06	0.43	0.06	0.37
9-May-06	0.01	0.00	0.01
10-May-06	0.00	0.00	0.00
11-May-06	0.00	0.00	0.00
12-May-06	0.36	0.05	0.31
13-May-06	0.20	0.03	0.17
14-May-06	0.02	0.00	0.02
15-May-06	0.05	0.01	0.04
16-May-06	0.01	0.00	0.01
17-May-06	0.00	0.00	0.00
18-May-06	0.00	0.00	0.00
19-May-06	0.00	0.00	0.00
20-May-06	0.00	0.00	0.00
21-May-06	0.00	0.00	0.00
22-May-06	0.00	0.00	0.00
23-May-06	0.00	0.00	0.00
24-May-06	0.00	0.00	0.00
25-May-06	0.39	0.06	0.33
26-May-06	0.00	0.00	0.00
27-May-06	0.00	0.00	0.00
28-May-06	0.00	0.00	0.00
29-May-06	0.46	0.07	0.39
30-May-06	0.00	0.00	0.00

TABLE 2

2005 AND 2006 RAINFALL AND RUNOFF SUMMARY
INFILTRATION ANALYSIS
SKI LANE RAVINE
NORTH OAKS, MINNESOTA

2005 Daily Rainfall Data
from Mounds Park, East Metro, Saint Paul, MN

Date	Rainfall (in.)	Runoff (in.)	Loss (in.)
31-May-05	0.00	0.00	0.00
1-Jun-05	0.00	0.00	0.00
2-Jun-05	0.00	0.00	0.00
3-Jun-05	0.00	0.00	0.00
4-Jun-05	0.45	0.07	0.38
5-Jun-05	0.07	0.01	0.06
6-Jun-05	0.02	0.00	0.02
7-Jun-05	0.04	0.01	0.03
8-Jun-05	0.60	0.11	0.49
9-Jun-05	0.00	0.00	0.00
10-Jun-05	0.40	0.06	0.34
11-Jun-05	0.14	0.02	0.12
12-Jun-05	0.00	0.00	0.00
13-Jun-05	0.09	0.01	0.08
14-Jun-05	0.07	0.01	0.06
15-Jun-05	0.04	0.01	0.03
16-Jun-05	0.00	0.00	0.00
17-Jun-05	0.00	0.00	0.00
18-Jun-05	0.00	0.00	0.00
19-Jun-05	0.00	0.00	0.00
20-Jun-05	0.00	0.00	0.00
21-Jun-05	0.00	0.00	0.00
22-Jun-05	0.00	0.00	0.00
23-Jun-05	0.00	0.00	0.00
24-Jun-05	0.01	0.00	0.01
25-Jun-05	0.00	0.00	0.00
26-Jun-05	0.00	0.00	0.00
27-Jun-05	1.25	0.33	0.92
28-Jun-05	0.00	0.00	0.00
29-Jun-05	0.40	0.06	0.34
30-Jun-05	0.02	0.00	0.02
1-Jul-05	0.00	0.00	0.00
2-Jul-05	0.00	0.00	0.00
3-Jul-05	0.17	0.03	0.14
4-Jul-05	0.00	0.00	0.00
5-Jul-05	0.00	0.00	0.00
6-Jul-05	0.00	0.00	0.00
7-Jul-05	0.00	0.00	0.00
8-Jul-05	0.00	0.00	0.00
9-Jul-05	0.00	0.00	0.00
10-Jul-05	0.00	0.00	0.00
11-Jul-05	0.00	0.00	0.00
12-Jul-05	0.00	0.00	0.00
13-Jul-05	0.00	0.00	0.00
14-Jul-05	0.00	0.00	0.00
15-Jul-05	0.00	0.00	0.00
16-Jul-05	0.00	0.00	0.00
17-Jul-05	0.19	0.03	0.16
18-Jul-05	0.00	0.00	0.00
19-Jul-05	0.00	0.00	0.00
20-Jul-05	0.26	0.04	0.22
21-Jul-05	0.00	0.00	0.00
22-Jul-05	0.00	0.00	0.00

