Infiltration Monitoring Report - 2001

This report is being submitted to the South Washington Watershed District as a continuation of the work started during the Infiltration Management Study. This report is being submitted in conjunction with the Infiltration Monitoring Report – 2000. Comparison of infiltration rates and analysis, conclusions and recommendations will be presented for both reports at the end of the document.

I. Background and Overview

Infiltration of stormwater has been shown to be a dominant component of the natural hydrologic system of the South Washington Watershed District (SWWD). This is evidenced by the numerous landlocked basins in the District which have been maintained over time by storing and infiltrating stormwater runoff. The majority of the watershed does not have well defined outlets to the Mississippi River. As land-use changes and development in the District increases, the potential for disrupting the natural hydrologic balance of these landlocked systems is increased. The SWWD has been monitoring infiltration as part of the Infiltration Management Study (IMS), which was initiated in 1997. The objective of the Infiltration Management Study was to evaluate the potential for storing and infiltrating stormwater runoff in areas such as these landlocked basins within the District. A detailed description of past monitoring activities including infiltration monitoring, surface water quality monitoring, and groundwater quality monitoring can be found in the IMS Progress Report, 1998, IMS Phase II Report, 2001, and Infiltration Monitoring Report – 2000, 2001.

The IMS was concluded in 2000 with the completion of the IMS Phase II Report, 2001. Additional funding has been provided by the SWWD to continue the monitoring efforts initiated during the IMS. The results of these monitoring efforts for the spring snowmelt event and summer events of 2001 are described within this report.

Since the completion of the IMS, a new naming system has been developed for ponding areas in the SWWD. The flowing Table summarizes the new nomenclature for future reference.

Table I-1. Summary of New Nomenclature for SWWD Ponding Areas

Old Nomenclature	New Nomenclature	Common Name
CD-P50	CL-P2.1	Eagle Valley Golf Course Basin
CD-P69	BL-P2.1	Pioneer Drive Wetland
CD-P76	BL-P5.2	Mile Drive Basin
CD-P82	BL-P7.2	County Road 19 Basin
CD-P85	BL-P5.1	CD-P85- Regional Infiltration Basin

The following Table summarizes the available infiltration data in the SWWD.

Table I-2. Summary of Available Infiltration Data

Basin	1997	1998	1999		2000		2001	
	Summer	Summer	Spring	Summer	Spring	Summer	Spring	Summer
CD-P50			X	X	X		X	
CD-P69			X	X	X	X	X	X
CD-P76			X		X		X	
CD-P82			X	X	X		X	
CD-P85	X	X		X		X		X

This report summarizes the results of the following monitoring events: the spring infiltration events at CD-P50, CD-P69, CD-P76, and CD-P82; and the summer infiltration events at CD-P69 and CD-P85. Data is not available for other time periods because basins were predominately dry. This report presents data collected in the field, surface water and groundwater quality data, groundwater levels, and an analysis of monitored infiltration rates. Comparison of measured infiltration rates from 1997 to 2001 and recommendations are found at the end of the document.

II. Water Quality and Groundwater Monitoring Methodology and Results

The water quality and groundwater monitoring results presented in this report include data that has been collected during the year 2001. Data collection and analysis prior to 2001 can be found in the IMS Phase II Report, 2000 and the Infiltration Monitoring Report – 2000, 2001.

II-A METHODOLOGY

Water Quality

An evaluation of both surface water (stormwater) quality and groundwater quality is important when monitoring the performance of infiltration facilities. The quality of water being infiltrated will have an affect on the clogging of soils due to particulate loads and chemical processes. The quality of water being infiltrated also has the potential to impact receiving groundwater systems. As a result, the monitoring of both surface water and groundwater quality is important in establishing a baseline of information which may be used to evaluate the short- and long-term performance of a particular infiltration practice as well as an evaluation of its potential impacts to groundwater.

Groundwater has been sampled by the SWWD since 1998. Groundwater samples were not taken during the spring 2001 event. Results of past sampling efforts can be found in the IMS Phase II Report, 2001 and the SWWD Groundwater Monitoring and Protection Program report, July 2000.

Surface Water Quality

Surface water in CD-P85 was sampled by taking grab samples on April 16, 2001 and on June 26, 2001 and surface water quality samples were taken at CD-P82 on April 16, 2001.

Surface water samples were analyzed for:

- Total metals* (cadmium, lead, nickel, manganese, zinc, copper)
- Volatile suspended solids
- Total suspended solids
- Total phosphorus
- Ortho phosphorus
- Total Kjeldahl nitrogen
- Nitrate + Nitrite
- Chloride
- Volatile Organic Compounds (VOCs)
- Polynuclear Aromatic Hydrocarbons (PAHs)

* Samples were analyzed for total metals first, and then the samples were filtered and preserved in order to obtain dissolved concentrations if needed.

Surface water quality has been monitored by the SWWD in CD-P85 since 1997. Results of past water quality sampling can be found in the Infiltration Management Study Phase I and Phase II reports and the Infiltration Monitoring Report – 2000, 2001.

Appendix A contains a copy of the lab reports.

Analytical results were compared with the Minnesota Department of Health Standards for drinking water, EPA Federal drinking water standards, and Minnesota Pollution Control Agency (MPCA) 7050 Class 2B water quality standards. The Department of Health identifies Health Risk Limits (HRLs) as the exposure value that can be safely consumed daily for a lifetime. One analyte, chloride, does not have a Minnesota standard. The EPA has a secondary standard for this analyte. Secondary standards are not enforceable at any level, but provide a baseline for aesthetic quality of drinking water. The MPCA 7050 Rules identify allowable analyte concentrations that will maintain a healthy community of cool or warm water sport or commercial fish and associated aquatic life and their habitats. Class 2B waters are not protected as a source of drinking water.

Groundwater Level Monitoring

Groundwater mounding, the process by which infiltrating water creates a mound on the water table, can be a limiting factor for infiltration. Depth to groundwater, bedrock, and other impermeable layers all contribute to mounding. If groundwater mounding becomes significant, it can intersect the bottom of the basin and contribute to ponding conditions in the basin, thus controlling the rate of infiltration. According to the literature a minimum depth to the water table, bedrock, or impeding layers of 2 to 4 feet is recommended. The Wisconsin Department of Natural Resources recommends that a minimum of 5 feet be maintained.

Seven monitoring wells were installed by the SWWD downstream of each of the basins and have been monitored for water levels beginning in the fall of 1998. The City of Woodbury has monitored groundwater levels for the past several years at CD-P85. Water table elevations at CD-P85 were recorded monthly by the Washington County Soil and Water Conservation District. The SWWD and City of Woodbury wells are identified on Figure II-1.

Water level readings were taken with the use of an electronic water level tape at each well.

II-B RESULTS

Water Quality

The results from the April and June 2001 CD-P85 and CD-P82 surface water quality sampling are presented in Table II-1. Two sets of sampled were obtained from CD-P85 and one from CD-P82 during the April event, and two sets of samples were obtained from CD-P85 during the June event.

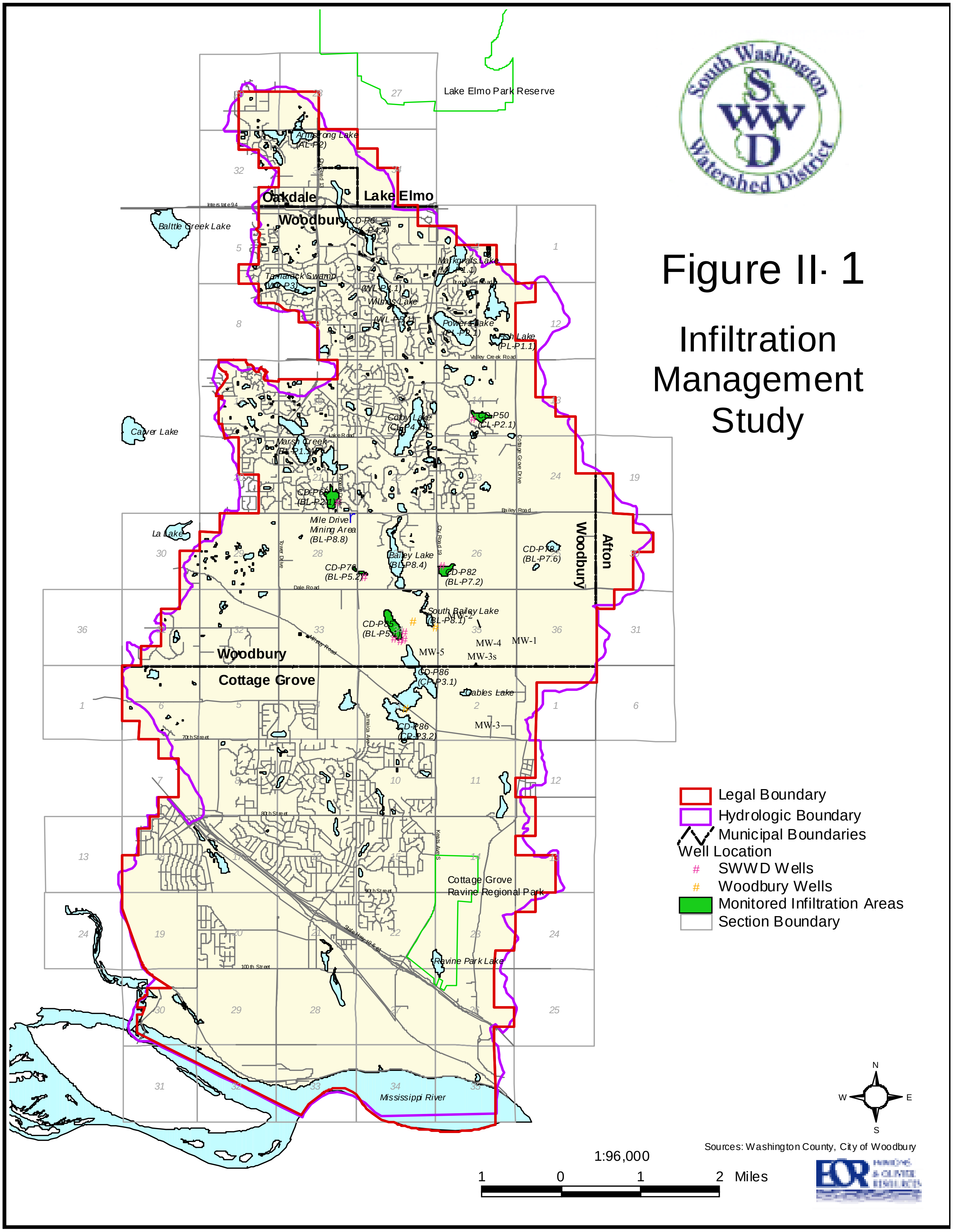


Figure II- 1
Infiltration Management Study
South Washington Watershed District
Legal Boundary
Hydrologic Boundary
Municipal Boundaries
Well Location
SWWD Wells
Woodbury Wells
Monitored Infiltration Areas
Section Boundary
Lake Elmo Park Reserve
Oakdale
Lake Elmo
Woodbury
Afton
Cottage Grove
Armstrong Lake (AL-P2)
Battle Creek Lake
Tamarack Swamp (WL-P3)
Markgrafs Lake
Wilmes Lake
Powers Lake (CL-P2.1)
Fish Lake (PL-P1.1)
Colby Lake
Carver Lake
CD-P50 (CL-P2.1)
Marsh Creek
La Lake
Mile Drive Mining Area (BL-P8.8)
Bailey Lake (BL-P8.4)
CD-P82 (BL-P7.2)
CD-P78.1 (BL-P7.6)
CD-P76 (BL-P5.2)
South Bailey Lake
MW-1
MW-4
MW-5
MW-3s
MW-3
CD-P86 (CP-P3.1)
CD-P86 (CP-P3.2)
Gables Lake
Cottage Grove Ravine Regional Park
Ravine Park Lake
Mississippi River
1:96,000
1 0 1 2 Miles
Sources: Washington County, City of Woodbury

CD-P85 and CD-P82 were both chosen for surface water analysis in April of 2001. The stormwater entering CD-P85 predominately originates from urban landuses. The stormwater has been passed through many water quality ponds, wetlands, and lakes prior to being discharged to CD-P85. The stormwater runoff entering CD-P82 originates from agricultural, row-cropped landuses. There is one large nursery in the CD-P82 subwatershed that contributes excess runoff and nutrients to the basin.

