

Infiltration Monitoring Report - 2000

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 – 2001. 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 and the IMS Phase II Report, 2000.

The IMS was concluded in 2000 with the completion of the IMS Phase II Report, 2000. 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/fall events of 2000 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 following 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	
	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer
CD-P50					X	X	X	
CD-P69					X	X	X	X
CD-P76					X		X	
CD-P82					X	X	X	
CD-P85		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/fall 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, an analysis of monitored infiltration rates, conclusions and recommendations.

II. Water Quality and Groundwater Monitoring Methodology and Results

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

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 Quality

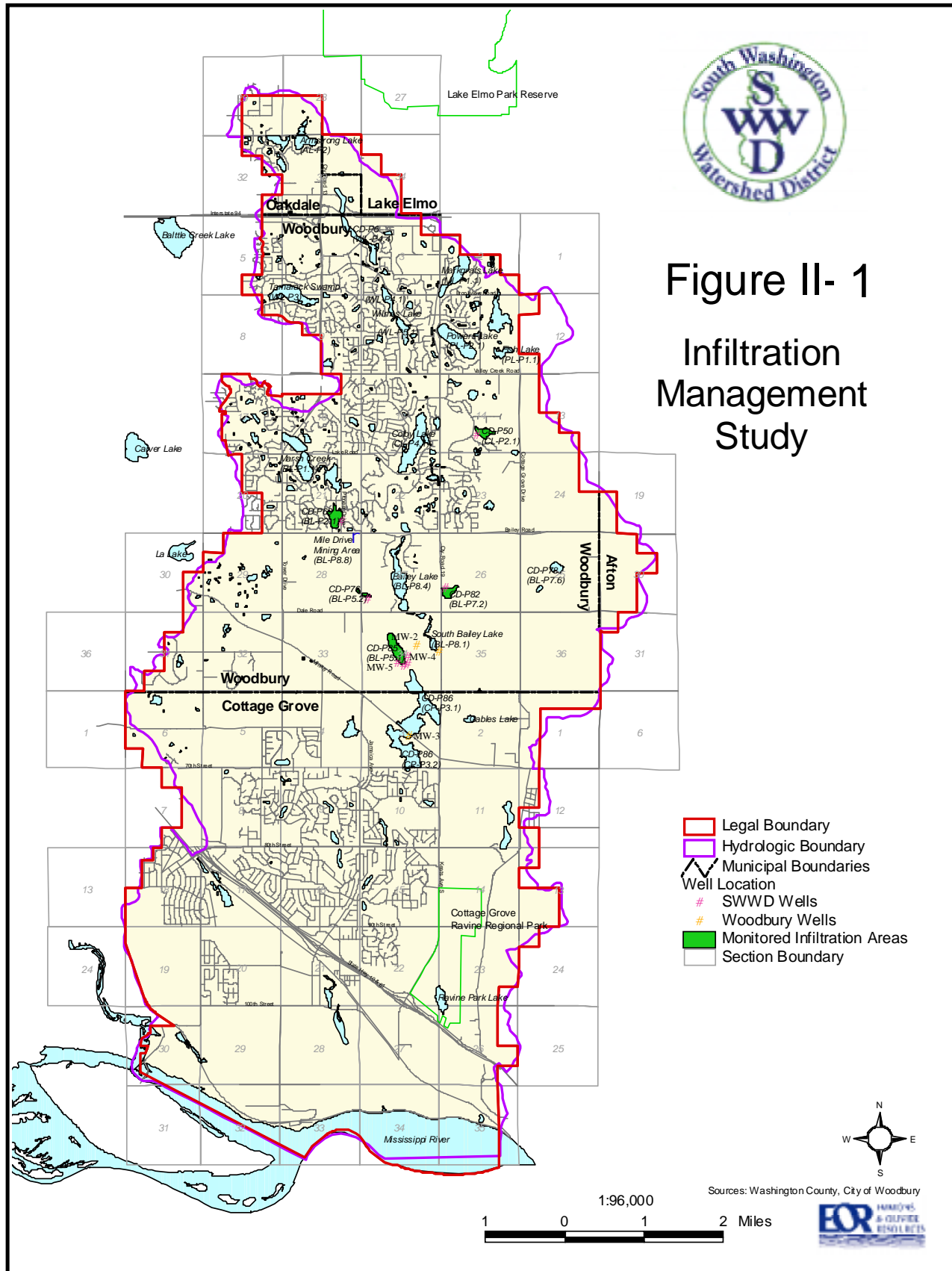
Groundwater quality data was sampled only at CD-P85. Groundwater was sampled from well 3s which is located southeast and downstream of CD-P85 (see Figure II-1). This well is screened at the water table at a depth of 70-80 feet below the surface which corresponds to an elevation of 835 to 845 feet.