2006 Daily Rainfall Data
from Mounds Park, East Metro, Saint Paul, MN

Date	Rainfall (in.)	Runoff (in.)	Loss (in.)
31-May-06	0.00	0.00	0.00
1-Jun-06	0.06	0.01	0.05
2-Jun-06	0.00	0.00	0.00
3-Jun-06	0.00	0.00	0.00
4-Jun-06	0.00	0.00	0.00
5-Jun-06	1.29	0.34	0.95
6-Jun-06	0.00	0.00	0.00
7-Jun-06	0.00	0.00	0.00
8-Jun-06	0.00	0.00	0.00
9-Jun-06	0.01	0.00	0.01
10-Jun-06	0.01	0.00	0.01
11-Jun-06	0.00	0.00	0.00
12-Jun-06	0.00	0.00	0.00
13-Jun-06	0.00	0.00	0.00
14-Jun-06	0.00	0.00	0.00
15-Jun-06	0.00	0.00	0.00
16-Jun-06	0.68	0.12	0.56
17-Jun-06	0.10	0.02	0.08
18-Jun-06	0.00	0.00	0.00
19-Jun-06	0.00	0.00	0.00
20-Jun-06	0.02	0.00	0.02
21-Jun-06	0.00	0.00	0.00
22-Jun-06	0.00	0.00	0.00
23-Jun-06	0.00	0.00	0.00
24-Jun-06	0.23	0.03	0.20
25-Jun-06	0.14	0.02	0.12
26-Jun-06	0.04	0.01	0.03
27-Jun-06	0.00	0.00	0.00
28-Jun-06	0.00	0.00	0.00
29-Jun-06	0.00	0.00	0.00
30-Jun-06	0.00	0.00	0.00
1-Jul-06	0.06	0.01	0.05
2-Jul-06	0.00	0.00	0.00
3-Jul-06	0.00	0.00	0.00
4-Jul-06	0.00	0.00	0.00
5-Jul-06	0.00	0.00	0.00
6-Jul-06	0.00	0.00	0.00
7-Jul-06	0.00	0.00	0.00
8-Jul-06	0.01	0.00	0.01
9-Jul-06	0.00	0.00	0.00
10-Jul-06	0.00	0.00	0.00
11-Jul-06	0.00	0.00	0.00
12-Jul-06	0.00	0.00	0.00
13-Jul-06	0.00	0.00	0.00
14-Jul-06	0.06	0.01	0.05
15-Jul-06	0.00	0.00	0.00
16-Jul-06	0.25	0.04	0.21
17-Jul-06	0.00	0.00	0.00
18-Jul-06	0.00	0.00	0.00
19-Jul-06	0.47	0.07	0.40
20-Jul-06	0.00	0.00	0.00
21-Jul-06	0.01	0.00	0.01
22-Jul-06	0.00	0.00	0.00