Table II-1. Water Quality Results - 2001

			April 16, 2001			***June 26, 2001***	
Analyte	*MN HRL*	*MN Class 2B Waters*	*CD-P85 Surface Water #1*	*CD-P85 Surface Water #2*	*CD-P82 Surface Water*	*CD-P85 Surface Water #1*	*CD-P85 Surface Water #2*
Lead, total [mg/L]	0.015	0.0077	<0.002	<0.002	<0.002	<0.002	<0.002
Cadmium, total [mg/L]	0.004	0.002	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese, total [mg/L]	0.1		0.090	0.089	0.081	0.017	0.016
Nickel, total [mg/L]	0.1	0.283	<0.009	<0.009	<0.009	0.010	<0.009
Copper, total [mg/L]	--	0.015	<0.012	<0.012	<0.012	<0.004	<0.004
Zinc, total [mg/L]	2	0.191	0.026*	0.011*	0.019*	0.025[1]	0.042[1]
Zinc, dissolved	2	0.191 mg/L	N/a	N/a	N/a	0.018	0.016
Volatile suspended solids [mg/L]	--	--	36.0	6.0	13.3	6.0	6.3
Total suspended solids [mg/L]	--	--	60.0	8.0	58.0	11.0	10.0
Total phosphorus [mg/L]	--	--	0.146	0.130	0.476	0.095	0.124
Ortho phosphorus [mg/L]	--	--	0.027	0.017	0.359	0.088*	0.089*
Total Kjeldahl nitrogen [mg/L]	--	--	1.63	1.50	2.49	5.91	1.45
Nitrate + nitrite [mg/L]	10	--	0.36	<0.08	1.64	<0.08	<0.08
Chloride [mg/L]	250**	230	34.8	34.6	7.11	4.87	5.05
Volatile Organic Compounds (VOCs) [ug/L]	vary	vary	BDL	BDL	BDL	BDL	BDL
Polynuclear Aromatic Hydrocarbons (PAHs) [ug/L]	vary	vary	ND	ND	ND	ND	ND

MPCA Rule 7050 standards apply to waters with a hardness concentration of 200 mg/L.
* Digested blank concentration = 0.017 mg/L
** EPA Secondary Standards – not enforceable
N/a – Not applicable, was not analyzed for this parameter
[1] Digested blank concentration = 0.012 mg/L
ND/BDL – Not Detectable/Below Detection Limit
MDH – Minnesota Department of Health
HRL – Health Risk Limit
* Out of holding time

All of the analyte concentrations were below the Health Risk Limit and the MPCA Class 2B water quality standard. The major differences in runoff quality between CD-P85 and CD-P82 during the April event are as follows:

- Chlorides were almost five times higher in the urban runoff than the agricultural runoff. Road de-icing chemicals (salt) in the urban setting are the probable source.
- Nutrients were several times higher in the agricultural setting compared with the urban landuse.

The June sampling round at CD-P85 resulted in the following conclusions:

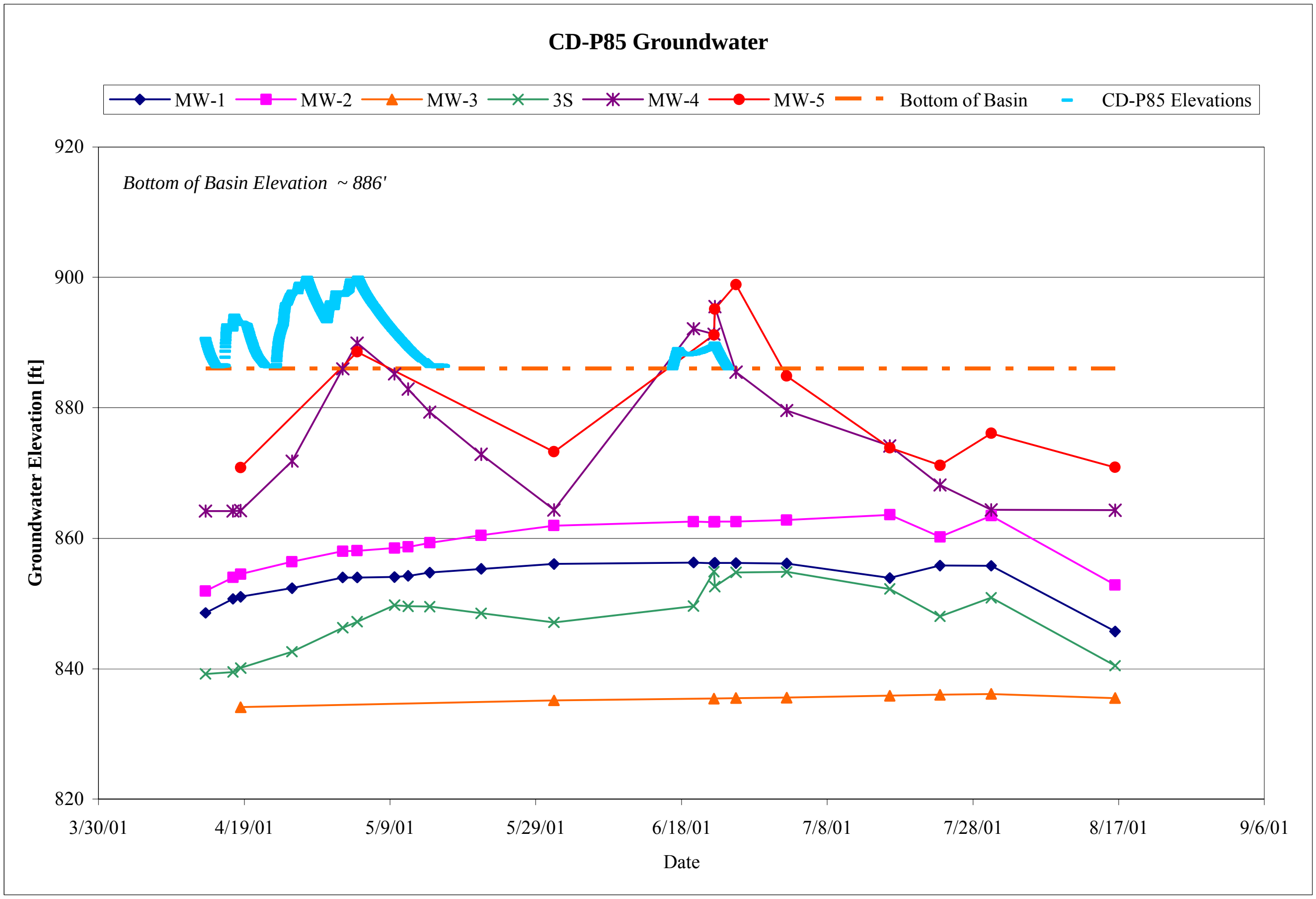
- The concentration of chlorides was much lower than the April sampling results. This is consistent with the lack of de-icing materials (salt) present in the summer months compared to spring.
- Manganese concentrations were more than four times higher during the spring runoff event than summer.

The data collected to date indicates that the addition of the infiltrated surface waters are not introducing heavy metals, VOCs, PAHs, or mobile nutrients such as nitrates and chlorides to the groundwater at concentrations that would negatively impact groundwater quality.

CD-P85 - Groundwater Level Monitoring

Groundwater levels at CD-P85 have continued to show fluctuating water levels during infiltration events at the basin. Figure II-2 summarizes the groundwater elevations and ponded water elevations at CD-P85 during infiltration events at this basin in 2001.

Figure II-2. Water Table Fluctuations at CD-P85



The groundwater rises correlate well with the changing water levels in the basin.

During the spring and summer of 2001, monitoring wells (MW) 1 and 2 showed slight increases in water levels over time. Water levels at MW-1 and MW-2 began to decrease following the last infiltration event at CD-P85. MW-3 shows a slight increase in water levels over the course of the spring / summer.

MW-3s, MW-4 and MW-5 showed significant changes in water levels during the spring and summer infiltration events at CD-P85. MW-3s showed two distinct rises associated with the infiltration events at CD-P85. The first rise showed a water level increase of 10.2 feet and the second showed an increase of 15.3 feet from pre-pumping water levels. These peaked 26 and 17 days after pumping began. The well screen at MW-3s is set in the water table, therefore these rises represent actual groundwater mounding on the water table. MW- 4 showed a water level increase of 25.8 feet during the first infiltration event and 22.6 feet during the second event. MW-5 showed a water level increase of 16.3 feet during the first infiltration event and 22.8 feet during the second event. The peaks occurred 22 and 8 days after pumping began in the basin. There have historically never been measurable water levels at MW-5 prior to 2001. The well screens at MW-4 and MW-5 are set at 864.2 and at 870.8 feet, respectively. These elevations are greater than twenty feet above the water table.

The water levels measured in MW-4 and MW-5 do not reflect the actual water table but rather the extent of saturated soils surrounding the basin. As CD-P85 begins to fill, there is vertical and horizontal movement of water away from the basin. This water saturates the soils surrounding the basin. Measurements taken in the well indicate temporarily saturated soils and are not a true indication of the water table. These saturated soils may be impeding the infiltration process at the surface, limiting the infiltration rate to the rate at which water is moving through the saturated soils.

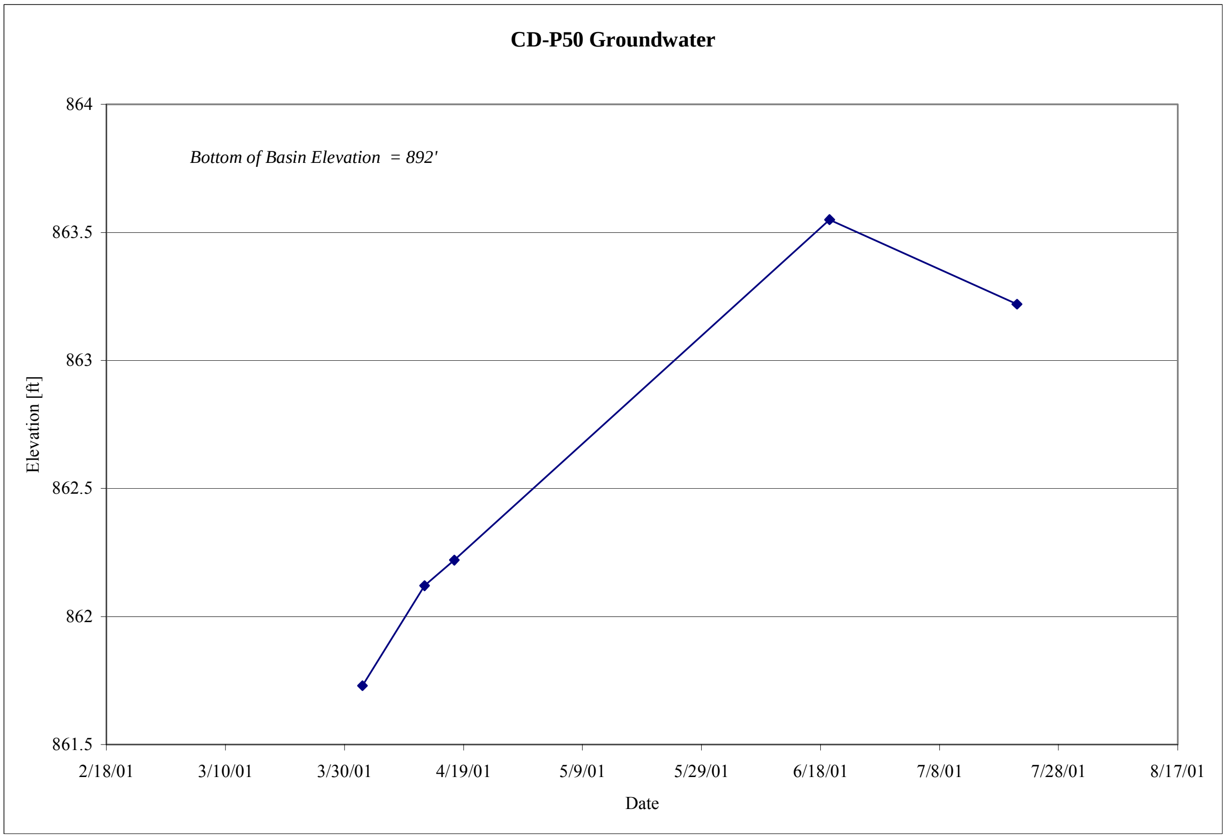
Comparison of these pumping/infiltration events to the August 1999 and September 2000 pumping events indicates that the wells responded in the same general fashion as they have previously. Mounds were recorded in both MW-4 and MW-3s for each of the two events. There were two changes from the previous trends.

1. The water level at MW-1 and MW-2 did not recede as pumping began at CD-P85 as they had during previous events and
2. A groundwater rise was measured in MW-5, where water levels were recorded as high as 22.8 feet above the bottom of the well.

CD-P50 - Groundwater Level Monitoring

Groundwater levels increased at CD-P50 during the spring snowmelt event but remained below the bottom of the basin. Figure II-3 is a summary of the groundwater levels found at CD-P50 during 2001.