Groundwater was sampled for the following parameters:

- Lead
- Chloride
- Total Kjeldahl Nitrogen
- Nitrate + Nitrite
- Hardness (CaCO₃)



Figure II- 1
Infiltration
Management
Study



Groundwater has been sampled by the SWWD since 1998. The results of previous sampling efforts can be found in the IMS Phase II Report, 2000 and the SWWD Groundwater Monitoring and Protection Program Report, 2000.

Appendix A contains a copy of the lab reports and chain of custody.

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.

Surface Water Quality

Surface water quality was obtained for CD-P85 only. Surface water in CD-P85 was sampled by taking grab samples on September 25, 2000 and October 10, 2000.

Surface water samples were analyzed for:

- Lead, dissolved
- Volatile suspended solids
- Total suspended solids
- Total phosphorus
- Total Kjeldahl nitrogen
- Nitrate + Nitrite
- Chloride

Surface water quality has been monitored by the SWWD in CD-P85 since 1997. The results of previous water quality sampling can be found in the Infiltration Management Study Phase I and Phase II reports.

Appendix A contains a copy of the lab reports and chain of custody.

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 and South Bailey Lake. 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 table elevations at CD-P85 were recorded twice daily for the first two weeks of the infiltration event and then weekly in all of the City of Woodbury and SWWD owned monitoring wells until water levels returned to pre-infiltration event levels. Water level readings were taken with the use of an electronic water level tape at each well.

II-B RESULTS

CD-P85

Water Quality

Groundwater was sampled once prior to pumping on September 18, 2000 and twice after pumping began on September 25, 2000 and October 2, 2000. Surface water in CD-P85 was sampled by taking grab samples on September 25, 2000 and October 10, 2000. Well 3s was chosen at CD-P85 for sampling based on it being located in the water table aquifer.

The results of water quality sampling for CD-P85 are presented in Table II-1.

Table II-1. Water Quality Results at CD-P85, September – October 2000

Analyte	MDH HRL	Surface	Surface	Surface	3S	3S	3S
		water 9/19/00	water 9/25/00	water 10/02/00	9/18/00	9/25/00	10/02/00
Lead (dissolved, * total) [mg/L]	0.015	<0.002	<0.002*	<0.002*	<0.002	0.030*	0.019*
Volatile suspended solids [mg/L]	--	0.72	0.72	0.64	N/a	N/a	N/a
Total suspended solids [mg/L]	--	12.0	6.0	8.0	N/a	N/a	N/a
Total hardness (CaCO ₃) [mg/L]	--	N/a	N/a	N/a	269.0	232.0	187.0
Total phosphorus [mg/L]	--	0.141	0.116	0.121	N/a	N/a	N/a
Total Kjeldahl nitrogen [mg/L]	--	19.2	1.97	1.71	9.8	0.78	1.12
Nitrate + nitrite [mg/L]	10	<0.08	<0.08	<0.08	2.38	1.12	<0.08
Chloride [mg/L]	250**	30.2	28.4	30.0	27.4	32.4	30.2