TABLE 2

2005 AND 2006 RAINFALL AND RUNOFF SUMMARY
INFILTRATION ANALYSIS
SKI LANE RAVINE
NORTH OAKS, MINNESOTA

2005 Daily Rainfall Data
from Mounds Park, East Metro, Saint Paul, MN

Date	Rainfall (in.)	Runoff (in.)	Loss (in.)
23-Jul-05	0.00	0.00	0.00
24-Jul-05	0.01	0.00	0.01
25-Jul-05	2.05	0.82	1.23
26-Jul-05	0.00	0.00	0.00
27-Jul-05	0.00	0.00	0.00
28-Jul-05	0.00	0.00	0.00
29-Jul-05	0.00	0.00	0.00
30-Jul-05	0.00	0.00	0.00
31-Jul-05	0.00	0.00	0.00
1-Aug-05	0.00	0.00	0.00
2-Aug-05	0.00	0.00	0.00
3-Aug-05	0.00	0.00	0.00
4-Aug-05	1.03	0.27	0.76
5-Aug-05	0.00	0.00	0.00
6-Aug-05	0.00	0.00	0.00
7-Aug-05	0.00	0.00	0.00
8-Aug-05	0.50	0.09	0.41
9-Aug-05	1.30	0.34	0.96
10-Aug-05	0.00	0.00	0.00
11-Aug-05	0.00	0.00	0.00
12-Aug-05	0.00	0.00	0.00
13-Aug-05	0.00	0.00	0.00
14-Aug-05	0.00	0.00	0.00
15-Aug-05	0.00	0.00	0.00
16-Aug-05	0.71	0.13	0.58
17-Aug-05	0.01	0.00	0.01
18-Aug-05	0.17	0.03	0.14
19-Aug-05	0.13	0.02	0.11
20-Aug-05	0.00	0.00	0.00
21-Aug-05	0.00	0.00	0.00
22-Aug-05	0.00	0.00	0.00
23-Aug-05	0.00	0.00	0.00
24-Aug-05	0.00	0.00	0.00
25-Aug-05	0.00	0.00	0.00
26-Aug-05	1.86	0.58	1.28
27-Aug-05	0.00	0.00	0.00
28-Aug-05	0.00	0.00	0.00
29-Aug-05	0.00	0.00	0.00
30-Aug-05	0.00	0.00	0.00
31-Aug-05	0.00	0.00	0.00
1-Sep-05	0.00	0.00	0.00
2-Sep-05	0.00	0.00	0.00
3-Sep-05	0.18	0.03	0.15
4-Sep-05	0.13	0.02	0.11
5-Sep-05	0.00	0.00	0.00
6-Sep-05	0.34	0.05	0.29
7-Sep-05	0.16	0.02	0.14
8-Sep-05	0.06	0.01	0.05
9-Sep-05	0.00	0.00	0.00
10-Sep-05	0.00	0.00	0.00
11-Sep-05	0.00	0.00	0.00
12-Sep-05	0.49	0.07	0.42
13-Sep-05	0.20	0.03	0.17

2006 Daily Rainfall Data
from Mounds Park, East Metro, Saint Paul, MN

Date	Rainfall (in.)	Runoff (in.)	Loss (in.)
23-Jul-06	0.00	0.00	0.00
24-Jul-06	0.44	0.07	0.37
25-Jul-06	0.00	0.00	0.00
26-Jul-06	0.00	0.00	0.00
27-Jul-06	0.00	0.00	0.00
28-Jul-06	0.00	0.00	0.00
29-Jul-06	0.00	0.00	0.00
30-Jul-06	0.00	0.00	0.00
31-Jul-06	0.00	0.00	0.00
1-Aug-06	0.66	0.12	0.54
2-Aug-06	1.89	0.59	1.30
3-Aug-06	0.00	0.00	0.00
4-Aug-06	0.00	0.00	0.00
5-Aug-06	0.00	0.00	0.00
6-Aug-06	0.41	0.06	0.35
7-Aug-06	0.00	0.00	0.00
8-Aug-06	0.00	0.00	0.00
9-Aug-06	0.00	0.00	0.00
10-Aug-06	0.00	0.00	0.00
11-Aug-06	0.00	0.00	0.00
12-Aug-06	0.00	0.00	0.00
13-Aug-06	0.37	0.06	0.31
14-Aug-06	0.00	0.00	0.00
15-Aug-06	0.00	0.00	0.00
16-Aug-06	0.00	0.00	0.00
17-Aug-06	0.06	0.01	0.05
18-Aug-06	0.00	0.00	0.00
19-Aug-06	0.00	0.00	0.00
20-Aug-06	0.00	0.00	0.00
21-Aug-06	0.00	0.00	0.00
22-Aug-06	0.00	0.00	0.00
23-Aug-06	0.80	0.15	0.65
24-Aug-06	1.42	0.37	1.05
25-Aug-06	0.00	0.00	0.00
26-Aug-06	0.01	0.00	0.01
27-Aug-06	0.00	0.00	0.00
28-Aug-06	0.03	0.00	0.03
29-Aug-06	0.01	0.00	0.01
30-Aug-06	0.00	0.00	0.00
31-Aug-06	0.00	0.00	0.00
1-Sep-06	0.00	0.00	0.00
2-Sep-06	0.00	0.00	0.00
3-Sep-06	0.80	0.15	0.65
4-Sep-06	0.01	0.00	0.01
5-Sep-06	0.00	0.00	0.00
6-Sep-06	0.04	0.01	0.03
7-Sep-06	0.00	0.00	0.00
8-Sep-06	0.00	0.00	0.00
9-Sep-06	0.00	0.00	0.00
10-Sep-06	0.04	0.01	0.03
11-Sep-06	0.00	0.00	0.00
12-Sep-06	0.00	0.00	0.00
13-Sep-06	0.00	0.00	0.00