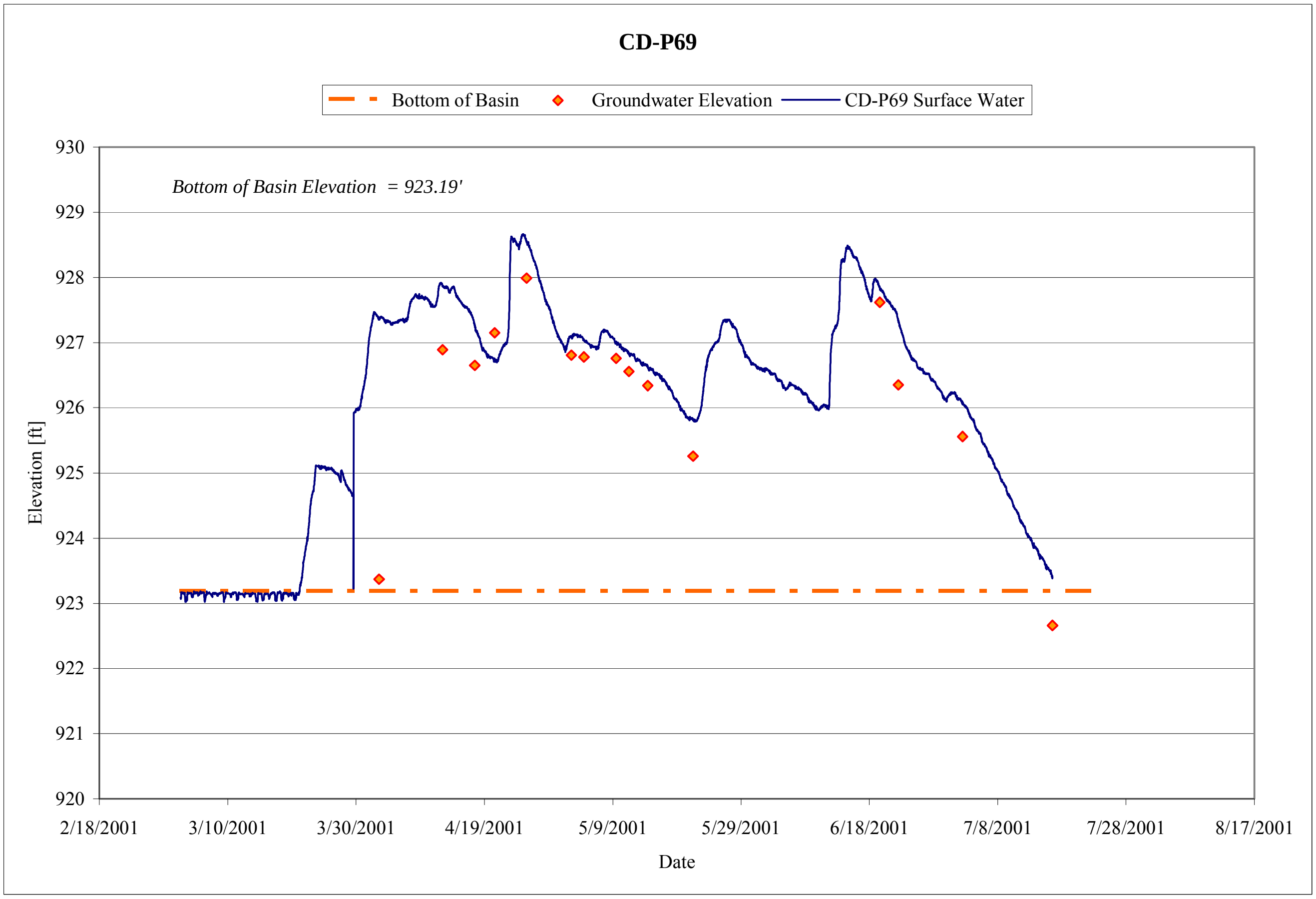
Figure II-3. Water Table Fluctuations at CD-P50



CD-P69 - Groundwater Level Monitoring

Groundwater levels at CD-P69 closely flowed changes in standing water in the basin. Recorded groundwater levels have been at a higher elevation than the bottom of the basin for most of the monitoring season. Figure II-4 is a summary of groundwater and surface water elevations at CD-P69 during 2001. Water levels in the well are approximately equal to the water levels in the basin for much of the event. This indicates that a groundwater mound is forming and intersecting the bottom of the basin and that the infiltration rates are being limited by the saturated hydraulic conductivity of the underlying sediments.

Figure II-4. Water Elevation Fluctuations at CD-P69



CD-P76 - Groundwater Level Monitoring

The well at CD-P76 is set 50 feet below the ground surface. Groundwater levels have remained below this level since installation in 1998; therefore no water levels have been recorded at this site.

CD-P82 - Groundwater Level Monitoring

Groundwater levels were not recorded at CD-P82 during the spring runoff event. High water levels around the basin made the well inaccessible during the spring runoff event.

III. Surface Water Level Data and Infiltration Analysis

III-A BACKGROUND

Infiltration data was collected for four basins during the spring snowmelt runoff event of 2001. These basins include CD-P50 - Eagle Valley Golf Course Basin, CD-P69 - Pioneer Drive Wetland, CD-P76 - Mile Drive Basin, and CD-P82 - County Road 19 Basin. Regional infiltration basin CD-P85 was not monitored for the spring snowmelt event due to a lack of runoff. Summer infiltration data was collected for CD-P69 and CD-P85. The remaining basins, CD-P50, CD-P82, and CD-P76, did not contain enough water during the summer months to monitor them. Appendix B contains a photo log for each of the infiltration events in 2001. Figure II-1 illustrates the location of each of these basins. The spring melt of 2001 was a result of above average snowfall during the winter months and above average rainfall during the spring season. Additional discussion of the spring melt and summer conditions is found in Section IV. Discussion of Infiltration Conditions.

III-B METHODOLOGY

In order to monitor infiltration rates, water level and flow-monitoring equipment was installed at each of the four sites. The following equipment was used for the 2001 monitoring events: American Sigma area/velocity flow meters to monitor flows and Telog water level pressure transducers to monitor water levels in the basins.

Staff gages were installed at each of the basins and their elevations were surveyed. Staff gage readings were obtained at each of the basins during the monitoring season.

Infiltration data was collected for each basin by conducting a water balance of each site and measuring the depth of water in the basin over time. Depth measurements were recorded with a pressure transducer located in the lowest portion of the basin and placed inside a PVC perforated tube. Data was recorded from the pressure transducer with a data logger located in the field.

Calibration and field inspection of each of the units was performed routinely. For CD-P69, additional data was collected at the inlets and outlet of the basin. All inflows and outflows to the basin were recorded using flow meters, which were installed in the stormwater pipes. Field measurements were taken an incorporated in the data analysis.

The equipment used to monitor the spring snowmelt event was installed on March 2 at CD-P76, CD-P69, and CD-P50. Monitoring equipment was not installed at CD-P82. Water levels were staked daily and later surveyed in for elevations. All of the basins were dry at the time of equipment installation. Monitoring of the basins occurred until most of the runoff generated by the event had infiltrated in the basin. CD-P76, CD-P50, and CD-P82 did not contain significant amounts of water during the rest of the summer. CD-P69 continued to be monitored for the rest of the summer. The equipment used to monitor the pumping event in CD-P85 was installed on April 13, 2001 and continues to collect data in the trench at the time of this report.

III-C. INFILTRATION BASIN RESULTS

As mentioned previously the following basins were monitored during the spring snowmelt event: CD-P50, CD-P69, CD-P76 and CD-P82. The results of the spring 2001 event are presented for each of the basins in a graphical and tabular format. The results of the April and June 2001 pumping events at CD-P85 are also presented in a graphical and tabular format.

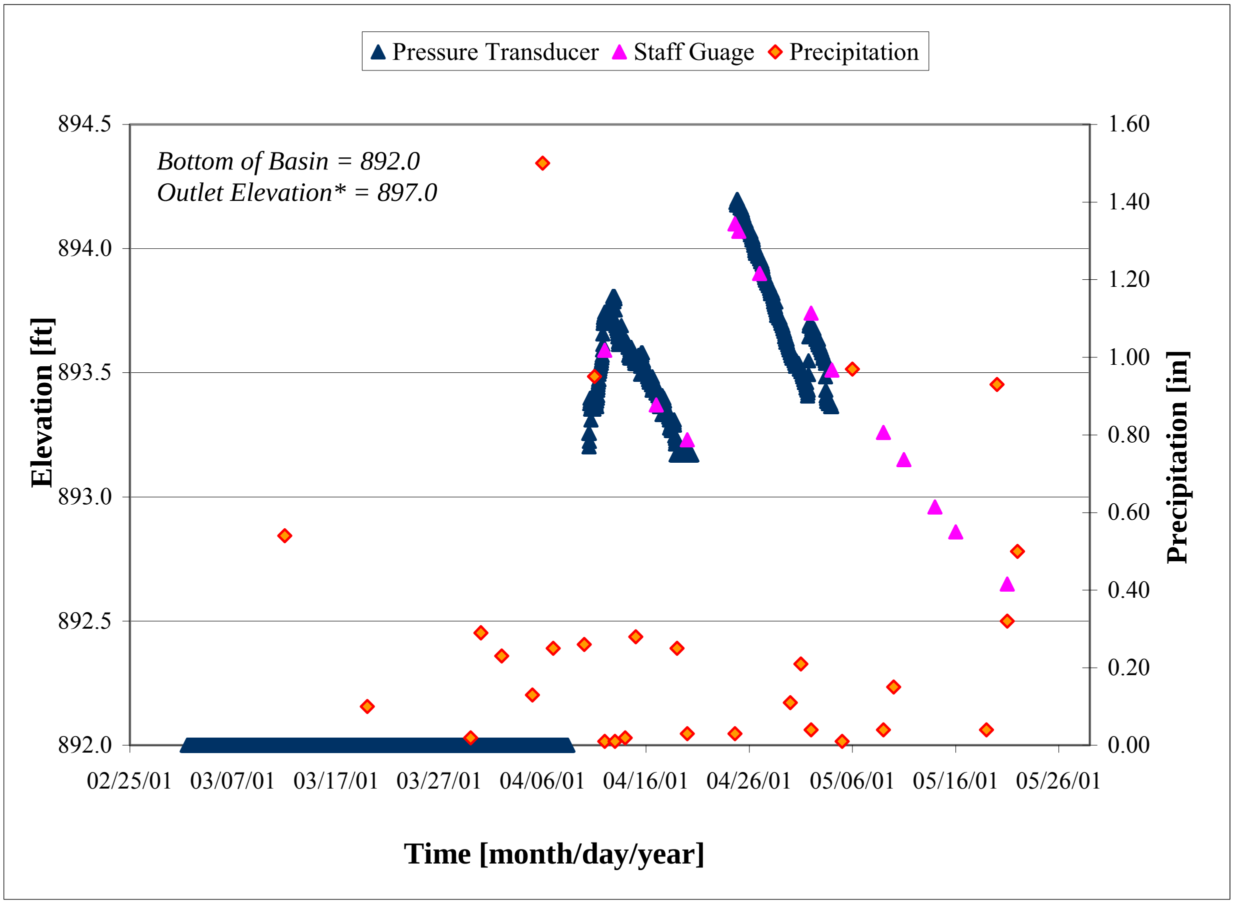
CD-P50 – Eagle Valley Golf Course Basin

Infiltration Rates

A single water level recorder was installed in CD-P50 on March 2, 2001. On April 20, 2001, there was evidence that the water level recorder had been tampered with and the recorder was removed to check for damage and calibration. Data was not collected from April 20 to April 23. The water level recorder was replaced in the basin on April 24, 2001.

Infiltration rates for CD-P50 were determined by calculating the slope of the depth vs. time curve (Figure III-1) for elevation intervals with similar slopes. The slope (Δ Depth/Δ Time) is equivalent to the infiltration rate measured in feet/hour (see Table III-1). Infiltration flow rates are computed by multiplying the rates shown in Table III-1 by the average area of the basin at the corresponding elevations.

Figure III-1. Depth vs. Time and Precipitation at CD-P50 for Spring 2001



* Pumped outlet in not yet operational

Table III-1. Infiltration Rates at CD-P50 for Spring 2001

Basin Depth [feet]	**Average Area** [acre]	**Infiltration Rate** [ft/hr]	[ft/min]	[inches/hr]	**Volumetric Infiltration Rate** [cfs]
1.5-1.0	1.6	.012	.00020	0.144	0.23
1.0-0.5	1.0	.002	.00004	0.025	0.03

Monitoring Results

- Spring water levels were lower in 2001 than in 1999 and 2000.
- Data collected for CD-P50 represents spring infiltration data. 2000 spring infiltration data for CD-P50 is presented in the 2000 Infiltration Monitoring Report.
- For the first drawdown, water levels fell from a depth of 1.2 feet on April 12th to a depth of .8 feet on April 20th. For the second drawdown, water levels fell from a depth of 1.7 feet on April 24th to a depth of 0.4 feet on May 18th.
- Snowmelt infiltration rates ranged from 0.03 to 0.14 inches per hour over the spring event.
- The jurisdictional wetland boundary corresponds to an elevation of 895.6 to 895.8, which is a depth in the basin of 3.6 to 3.8 feet. Therefore, infiltration data was not measured for non-wetland soils during 2001.

CD-P69 – Pioneer Drive Wetland

Infiltration Rates

Two water level recorders were installed to monitor the Pioneer Drive Wetland basin on March 2, 2001. The first water level recorder was installed in the basin itself while the second water level recorder was installed in the upstream wetland at the Savanna Oaks outlet structure to measure inflows into the basin.

A flowmeter was also installed on March 2, 2001 in the west inlet culvert to measure additional inflows that may be present. The equipment remained in the field for the spring and summer and is still collecting data at the time of this report.

Infiltration rates for the March snowmelt event in CD-P69 were determined by calculating the slope of the depth vs. time curve (Figure III-2) starting 24 hours after the basin water level peaked on March 26, 2001 until just prior to the rainfall event on March 28, 2001.