** EPA Secondary Standards – not enforceable

N/a – Not applicable, was not analyzed for this parameter

MDH – Minnesota Department of Health

HRL – Health Risk Limit

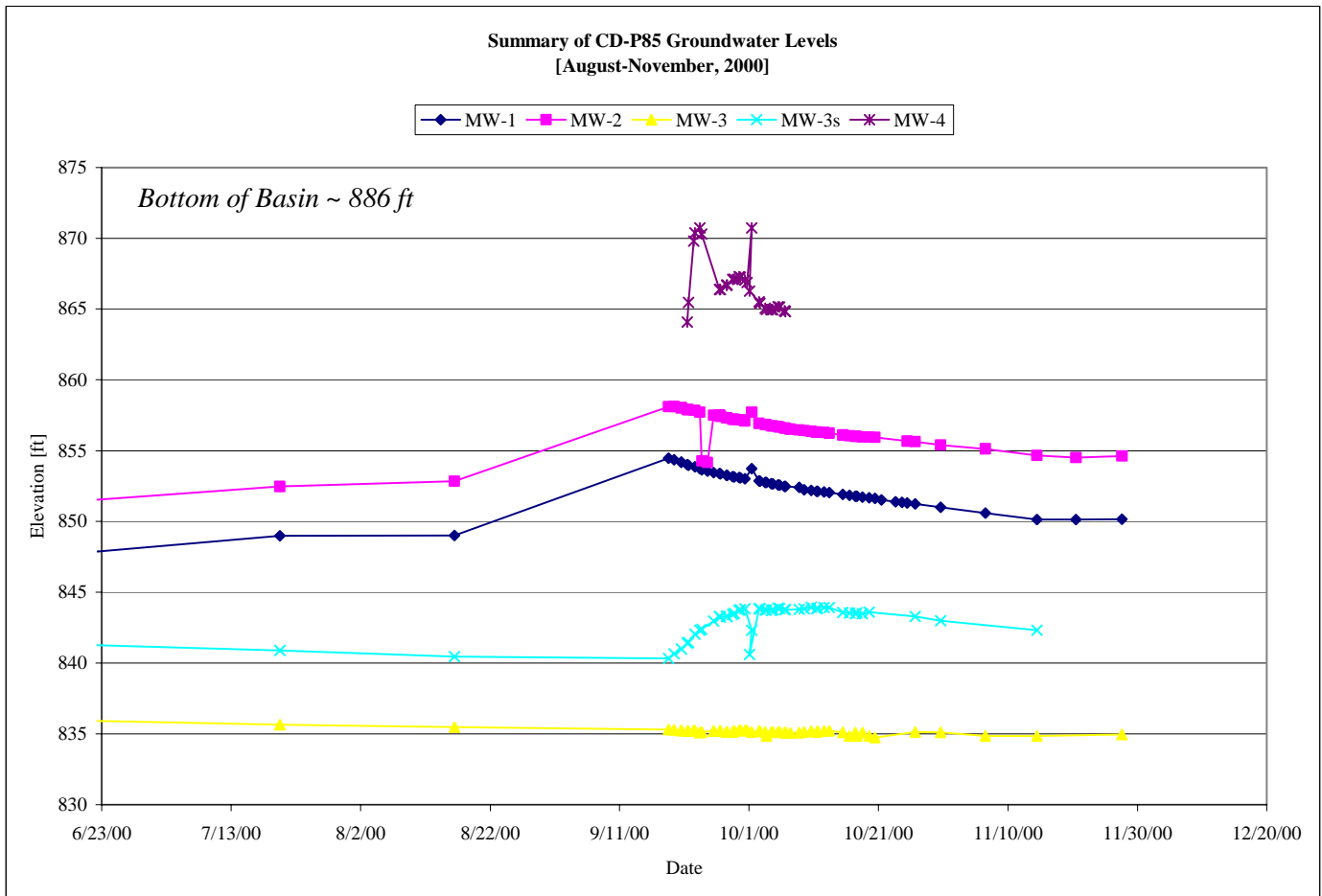
The groundwater samples indicate that well 3S at CD-P85 has exceeded the MDH recommended concentrations for lead during the September 25 through October 2, 2000 monitoring event. This is due to the samples not being filtered prior to analysis. A complete discussion of filtered versus non-filtered sampling is provided in the IMS Phase II Report, 2000. These non-filtered samples do not represent the amount of lead dissolved in the groundwater and therefore cannot be compared with MN HRL standards. By contrast, the surface water samples had no detectable amounts of the metals. The limited data that includes low surface water concentrations indicates

that the infiltrated surface waters are not introducing heavy metals, or mobile nutrients, such as nitrates to the groundwater at concentrations that would negatively impact groundwater quality. Chlorides were approximately the same concentration for both surface and groundwaters.

Groundwater Level Monitoring

Water levels have generally decreased since July 1998. Because the subsurface material is granular, consisting of sand and gravel, the transmissivity (rate at which water moves through the substrate) is very high. This allows the water table to recover relatively quickly after significant infiltration events. There was no measurable amount of water in MW-5 during the infiltration events in 2000.