TABLE 2

2005 AND 2006 RAINFALL AND RUNOFF SUMMARY
INFILTRATION ANALYSIS
SKI LANE RAVINE
NORTH OAKS, MINNESOTA

2005 Daily Rainfall Data
from Mounds Park, East Metro, Saint Paul, MN

Date	Rainfall (in.)	Runoff (in.)	Loss (in.)
14-Sep-05	0.00	0.00	0.00
15-Sep-05	0.00	0.00	0.00
16-Sep-05	0.00	0.00	0.00
17-Sep-05	0.00	0.00	0.00
18-Sep-05	0.00	0.00	0.00
19-Sep-05	0.16	0.02	0.14
20-Sep-05	0.00	0.00	0.00
21-Sep-05	1.99	0.62	1.37
22-Sep-05	0.01	0.00	0.01
23-Sep-05	0.00	0.00	0.00
24-Sep-05	0.17	0.03	0.14
25-Sep-05	0.69	0.13	0.56
26-Sep-05	0.00	0.00	0.00
27-Sep-05	0.00	0.00	0.00
28-Sep-05	0.37	0.06	0.31
29-Sep-05	0.00	0.00	0.00
30-Sep-05	0.00	0.00	0.00
1-Oct-05	0.00	0.00	0.00
2-Oct-05	0.00	0.00	0.00
3-Oct-05	0.00	0.00	0.00
4-Oct-05	0.11	0.02	0.09
5-Oct-05	0.39	0.06	0.33
6-Oct-05	0.00	0.00	0.00
7-Oct-05	0.00	0.00	0.00
8-Oct-05	0.00	0.00	0.00
9-Oct-05	0.00	0.00	0.00
10-Oct-05	0.00	0.00	0.00
11-Oct-05	0.00	0.00	0.00
12-Oct-05	0.06	0.01	0.05
13-Oct-05	0.00	0.00	0.00
14-Oct-05	0.01	0.00	0.01
15-Oct-05	0.00	0.00	0.00
16-Oct-05	0.00	0.00	0.00
17-Oct-05	0.11	0.02	0.09
18-Oct-05	0.00	0.00	0.00
19-Oct-05	0.00	0.00	0.00
20-Oct-05	0.80	0.15	0.65
21-Oct-05	0.02	0.00	0.02
22-Oct-05	0.00	0.00	0.00
23-Oct-05	0.04	0.01	0.03
24-Oct-05	0.00	0.00	0.00
25-Oct-05	0.00	0.00	0.00
26-Oct-05	0.00	0.00	0.00
27-Oct-05	0.00	0.00	0.00
28-Oct-05	0.00	0.00	0.00
29-Oct-05	0.00	0.00	0.00
30-Oct-05	0.12	0.02	0.10
31-Oct-05	0.00	0.00	0.00
1-Nov-05	0.00	0.00	0.00
2-Nov-05	0.00	0.00	0.00
3-Nov-05	0.00	0.00	0.00
4-Nov-05	0.00	0.00	0.00
5-Nov-05	0.10	0.02	0.08