By recording depths and developing stage/discharge curves for the inflows from the Savanna Oaks outlet structure and the outflows at the south end of CD-P69, a water balance of the basin was calculated to obtain the infiltration capacity of CD-P69 for the spring and summer rainfall events. This same methodology was used to determine the infiltration rates in CD-P69 for the 1999 and 2000 monitoring seasons.

Volumetric infiltration flow rates were computed by multiplying the rates shown in Table III-2a and III-2b by the area of the basin at the corresponding elevations. The water balance was calculated in the following manner:

$$i = \frac{\Delta V_{basin} + (V_{in} - V_{out})}{area}$$

1. Determine discharge and volume inputs (at 4-hour time intervals Δt) for Savanna Oaks outlet structure (Q_{in}:V_{in})
2. Determine discharge and volume outputs (at 4-hour time intervals Δt) for Pioneer Drive Wetland V-notch outlet structure (Q_{out}:V_{out})
3. Calculate the difference in volume for each time step ($V_{in} - V_{out}$)
4. Calculate the additional volume being infiltrated as water elevation in the basin decreases (V_{basin})
5. Calculate total volume being infiltrated at each time step (($V_{in} - V_{out}$) + V_{basin})
6. Average results over the defined elevation range to obtain a composite average infiltration rate for the basin for the elevation range

The water balance for the spring event was performed for four separate time periods consisting of one period of 1 day, two periods of 2 days, and one period of 3 days. The summer event consisted of two time periods of 6 and 7 days. Each period began two days after the last rainfall event and ended the day preceding the next rainfall event. This approach minimizes any unmeasured inputs to the basin from precipitation or runoff from the surrounding development. By using this approach, it is estimated that no additional inputs were occurring during the period used for calculating infiltration rates. If there were additional inputs not measured, the infiltration rates calculated here would be underestimated.

Figure III-2. Depth vs. Time and Precipitation at CD-P69.

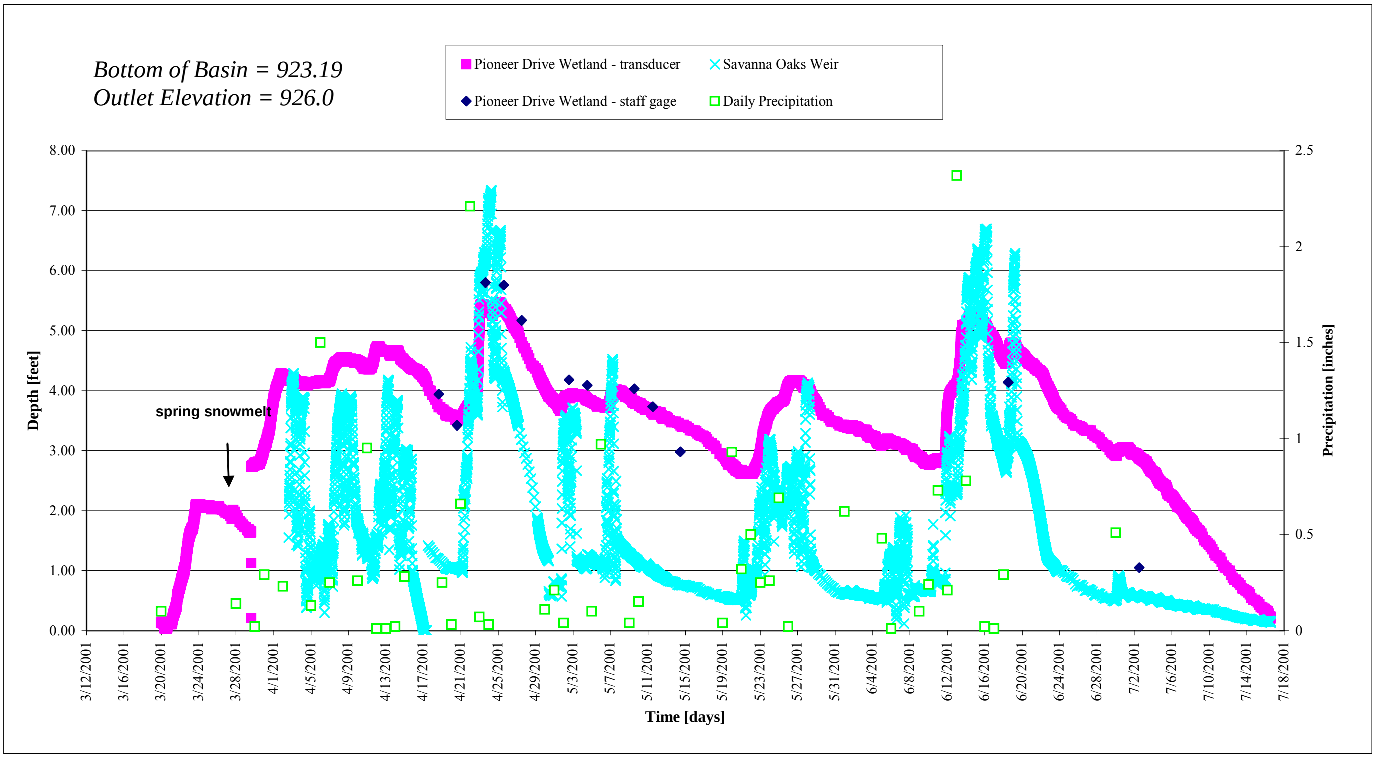


Table III-2a. Infiltration Rates at CD-P69 for Spring 2001.

Basin Depth [feet]	**Average Area** [acre]	**Infiltration Rate** [ft/hr]	[ft/min]	[inches/hr]	**Volumetric Infiltration Rate** [cfs]
5 - 4.5	9.0	0.010	0.0002	0.12	1.31
4.5 - 3.5	6.0	0.017	0.0003	0.21	1.53
3.5 - 3.0	4.9	0.009	0.0002	0.11	0.71
2.0 - 1.5	4.0	0.006	0.0001	0.07	0.29

Table III-2b. Infiltration Rates at CD-P69 for Summer 2001.

Basin Depth [feet]	**Average Area** [acre]	**Infiltration Rate** [ft/hr]	[ft/min]	[inches/hr]	**Volumetric Infiltration Rate** [cfs]
4.0 - 3.0	5.6	0.010	0.0002	0.12	0.81
2.0 – 0.5	4.0	0.009	0.0002	0.11	0.58

Monitoring Results

a. Spring Infiltration Data

- Spring infiltration rates from 0.07 to 0.12 inches/hour were calculated for depths of 5.0 feet to 1.5 feet.
- An overflow structure (v-notch weir) is located approximately 3 feet above the bottom of the basin.
- This basin has operated as a stormwater detention area and natural infiltration site for approximately the last six to ten years in an urbanizing setting with a large drainage area (approximately 1,550 acres).
- The slightly lower infiltration rate calculated at the highest elevations is contrary to trends experienced in all the other monitoring sites. This could be attributed to the difficulty in accurately calculating the water budget due to lack of accurate inflow monitoring into CD-P69, both at the Savanna Oak outlet structure and the one major inlet to the wetland and unmeasured inflows from local precipitation. These inaccuracies only mean that the infiltration rates calculated for this report are underestimated and below the actual infiltration rates. Another factor could be high groundwater elevations, groundwater monitoring results indicated that the water table was at the same elevation as the water in the basin. Groundwater mounding limits the surface infiltration rate, limiting it to the rate water can move through saturated (versus unsaturated) sediments.
- The rates shown in Table III-2a could be lower than the actual rates due to unmeasured inputs into the basin.

b. Summer Infiltration Data

- Average summer infiltration rates of 0.1 inches/hour were calculated in the basin at depths of 0.5 to 2 and 3 to 4 feet.
- The rates shown in Table III-2b could be lower than the actual rates due to unmeasured inputs into the basin.

CD-P76 - Mile Drive Basin

Infiltration Rates

A single water level recorder was installed in CD-P76 on March 2, 2001. Staff gage readings were also taken throughout the infiltration event. Figure III-3 is a graph of the water levels in the basin taken from the staff gage on site. The water level recorders do not accurately record depths of less than 0.5 feet; therefore this data was not used in the analysis. Staff gage readings were used to develop the infiltration rates. The water level recorder was removed from the basin on April 6, 2001.

Infiltration rates for CD-P76 were determined by calculating the slope of the depth vs. time curve (Figure III-3) for elevation intervals with similar slopes. The slope (Δ Depth/Δ Time) is equivalent to the infiltration rate measured in feet/hour (see Table III-3). Infiltration volumetric flow rates were computed by multiplying the rates shown in Table III-3 by the average area of the basin at the corresponding elevations.

Figure III-3. Depth vs Time and Precipitation at CD-P76 for Spring 2001

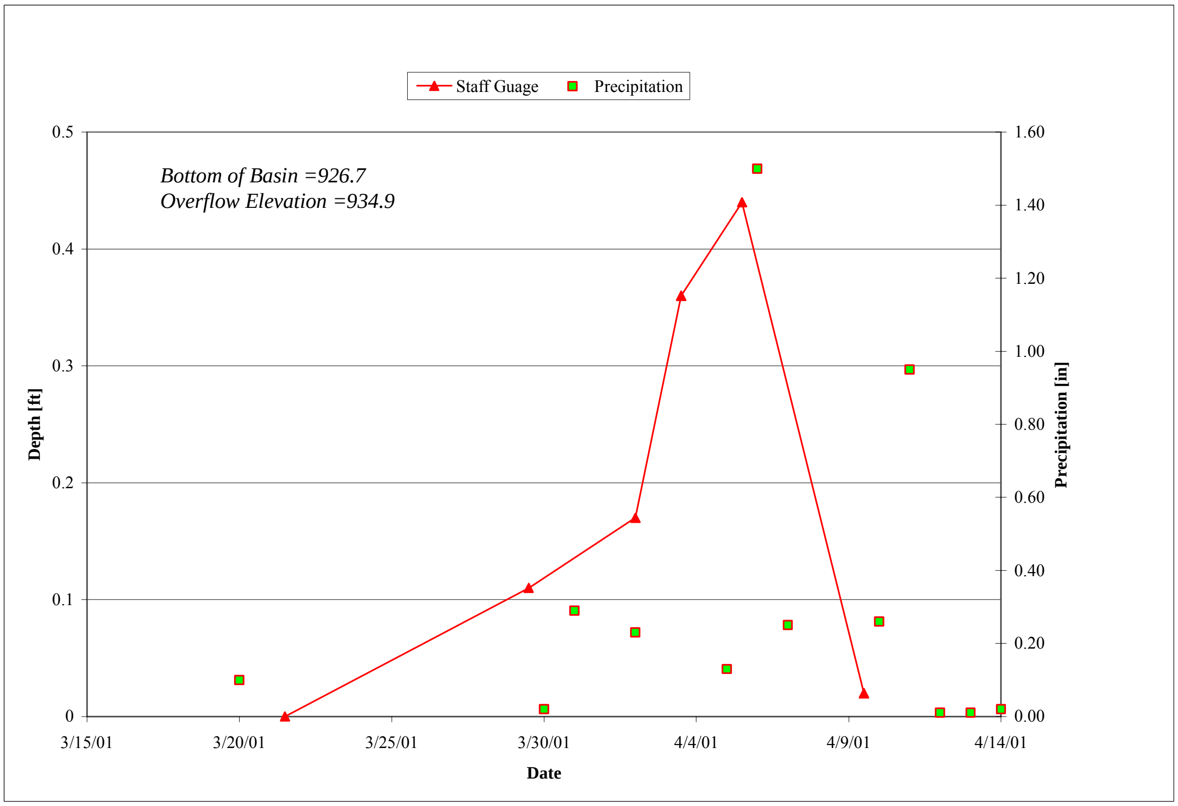


Table III-3. Infiltration Rates at CD-P76 for Spring 2001

Basin Depth [feet]	Average Area [acre]	Infiltration Rate [ft/hr]	[ft/min]	[inches/hr]	Volumetric Infiltration Flow Rate [cfs]
0.5-0.0*	0.9	0.004	0.00007	0.05	0.05

*Precipitation occurred during the time period that these infiltration rates were measured (see Figure III-3). As a result, the actual infiltration rates were higher than the values presented in this table.

Monitoring Results

- Data collected for CD-P76 represents spring infiltration data. 2000 spring infiltration data for CD-P76 is presented in the 2000 Infiltration Monitoring Report.
- CD-P76 reached a maximum depth of 0.44 feet on April 5, 2001. Average infiltration rates of 0.05 inches per hour were calculated for depths of 0.0 to 0.5 feet.
- Spring conditions in CD-P76 were different than in previous years. Little water ponded during the spring snowmelt and the basin remained dry throughout the rest of the year.

CD-P82 – County Road 19 Basin

Infiltration Rates

Data points were obtained by surveying the water level in the basin over the course of the infiltration event, beginning April 5, 2001. The surveyed data points are graphically presented in Figure III-4.

Infiltration rates for CD-P82 were determined by calculating the slope of the depth vs. time curve (Figure III-4) for elevation intervals with similar slopes. The slope (Δ Depth/Δ Time) is equivalent to the infiltration rate measured in feet/hour (see Table III-4). Infiltration volumetric flow rates were computed by multiplying the rates shown in Table III-4 by the average area of the basin at the corresponding elevations.