2006 Daily Rainfall Data
from Mounds Park, East Metro, Saint Paul, MN

Date	Rainfall (in.)	Runoff (in.)	Loss (in.)
14-Sep-06	0.00	0.00	0.00
15-Sep-06	0.00	0.00	0.00
16-Sep-06	0.18	0.03	0.15
17-Sep-06	0.08	0.01	0.07
18-Sep-06	0.03	0.00	0.03
19-Sep-06	0.01	0.00	0.01
20-Sep-06	0.00	0.00	0.00
21-Sep-06	0.42	0.06	0.36
22-Sep-06	0.25	0.04	0.21
23-Sep-06	0.15	0.02	0.13
24-Sep-06	0.01	0.00	0.01
25-Sep-06	0.00	0.00	0.00
26-Sep-06	0.02	0.00	0.02
27-Sep-06	0.17	0.03	0.14
28-Sep-06	0.01	0.00	0.01
29-Sep-06	0.02	0.00	0.02
30-Sep-06	0.03	0.00	0.03
1-Oct-06	0.00	0.00	0.00
2-Oct-06	0.00	0.00	0.00
3-Oct-06	0.00	0.00	0.00
4-Oct-06	0.00	0.00	0.00
5-Oct-06	0.00	0.00	0.00
6-Oct-06	0.00	0.00	0.00
7-Oct-06	0.00	0.00	0.00
8-Oct-06	0.00	0.00	0.00
9-Oct-06	0.00	0.00	0.00
10-Oct-06	0.00	0.00	0.00
11-Oct-06	0.17	0.03	0.14
12-Oct-06	0.00	0.00	0.00
13-Oct-06	0.00	0.00	0.00
14-Oct-06	0.00	0.00	0.00
15-Oct-06	0.00	0.00	0.00
16-Oct-06	0.17	0.03	0.14
17-Oct-06	0.02	0.00	0.02
18-Oct-06	0.04	0.01	0.03
19-Oct-06	0.00	0.00	0.00
20-Oct-06	0.00	0.00	0.00
21-Oct-06	0.00	0.00	0.00
22-Oct-06	0.00	0.00	0.00
23-Oct-06	0.00	0.00	0.00
24-Oct-06	0.00	0.00	0.00
25-Oct-06	0.00	0.00	0.00
26-Oct-06	0.00	0.00	0.00
27-Oct-06	0.00	0.00	0.00
28-Oct-06	0.00	0.00	0.00
29-Oct-06	0.00	0.00	0.00
30-Oct-06	0.00	0.00	0.00
31-Oct-06	0.00	0.00	0.00
1-Nov-06	0.00	0.00	0.00
2-Nov-06	0.00	0.00	0.00
3-Nov-06	0.00	0.00	0.00
4-Nov-06	0.00	0.00	0.00
5-Nov-06	0.00	0.00	0.00

TABLE 2

2005 AND 2006 RAINFALL AND RUNOFF SUMMARY
INFILTRATION ANALYSIS
SKI LANE RAVINE
NORTH OAKS, MINNESOTA

2005 Daily Rainfall Data
from Mounds Park, East Metro, Saint Paul, MN

Date	Rainfall (in.)	Runoff (in.)	Loss (in.)
6-Nov-05	0.00	0.00	0.00
7-Nov-05	0.02	0.00	0.02
8-Nov-05	0.00	0.00	0.00
9-Nov-05	0.00	0.00	0.00
10-Nov-05	0.00	0.00	0.00
11-Nov-05	0.00	0.00	0.00
12-Nov-05	0.08	0.01	0.07
13-Nov-05	0.23	0.03	0.20
14-Nov-05	0.04	0.01	0.03
15-Nov-05	0.15	0.02	0.13
16-Nov-05	0.00	0.00	0.00
17-Nov-05	0.00	0.00	0.00
18-Nov-05	0.00	0.00	0.00
19-Nov-05	0.02	0.00	0.02
20-Nov-05	0.00	0.00	0.00
21-Nov-05	0.00	0.00	0.00
22-Nov-05	0.00	0.00	0.00
23-Nov-05	0.00	0.00	0.00

2006 Daily Rainfall Data
from Mounds Park, East Metro, Saint Paul, MN

Date	Rainfall (in.)	Runoff (in.)	Loss (in.)
6-Nov-06	0.01	0.00	0.01
7-Nov-06	0.00	0.00	0.00
8-Nov-06	0.00	0.00	0.00
9-Nov-06	0.00	0.00	0.00
10-Nov-06	0.00	0.00	0.00
11-Nov-06	0.00	0.00	0.00
12-Nov-06	0.03	0.00	0.03
13-Nov-06	0.08	0.01	0.07
14-Nov-06	0.00	0.00	0.00
15-Nov-06	0.00	0.00	0.00
16-Nov-06	0.00	0.00	0.00
17-Nov-06	0.00	0.00	0.00
18-Nov-06	0.00	0.00	0.00
19-Nov-06	0.00	0.00	0.00
20-Nov-06	0.00	0.00	0.00
21-Nov-06	0.00	0.00	0.00
22-Nov-06	0.00	0.00	0.00
23-Nov-06	0.00	0.00	0.00

TABLE 2

2005 AND 2006 RAINFALL AND RUNOFF SUMMARY
INFILTRATION ANALYSIS
SKI LANE RAVINE
NORTH OAKS, MINNESOTA

2005 Daily Rainfall Data
from Mounds Park, East Metro, Saint Paul, MN

Date	Rainfall (in.)	Runoff (in.)	Loss (in.)
24-Nov-05	0.00	0.00	0.00
25-Nov-05	0.00	0.00	0.00
26-Nov-05	0.00	0.00	0.00
27-Nov-05	0.14	0.02	0.12
28-Nov-05	0.39	0.06	0.33
29-Nov-05	0.03	0.00	0.03
30-Nov-05	0.00	0.00	0.00
1-Dec-05	0.00	0.00	0.00
2-Dec-05	0.00	0.00	0.00
3-Dec-05	0.00	0.00	0.00
4-Dec-05	0.00	0.00	0.00
5-Dec-05	0.00	0.00	0.00
6-Dec-05	0.00	0.00	0.00
7-Dec-05	1.28	0.33	0.95
8-Dec-05	0.00	0.00	0.00
9-Dec-05	0.00	0.00	0.00
10-Dec-05	0.00	0.00	0.00
11-Dec-05	0.00	0.00	0.00
12-Dec-05	0.00	0.00	0.00
13-Dec-05	0.00	0.00	0.00
14-Dec-05	0.00	0.00	0.00
15-Dec-05	0.00	0.00	0.00
16-Dec-05	0.00	0.00	0.00
17-Dec-05	0.00	0.00	0.00
18-Dec-05	0.00	0.00	0.00
19-Dec-05	0.00	0.00	0.00
20-Dec-05	0.00	0.00	0.00
21-Dec-05	0.00	0.00	0.00
22-Dec-05	0.16	0.02	0.14
23-Dec-05	0.09	0.01	0.08
24-Dec-05	0.00	0.00	0.00
25-Dec-05	0.01	0.00	0.01
26-Dec-05	0.00	0.00	0.00
27-Dec-05	0.00	0.00	0.00
28-Dec-05	0.00	0.00	0.00
29-Dec-05	0.00	0.00	0.00
30-Dec-05	0.05	0.01	0.04
31-Dec-05	0.00	0.00	0.00
Total	28.67	6.19	22.48