Figure III-4. Depth vs. Time at CD-P82 for Spring 2001

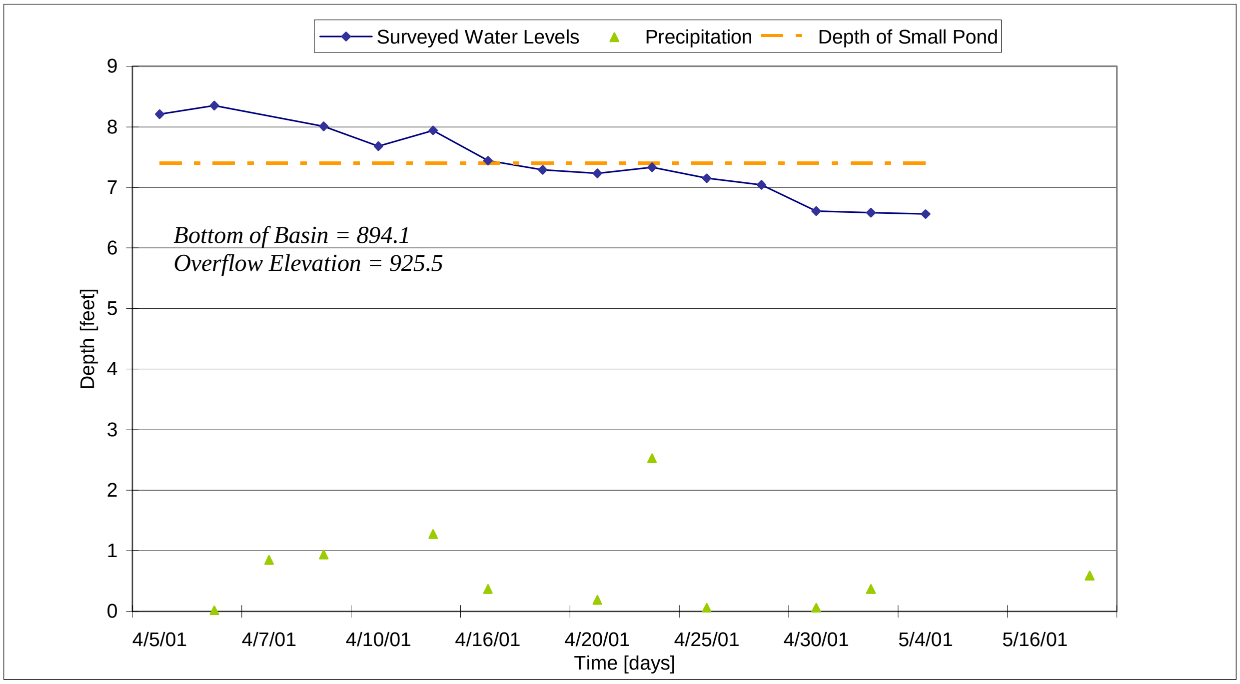


Table III-4. Infiltration Rates at CD-P82 for Spring 2001

Basin Depth [feet]	**Average Area** [acre]	**Infiltration Rate** [ft/hr]	[ft/min]	[inches/hr]	**Volumetric Infiltration Flow Rate** [cfs]
8.5 - 7.5*	9.0	0.004	0.0007	0.05	0.46
7.5 - 6.5*	8.3	0.003	0.0005	0.04	0.30

*Precipitation occurred during the time period that these infiltration rates were measured (see Figure III-4). As a result, the actual infiltration rates were higher than the values presented in this table.

Monitoring Results

The bottom 7.5 feet of the basin consists of a small depression lines with fine soils that often contains standing water. Above this depth, gradual slopes extend out and the area is used for agricultural purposes.

- Data collected at CD-P82 is comparable to data collected in 1999 and 2000 at CD-P82. This data is available in the IMS Phase II, 2001 and the Infiltration Monitoring Report - 2000.

- Average infiltration rates of 0.04 to 0.05 inches/hour were calculated for depths of 6.5 to 8.5 feet.
- Based on similar soils, geologic characteristics, and data trends exhibited in CD-P85, higher infiltration rates are anticipated at elevations above those observed during the monitoring season.

CD-P85 – Regional Infiltration Basin

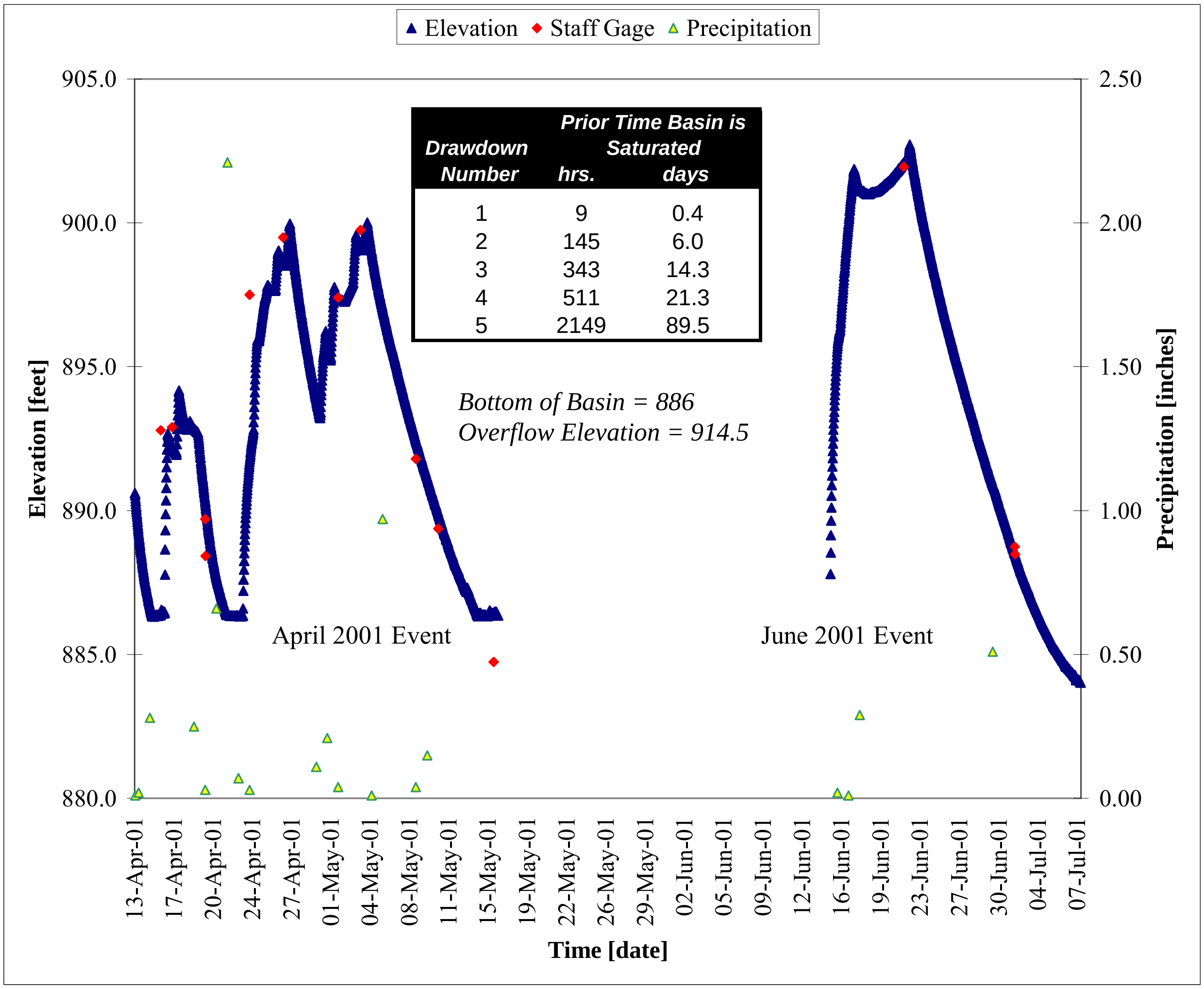
Infiltration Rates

The monitoring data gathered in 2001 includes data from both the spring and summer 2001 pumping events. Data collected during this event represents the infiltration capacity of the basin after three years with improvements: the infiltration tubes were constructed in 1998 and the infiltration trenches were constructed in 1999. These improvements, infiltration tubes and infiltration trenches, are presented in detail in both the Infiltration Management Studies (Phase I and II).

On April 13, 2001, the City of Woodbury began pumping water from South Bailey Lake into regional infiltration basin CD-P85. The city pumped water until May 14, 2001. A second pumping event began on June 15, 2001 and ended on July 7, 2001. Water levels in the basin were recorded with a pressure transducer located in the southern portion of the basin coupled with weekly staff gage readings. The pressure transducer was installed before each pumping event began. Figure III-5 represents the water levels in CD-P85 over the course of both pumping events. The April 2001 event resulted in four recession curves and the June 2001 event resulted in one recession curve. Data is analyzed only during the recessions, when the pumps are off, since there is no accurate means to monitor pumped flows.

The data collected during the June pumping event required an adjustment prior to the infiltration rate analysis: the recorded water levels had to be adjusted for the actual elevation of the pressure transducer since it was relocated into the infiltration trench during the course of the event.

Figure III-5. Depth vs. Time at CD-P85; April 2001 and June 2001 Events



Infiltration rates for both 2001 events were determined by calculating the slope of the depth vs. time curve (Figure III-5) averaged over a four hour time period for the corresponding elevation intervals. The slope (ΔDepth/ΔTime) is equivalent to the overall basin infiltration rate measured in feet per hour (ft/hr). Infiltration volumetric flow rates (cubic-feet per second, cfs) were calculated by multiplying the infiltration rates by the average area of the basin at the corresponding elevations. This analysis was performed for all drawdowns to compare the change in infiltration rates over both pumping events. The results of this analysis are presented in Table III-5 and III-6. The data points plotted in Figure III-6 represent the infiltration rates for all five drawdowns and the data points plotted in Figure III-7 represent the volumetric infiltration rates for all five drawdowns. In both figures, all nine drawdowns were fit with a linear trendline to establish a "best-fit" line.

As Figures III-6 and III-7 illustrate, the infiltration rates for the 2001 pumping event fit within a range. The infiltration rates exhibited for the first recession curve (Drawdown 1) and the infiltration rates exhibited by the last recession curve (Drawdown 5) bracket this range. To simplify the discussion of this infiltration rate analysis, this range of infiltration rates will be referred as the "infiltration rate envelope". The data points plotted in Figure III-8 represent the infiltration rate envelope and the data points plotted in Figure III-9 represent the volumetric rate envelope.

Table III-5: Infiltration Rates and Volumetric Flow Rates for CD-P85 April 2001 Event

Basin Elevation	Average Area	Drawdown 1 Infiltration Rate			Drawdown 1 Volumetric Infiltration Rate	Drawdown 4 Infiltration Rate			Drawdown 4 Volumetric Infiltration Rate
[Feet]	[Acre]	[Ft/hr]	[Ft/min]	[Inch/hr]	[CFS]	[Ft/hr]	[Ft/min]	[Inch/hr]	[CFS]
900.0	18.4	-	-	-	-	0.111	0.0019	1.33	24.2
899.5	17.9	-	-	-	-	0.108	0.0018	1.30	23.3
899.0	17.5	-	-	-	-	0.097	0.0016	1.17	20.4
898.5	16.9	-	-	-	-	0.087	0.0014	1.04	17.7
898.0	16.5	-	-	-	-	0.085	0.0014	1.03	17.0
897.5	15.9	-	-	-	-	0.065	0.0011	0.78	12.4
897.0	15.5	-	-	-	-	0.074	0.0012	0.88	13.6
896.5	14.9	-	-	-	-	0.076	0.0013	0.91	13.6
896.0	14.4	-	-	-	-	0.064	0.0011	0.78	11.0
895.5	13.6	-	-	-	-	0.061	0.0010	0.73	9.9
895.0	13.0	-	-	-	-	0.064	0.0011	0.77	10.0
894.5	12.3	-	-	-	-	0.070	0.0012	0.84	10.4
894.0	11.7	-	-	-	-	0.060	0.0010	0.72	8.4
893.5	11.0	-	-	-	-	0.061	0.0010	0.74	8.1
893.0	10.4	-	-	-	-	0.058	0.0010	0.70	7.2
892.5	9.6	-	-	-	-	0.061	0.0010	0.73	7.0
892.0	8.9	-	-	-	-	0.054	0.0009	0.65	5.7
891.5	7.9	-	-	-	-	0.050	0.0008	0.61	4.8
891.0	7.2	-	-	-	-	0.053	0.0009	0.63	4.5
890.5	6.4	0.216	0.0036	2.60	16.7	0.058	0.0010	0.69	4.4
890.0	5.7	0.179	0.0030	2.16	12.0	0.052	0.0009	0.62	3.5
889.5	4.7	0.146	0.0024	1.74	7.1	0.054	0.0009	0.65	3.0
889.0	4.1	0.141	0.0024	1.70	6.6	0.047	0.0008	0.57	2.3
888.5	3.4	0.129	0.0022	1.56	5.2	0.043	0.0007	0.55	1.7
888.0	2.9	0.114	0.0019	1.36	3.8	0.042	0.0007	0.50	1.4
887.5	2.2	0.084	0.0014	1.01	2.1	0.043	0.0007	0.52	1.2
887.0	1.8	0.078	0.0013	0.94	1.7	0.035	0.0006	0.42	0.8
886.5	1.4	0.070	0.0012	0.84	1.2	0.047	0.0008	0.56	0.8