2006 Daily Rainfall Data
from Mounds Park, East Metro, Saint Paul, MN

Date	Rainfall (in.)	Runoff (in.)	Loss (in.)
24-Nov-06	0.00	0.00	0.00
25-Nov-06	0.00	0.00	0.00
26-Nov-06	0.08	0.01	0.07
27-Nov-06	0.04	0.01	0.03
28-Nov-06	0.49	0.07	0.42
29-Nov-06	0.00	0.00	0.00
30-Nov-06	0.00	0.00	0.00
1-Dec-06	0.00	0.00	0.00
2-Dec-06	0.00	0.00	0.00
3-Dec-06	0.00	0.00	0.00
4-Dec-06	0.00	0.00	0.00
5-Dec-06	0.00	0.00	0.00
6-Dec-06	0.00	0.00	0.00
7-Dec-06	0.00	0.00	0.00
8-Dec-06	0.00	0.00	0.00
9-Dec-06	0.00	0.00	0.00
10-Dec-06	0.00	0.00	0.00
11-Dec-06	0.02	0.00	0.02
12-Dec-06	0.05	0.01	0.04
13-Dec-06	0.00	0.00	0.00
14-Dec-06	0.01	0.00	0.01
15-Dec-06	0.00	0.00	0.00
16-Dec-06	0.00	0.00	0.00
17-Dec-06	0.00	0.00	0.00
18-Dec-06	0.00	0.00	0.00
19-Dec-06	0.00	0.00	0.00
20-Dec-06	0.00	0.00	0.00
21-Dec-06	0.01	0.00	0.01
22-Dec-06	0.13	0.02	0.11
23-Dec-06	0.00	0.00	0.00
24-Dec-06	0.01	0.00	0.01
25-Dec-06	0.00	0.00	0.00
26-Dec-06	0.00	0.00	0.00
27-Dec-06	0.00	0.00	0.00
28-Dec-06	0.03	0.00	0.03
29-Dec-06	0.03	0.00	0.03
30-Dec-06	0.15	0.02	0.13
31-Dec-06	0.90	0.16	0.74
Total	22.15	4.26	17.89

Summary

Average Rainfall	25.41 in	
Average Runoff	5.23 in	230,868 ft^3/year
Average Loss	20.18 in	891,856 ft^3/year

Flow from groundwater pump will be 30 gpm

30 gpm = 15,768,000.00 gallons/year
2,107,875.70 ft^3/year

TABLE 3

LONG-TERM ANNUAL RAINFALL RUNOFF SUMMARY
INFILTRATION ANALYSIS
SKI LANE RAVINE
NORTH OAKS, MINNESOTA

Monthly Rainfall

	(mm)	(in.)
January	18	0.71
February	17	0.67
March	44	1.73
April	62	2.44
May	90	3.54
June	110	4.33
July	108	4.25
August	99	3.90
September	78	3.07
October	56	2.20
November	39	1.54
December	23	0.91
Total	744	29.29

Runoff Coefficient = 0.26

Summary

Rainfall	29.29 in	
Runoff	7.66 in	338,329 ft^3/year
Loss	21.63 in	955,890 ft^3/year

Flow from groundwater pump will be 30 gpm

30 gpm = 15,768,000.00 gallons/year
2,107,875.70 ft^3/year

Source:
Chaska, MN, United States of America
Latitude: 45.00N **Longitude:** 093.39W **Altitude**: 296m

The weather statistics displayed here represent the mean value of each meteorological parameter for each month of the year. The sampling period for this data covers 30 years from 1961 to 1990.

TABLE 4

HYDRAULIC CONDUCTIVITY CALCULATIONS
INFILTRATION ANALYSIS
SKI LANE RAVINE
NORTH OAKS, MINNESOTA

Hydraulic Conductivity of Clay Layer

Clay Layer 0-5ft. Bgs

d_{10} = 0.002 mm
0.0002 cm

K= $100*d_{10}^2$ (Hazen)
K= 4.00E-06 cm/s

k= $(6.54x10^{-4})*d_{10}^2$ (Harleman et al.)
k= 2.616E-11 cm^2

$K= \frac{k \rho . g}{\mu}$

K= $(998.2kg/m^3)(9.81m/s^2)/(1.002x10^{-3}kg/(m.sec))*k$
K= $9.77x10^6$ 1/(m.sec) * k
K= 2.56E-06 cm/s

Assume
K= 1.00E-06 cm/s

Hydraulic Conductivity of Sand Layer

Sand layer 5-40 ft. bgs

d_{10} = 0.1 mm
0.01 cm

K= $100*d_{10}^2$ (Hazen)
K= 0.01 cm/s

k= $(6.54x10^{-4})*d_{10}^2$ (Harleman et al.)
k= 6.54E-08 cm^2

$K= \frac{k \rho . g}{\mu}$

K= $(998.2kg/m^3)(9.81m/s^2)/(1.002x10^{-3}kg/(m.sec))*k$
K= $9.77x10^6$ 1/(m.sec) * k
K= 0.00639 cm/s