Table III-6: Infiltration Rates and Volumetric Flow Rates for CD-P85 June 2001 Event

Basin Elevation	Average Area	Infiltration Rate			Volumetric Infiltration Rate
[Feet]	[Acre]	[Ft/hr]	[Ft/min]	[Inch/hr]	[CFS]
902.0	19.8	0.101	0.0017	1.21	24.4
901.5	19.4	0.061	0.0010	0.74	22.0
901.0	19.1	0.089	0.0015	1.07	20.2
900.5	18.7	0.092	0.0015	1.10	19.5
900.0	18.4	0.077	0.0013	0.93	16.8
899.5	17.9	0.074	0.0012	0.88	15.1
899.0	17.5	0.074	0.0012	0.88	15.5
898.5	16.9	0.074	0.0012	0.88	14.7
898.0	16.5	0.069	0.0011	0.83	13.2
897.5	15.9	0.065	0.0011	0.78	12.4
897.0	15.5	0.066	0.0011	0.80	12.2
896.5	14.9	0.061	0.0010	0.74	11.0
896.0	14.4	0.061	0.0010	0.74	10.8
895.5	13.6	0.061	0.0010	0.74	9.8
895.0	13.0	0.057	0.0009	0.68	8.8
894.5	12.3	0.054	0.0009	0.65	8.7
894.0	11.7	0.056	0.0009	0.68	7.8
893.5	11.0	0.054	0.0009	0.65	7.1
893.0	10.4	0.057	0.0009	0.68	7.1
892.5	9.6	0.048	0.0008	0.57	6.2
892.0	8.9	0.053	0.0009	0.63	5.5
891.5	7.9	0.047	0.0008	0.56	5.0
891.0	7.2	0.049	0.0008	0.59	4.2
890.5	6.4	0.056	0.0009	0.67	4.1
890.0	5.7	0.040	0.0007	0.49	3.3
889.5	4.7	0.050	0.0008	0.61	2.6
889.0	4.1	0.051	0.0008	0.61	2.4
888.5	3.4	0.047	0.0008	0.56	2.1
888.0	2.9	0.046	0.0008	0.55	1.5
887.5	2.2	0.040	0.0007	0.48	1.0
887.0	1.8	0.039	0.0007	0.47	0.8
886.5	1.4	0.034	0.0006	0.41	0.6

Figure III-6. Infiltration Rate Curves for April 2001 Pumping Event for CD-P85

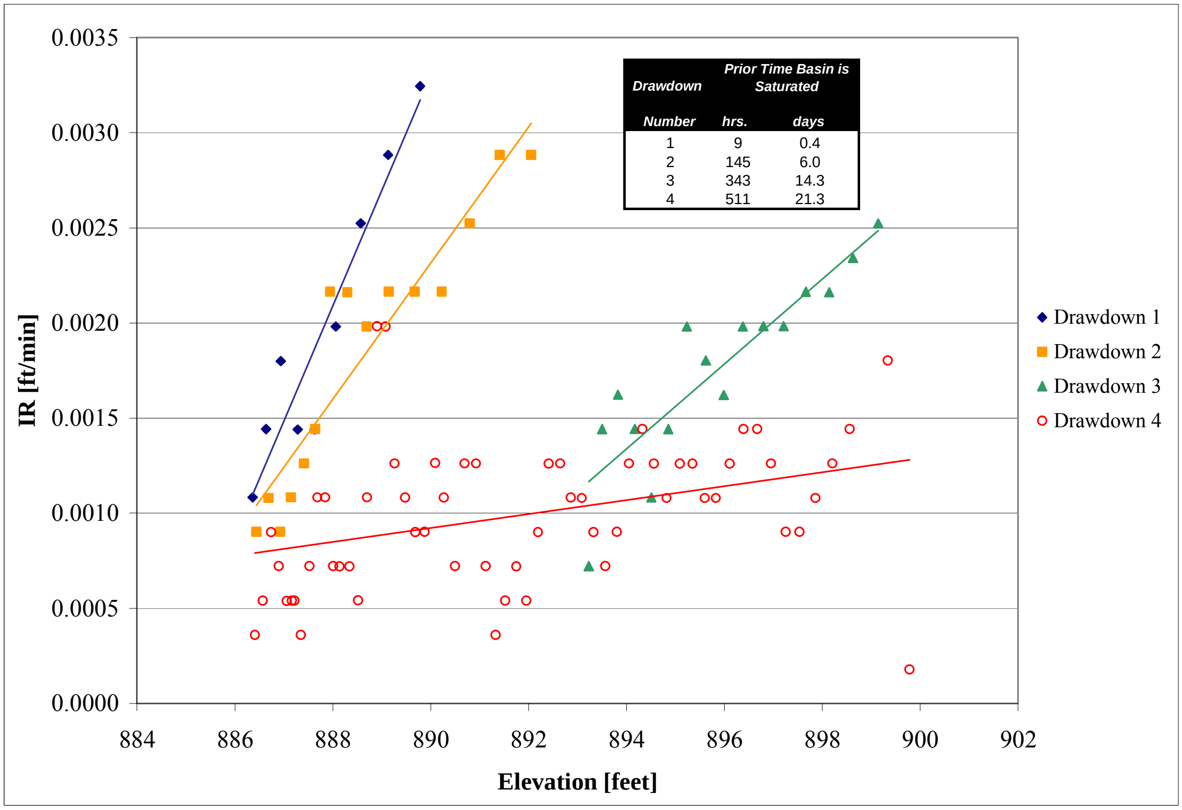


Figure III-7. Volumetric Infiltration Rate Curves for April 2001 Pumping Event for CD-P85

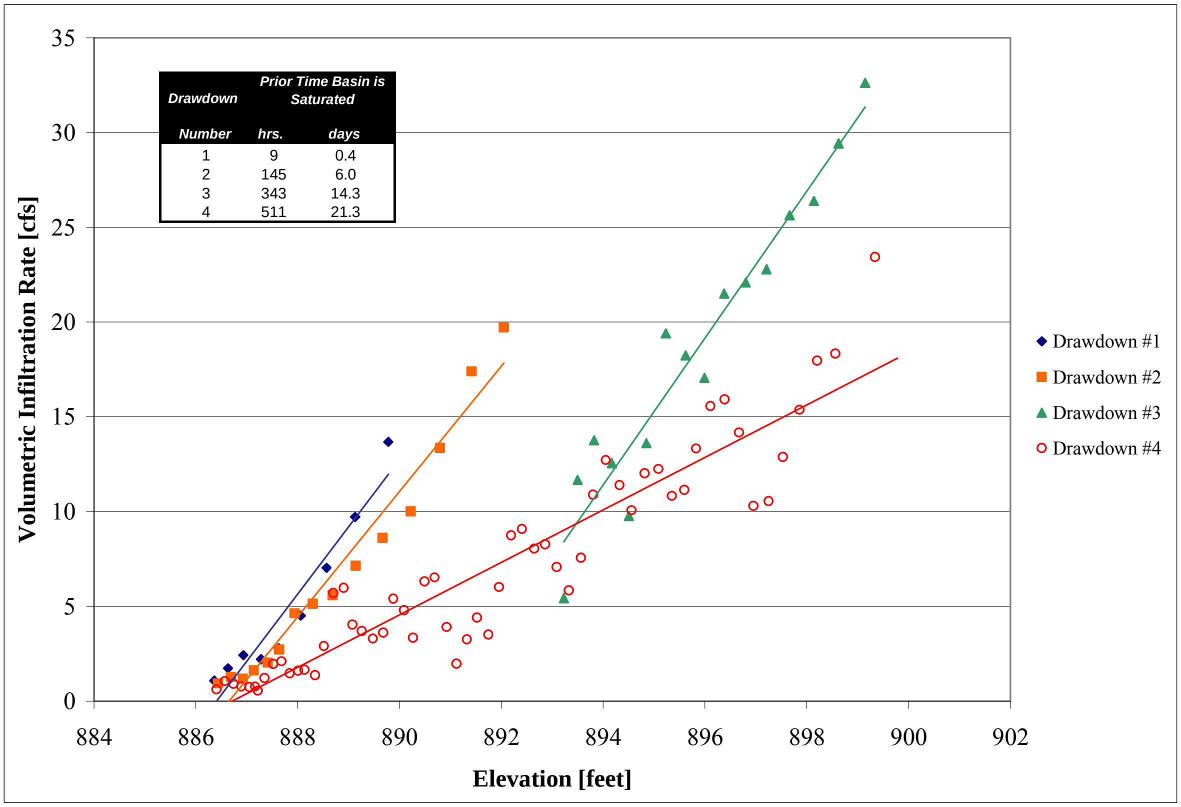


Figure III-8. Infiltration Rate Envelope for April 2001 Pumping Event for CD-P85

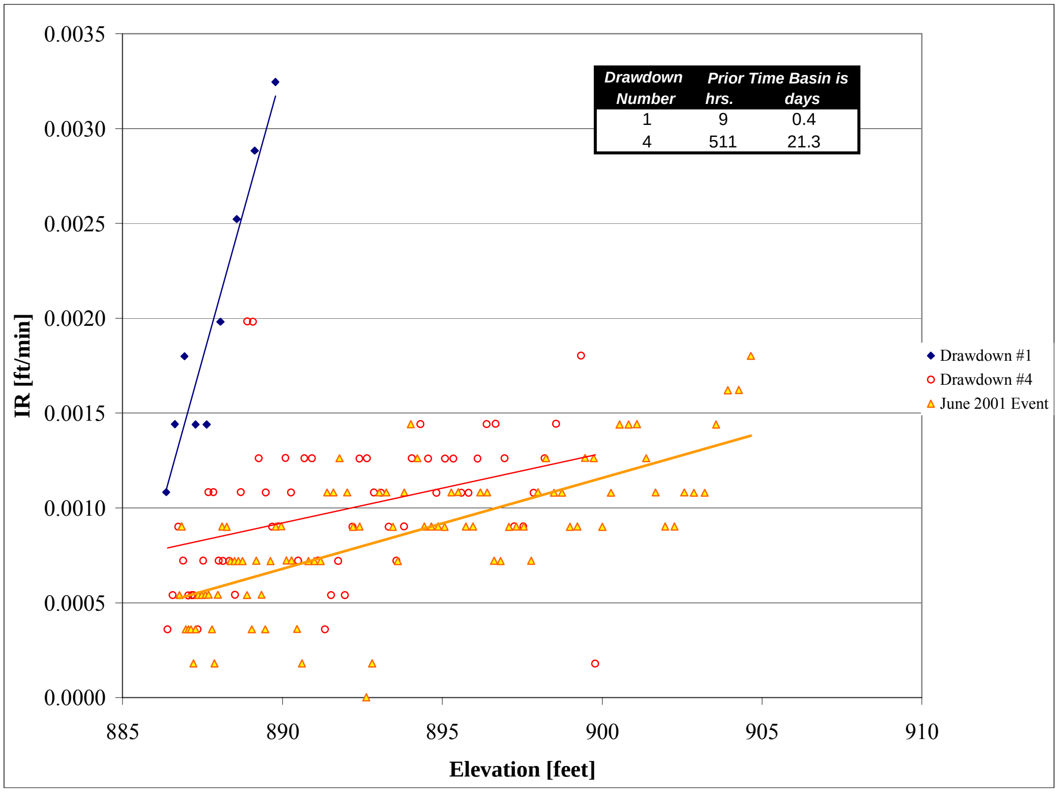


Figure III-9. Volumetric Infiltration Rate Envelope for April 2001 Pumping Event for CD-P85

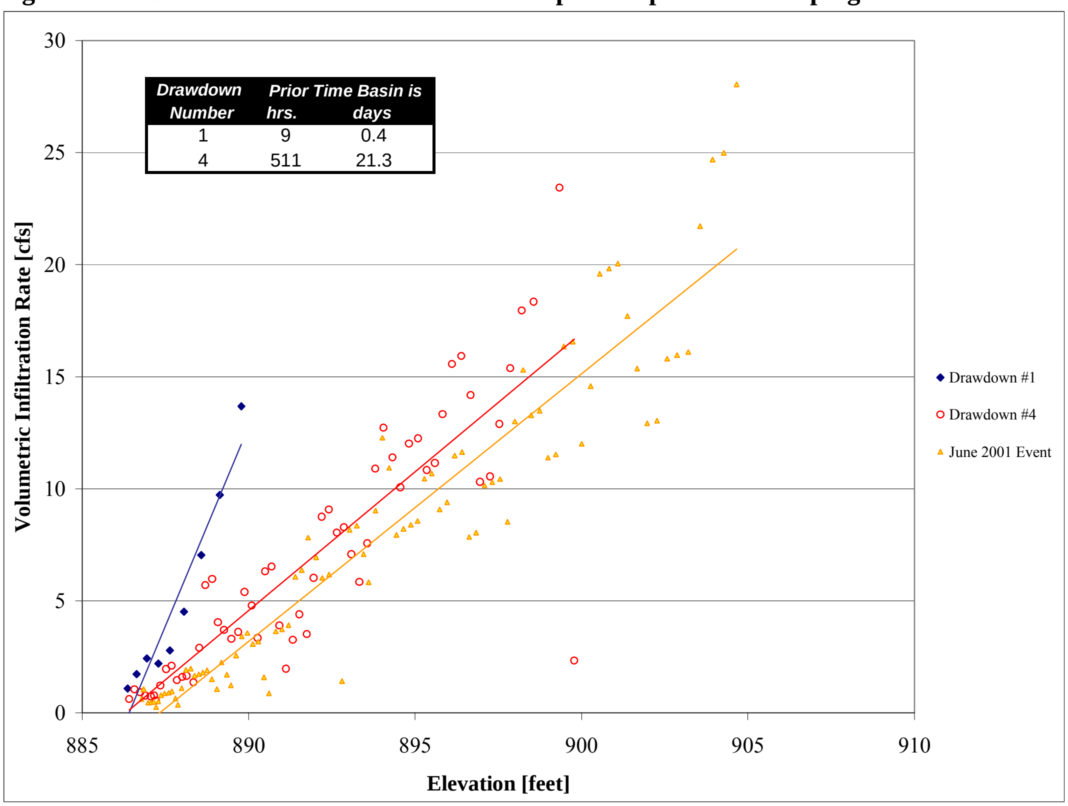


Figure III-10. Infiltration Rate Curve for June 2001 Pumping Event for CD-P85

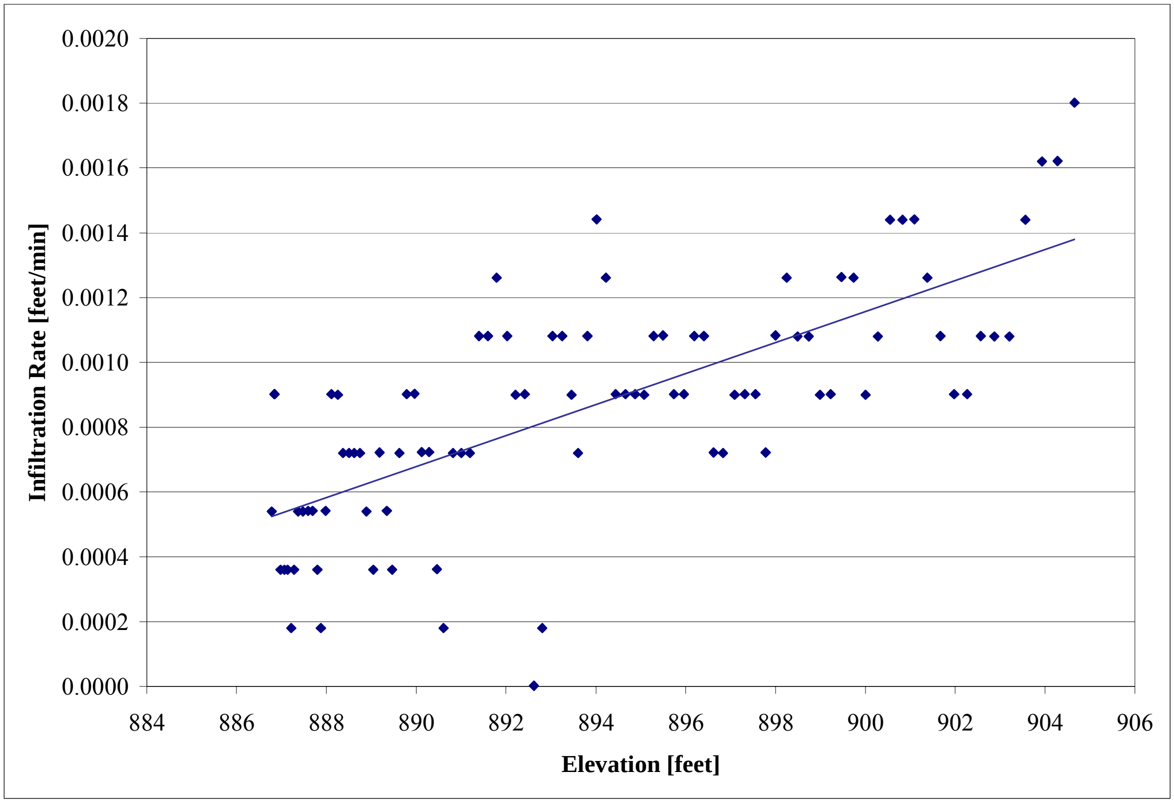
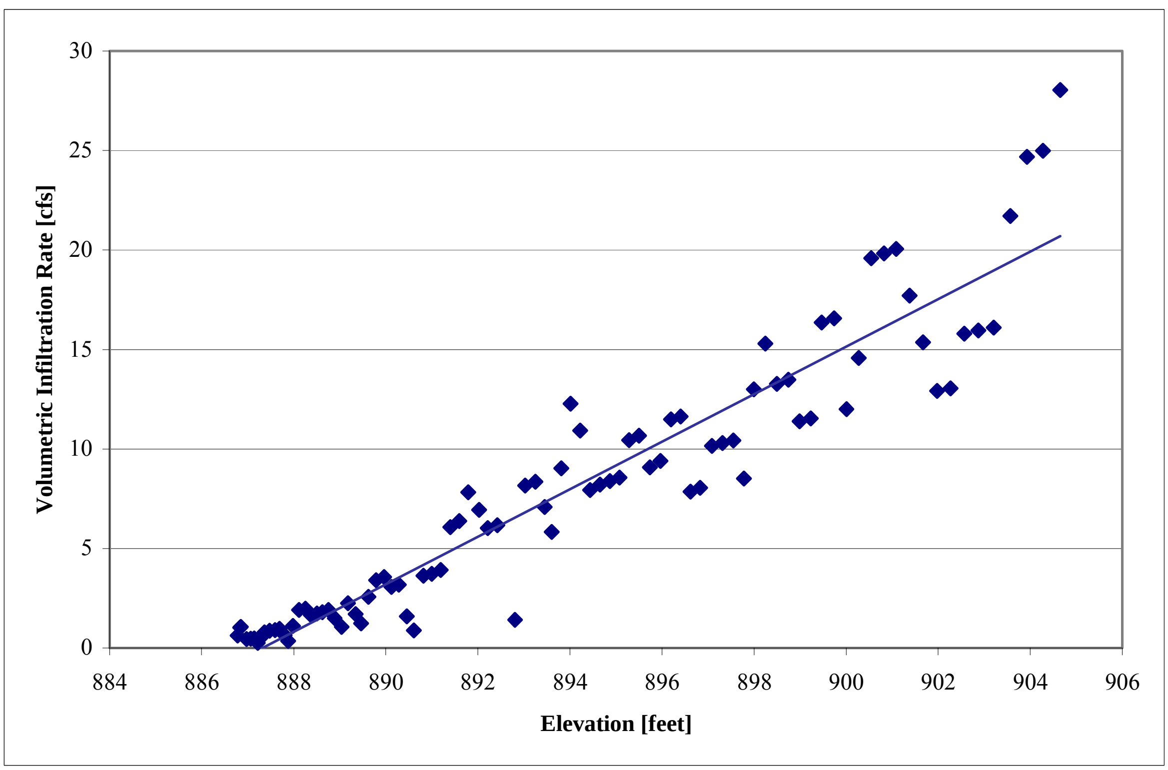


Figure III-11. Volumetric Infiltration Rate Curve for June 2001 Pumping Event for CD-P85



Monitoring Results

- Infiltration rates calculated for the April and June 2001 pumping events represent the infiltration capacity of the basin with three years of improvements: three years with the infiltration tubes and two years with the infiltration trenches. Data collected for CD-P85 in 2001 is comparable to data collected in 2000.
- The maximum depth observed for the April 2001 pumping event was 13.5 feet, which corresponds to an infiltration rate of 1.33 inches/hour.
- The maximum infiltration rate recorded for the April 2001 pumping event was 2.6 inches/hour (16.7 cfs). This rate corresponds to a four-foot depth of water in the basin. These rates are attributable to the soil conditions and the depth to the groundwater table at the time the pumping event began.
- For the April 2001 pumping event, infiltration rates decrease with time due predominantly to the saturation of the underlying soils as well as groundwater mounding. A comparison of Drawdown 1 and Drawdown 4 demonstrates that these factors play a stronger role in the infiltration capacity of the basin than previously thought. Even with 13.5 feet of head in the basin, the maximum infiltration rate for Drawdown 4 (1.3 inches/hour) is only half of the maximum infiltration rate observed for Drawdown 1 (2.6 inches/hour).
- The maximum depth observed for the June 2001 pumping event was 15.5 feet, which corresponds to an infiltration rate of 1.21 inches/hour or 24.4 cfs.
- The maximum infiltration rate observed for the June 2001 pumping event at elevation 902 (1.21 inches/hour) is less than the maximum infiltration rate observed for the April 2001 pumping event at elevation 890.5 (2.6 inches/hour). Infiltration rates observed for the June 2001 pumping event are comparable to those recorded for Drawdown 4 of the April 2001 pumping event because the underlying soils are still saturated. The basin was only dry for 30 days prior to the second pumping event. According to the observed infiltration rates, this is not enough time for the basin to re-establish its full infiltration capacity.

IV. Discussion of Infiltration Conditions

Spring Snowmelt in the Watershed

In Minnesota, melting of the winter snow is one of the most significant hydrologic events of the year. The volume of water generated by snowmelt runoff can be significant and the impact of this single event has raised concerns regarding stormwater infiltration systems.

The infiltration of runoff through the soil and percolation into the groundwater during the winter (frozen conditions) is a topic of research which includes work being performed at the University of Minnesota's Rosemount research site. Traditional surface water hydrologic modeling of spring snowmelt assumes very little to no infiltration based on the assumption of totally frozen ground during snowmelt. The assumption that no infiltration occurs in frozen soil conditions is not accurate. In reality, the infiltration process is slower under frozen conditions than under thawed conditions but infiltration does exist albeit at reduced rates. The study of snowmelt runoff and infiltration by the District thus far has focused on the natural basins where excess snowmelt waters collect. The amount of water reaching a basin depends on the overland travel efficiency as water is delivered it. The assumption in traditional modeling is full delivery of 7.2 inches per unit area. The process of retention and infiltration over the entire landscape has not been examined thus far by the watershed, so the assumptions on volume of runoff delivered have not been refined.

The topography and landforms of the South Washington Watershed consist of many deep natural basins. Most of the basins have a history of being used for agricultural purposes. This portion of the county went through a major land use conversion approximately 150 years ago for intensive agricultural use. Few of the basins still have remnants of natural vegetation. Sands and gravels from glacial outwash materials underlie the soils making them well drained. The numerous basins within the watershed are natural collection points for the excess spring snowmelt runoff. These depressions retain and store the runoff until it infiltrates into the ground. The infiltration process in these basins has been observed for several years and directly measured with monitoring equipment in the watershed in 2001 during the IMS study. The dynamic timedependent changes in infiltration rates raises issues for accurate hydrologic modeling an suggests that certain models are more appropriate to simulate this system.

Winter and Spring Climatic Data

An analysis of the average monthly temperature records for the Minneapolis/St. Paul Airport in Figure IV-1 shows that the average temperatures for 2001 are below the long-term average for that weather station. Figure IV-1 compares the average monthly temperature for 2001 to the average monthly temperatures for the last 50 years. The temperature for the December-March time period was 22 percent below average for the last 50 years with the month of December having the highest deviation from the average.

Figure IV-1. Average Monthly Temperature.