Assume
K= 0.005 cm/s

TABLE 5

STAGE STORAGE RELATIONSHIP
INFILTRATION ANALYSIS
SKI LANE RAVINE
NORTH OAKS, MINNESOTA

STAGE/STORAGE RELATIONSHIP								DRAWDOWN CALCULATIONS				
Elevation		Area		Depth		Total Storage		Infiltration Flow	Total Outflow	Time to Empty	Cumm. Time	Cumm. Time
(m)	(ft)	(m^2)	(ft^2)	(m)	(ft)	(m^3)	(ft^3)	(ft^3/s)	(ft^3/s)	(hours)	(hours)	(days)
275.83	905.0	151	1620	275.84	905.0	0	0	0.0000	0.0000	0		
276.14	906.0	311	3350	276.15	906.0	70	2485	0.0001	0.0001	10468	10468	436
276.74	908.0	1023	11008	276.76	908.0	477	16843	0.0006	0.0006	11239	21707	904
277.35	910.0	1765	19002	277.37	910.0	1327	46853	0.0012	0.0012	9137	30844	1285
277.96	912.0	2408	25922	277.98	912.0	2598	91777	0.0020	0.0020	7591	38435	1601
279.18	916.0	3704	39865	279.20	916.0	6324	223352	0.0042	0.0042	11740	50175	2091
280.40	920.0	8813	94864	280.42	920.0	13953	492810	0.0124	0.0124	8999	59174	2466

Infiltration Flow = (K * Area * h) / L

K = hydraulic conductivity of clay layer	3.281E-08	ft/s
h = head above bottom of layer	900	ft (bottom layer)
L = thickness of clay layer	5	ft

Note:
Volume for an interval calculated by Average End Area Method.

TABLE 6

INFILTRATION GALLERY SIZING (30 GPM)
INFILTRATION ANALYSIS
SKI LANE RAVINE
NORTH OAKS, MINNESOTA

Preliminary Infiltration Bed Design

Design objective: Design infiltration trench to handle 30 gpm

Volume from groundwater pump (30 gpm) =	5,775.00 ft^3	over 24 hours
Total Volume =	5,775.00 ft^3	over 24 hours
Required Flow Rate =	0.067 ft^3/s 30.0 gpm	

Hydraulic Conductivity of Sand Layer

Assume K= 0.005 cm/s

Bottom Area of Infiltration Trench (A)

$$A = \frac{1000\ V}{Pn\ \Delta t}$$

Volume to be infiltrated (V) =	163.5 m^3	
Percolation rate of surrounding soils (P) =	180 mm/hr	
Porosity of storage media (n) =	0.4	for clearstone
Retention time (delta t) =	24 hrs	

A= 95 m^2

$\boxed{1019\ ft^2}$

TABLE 7

INFILTRATION GALLERY SIZING (50 GPM)
INFILTRATION ANALYSIS
SKI LANE RAVINE
NORTH OAKS, MINNESOTA

Preliminary Infiltration Bed Design

Design objective: Design infiltration trench to handle 50 gpm

Volume from groundwater pump (30 gpm) =	9,625.00 ft^3	over 24 hours
Total Volume =	9,625.00 ft^3	over 24 hours
Required Flow Rate =	0.111 ft^3/s	
	50.0 gpm	

Hydraulic Conductivity of Sand Layer

Assume K= 0.005 cm/s

Bottom Area of Infiltration Trench (A)

$$A = \frac{1000\ V}{Pn\ \Delta t}$$

Volume to be infiltrated (V) =	272.5 m^3	
Percolation rate of surrounding soils (P) =	180 mm/hr	
Porosity of storage media (n) =	0.4	for clearstone
Retention time (delta t) =	24 hrs	

A= 158 m^2

$\boxed{1698\ ft^2}$