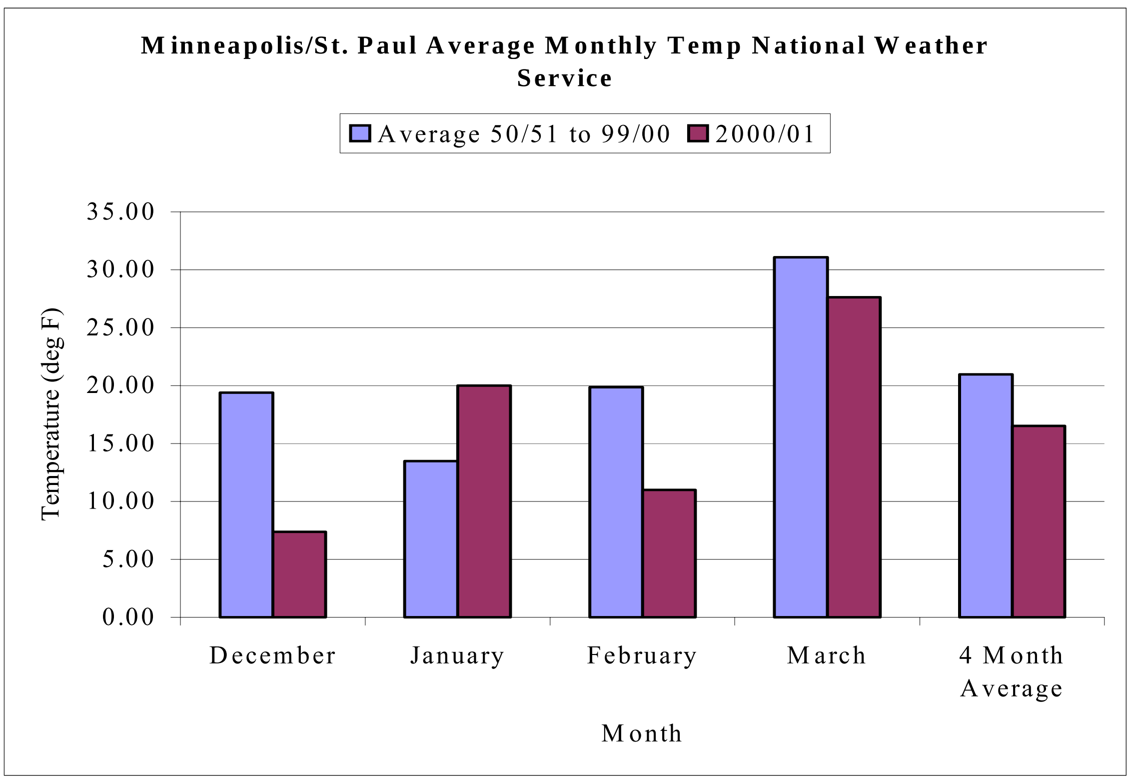


Figure IV-2 shows average total snowfall at the Minneapolis/St. Paul Airport. The graph compares the monthly snowfall for 2001 to the average monthly snowfall over the last 50 years. The average total snowfall for 2001 was eighteen percent above the average for the last 50 years. January received the largest amount of snow for the 2000-2001 season. Average daily temperatures and average snow depth are shown in Figure IV-3 for November 2000 through March 2001.

An analysis of the graphs indicates that the volume of snowmelt for the 2000-2001 season was distributed into two separate snowmelt events. The snow pack did not melt until mid March due to above average temperatures and was monitored in CD-P69, CD-P50, CD-P76, and CD-P82. Any snowfall in March melted by late-March and was monitored in all of the basins.

Figure IV-2. Snowfall during 2000-2001 Monitoring Season

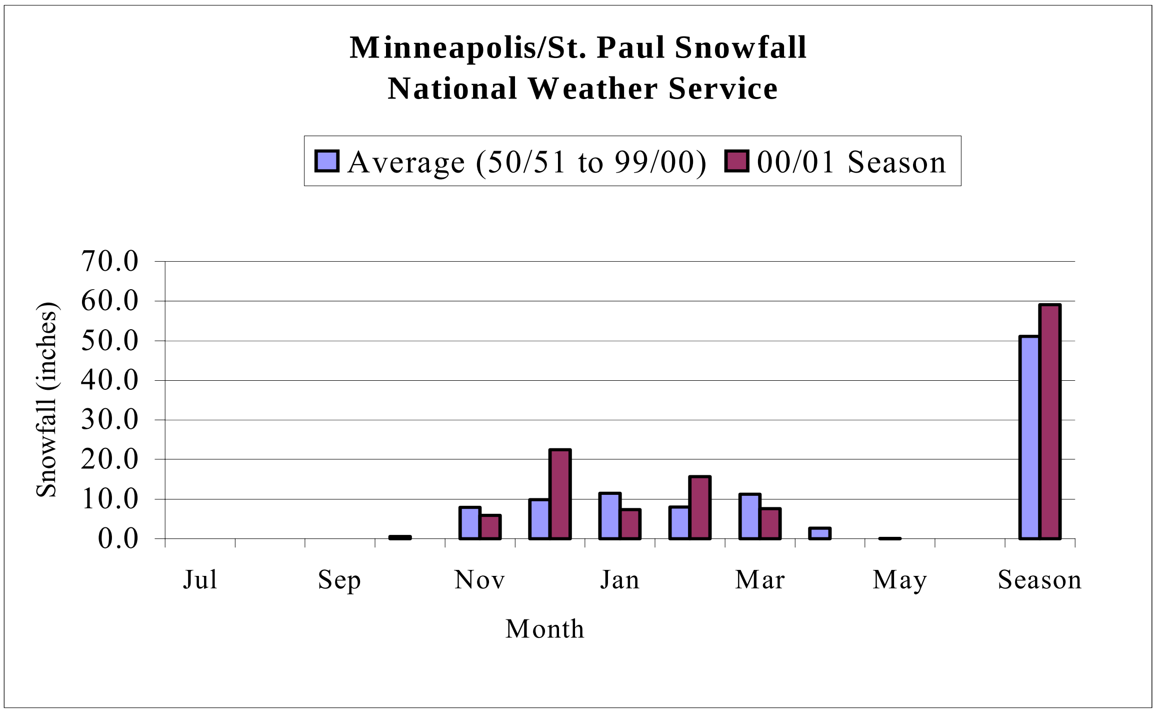
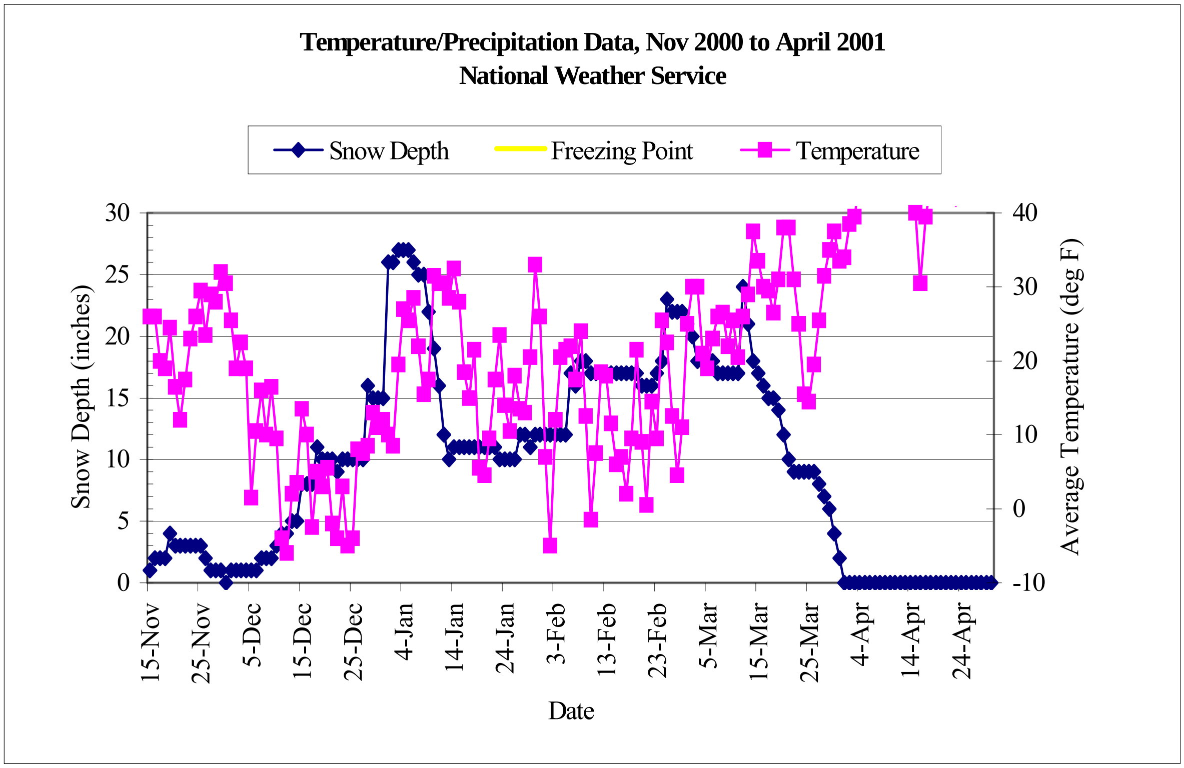


Figure IV-3. Daily Temperature and Precipitation, Nov 2000– March 2001



Snowmelt Infiltration Events

The results of the 2001 spring snowmelt runoff event clearly indicates that infiltration does occur during the spring snowmelt event in a glacial outwash setting such as that found in the SWWD. To evaluate the infiltration capacity of the basins under various snowmelt conditions additional monitoring is required in the future.

Non-Snowmelt Infiltration Events

The analysis of the rainfall record from the Minneapolis/St. Paul Airport (Figure IV-4) indicates that the total rainfall generated in March through June of 2001 was above average.

Figure IV-4. Precipitation March-June 2001

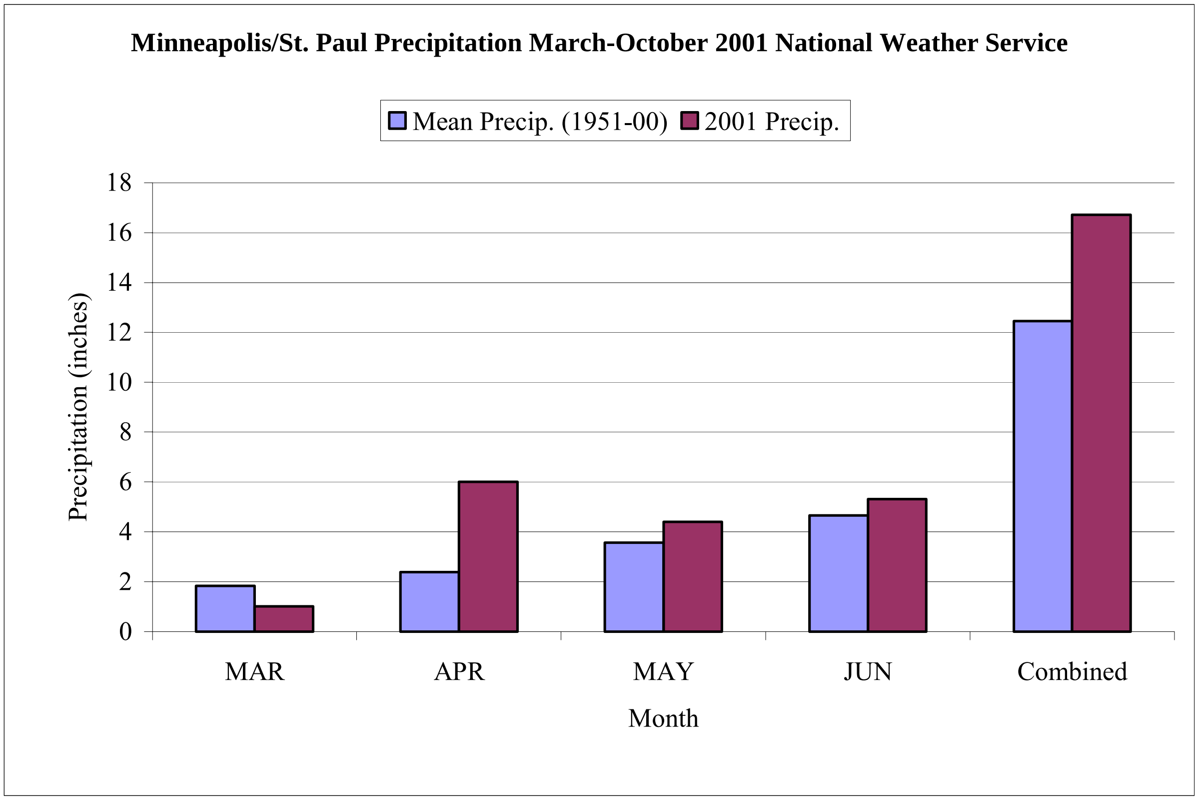


Figure IV-4 compares the total monthly precipitation for 2001 to the average monthly precipitation for the last 50 years. Total precipitation for the months of March, April, May and June of 2001 was 34 percent above the average for the last 50 years. During these above average conditions, no sustained ponded water was found in any of the monitored basins, except for CD-P69, after April 15 1999. Accordingly there was not an opportunity to directly measure summer infiltration rates for the majority of the sites. Several pumping events into CD-P85 during 1997-2001 provide the most complete infiltration rates measured under summer conditions in regional basins. Basin CD-P69 data is also valuable but the record is not as long or complete as that for CD-P85.

APPENDIX A
WATER QUALITY DATA
(not included in electronic document)

APPENDIX B
PHOTO LOGS


CD-P50: 4-03-2001


CD-P50: 4-12-2001

CD-P50: 4-25-2001

CD-P50: 4-30-2001


CD-P50: 5-08-2001


CD-P50: 6-19-2001


CD-P69: 4-03-2001


CD-P69: 4-09-2001


CD-P69: 4-17-2001


CD-P69: 5-08-2001


CD-P69: 6-19-2001


CD-P69: 7-16-2001


CD-P76: 3-09-2001


CD-P76: 4-03-2001


CD-P76: 4-04-2001


CD-P76: 4-09-2001


CD-P76: 4-10-2001


CD-P76: 4-12-2001

CD-P82: 4-03-2001

CD-P82: 4-04-2001


CD-P82: 4-12-2001


CD-P82: 4-25-2001


CD-P82: 4-30-2001


CD-P82: 6-19-2001


CD-P85: 4-13-2001


CD-P85: 4-17-2001


CD-P85: 4-30-2001


CD-P85: 5-16-2001


CD-P85: 6-19-2001


CD-P85: 7-2-2001


CD-P85: 7-10-2001


CD-P85: 7-16-2001