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



Monitoring wells (MW) 1 and 2 showed similar groundwater level patterns. These wells are located between CD-P85 and South Bailey Lake. The pattern was probably due to high groundwater levels at South Bailey Lake prior to pumping as a result of high surface water levels in South Bailey Lake. After pumping of South Bailey Lake began, the water table began to drop in accordance with the drop in surface water elevations.

MW-3 did not appear to show any response to the pumping event at CD-P85. This is probably due to the fact that MW-3 is located greater than 4,000 feet downstream from CD-P85. Delayed fluctuations have been measured at MW-3 in past events such as August 1999, but the 2000 event did not appear to have an effect at this distance.

MW-4 showed the most dramatic change in water level over time. Groundwater levels reached a peak of seven feet six days after pumping/infiltration began at CD-P85. This water level quickly dissipated two days later to a level of three feet followed by groundwater levels returning to normal conditions on October 9, 2000. MW-4 is set well above the actual water table; therefore the water level measured in MW-4 does not reflect the water table but rather the extent of saturated sediments surrounding CD-P85.

The water table at MW-3s also showed a mounding response beginning as soon as pumping began. The screen at MW-3s is set within the water table and so the mounding response is immediately recorded at this well location. The mound peaked 25 days after pumping began with an elevation of 843.92 feet.

Comparison of this pumping/infiltration event to the August 1999 event indicates that the wells responded in the same general fashion as they had previously. Mounds were recorded in both MW-4 and MW-3s. In well near South Bailey Lake, MW-1 and MW-2, water table elevations also responded similarly, both decreasing in elevation as soon as pumping began.

CD-P50

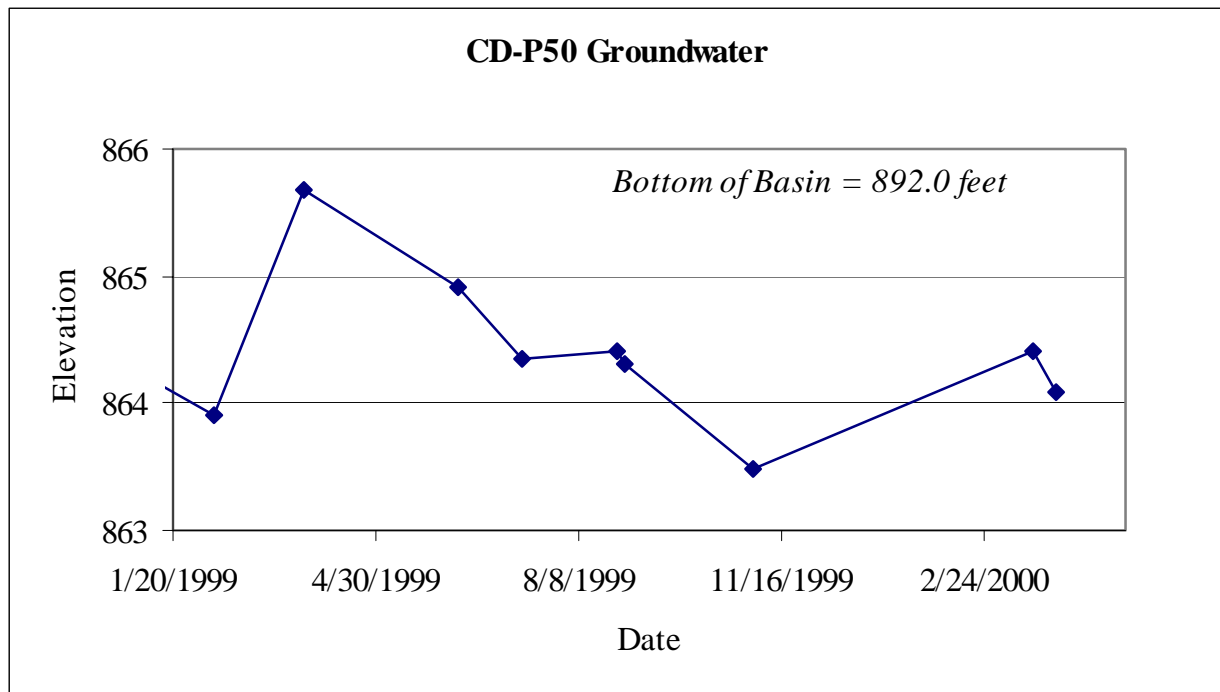
Water Quality

Surface and groundwater quality was not sampled during 2000.

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 measured at CD-P50.

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



CD-P69

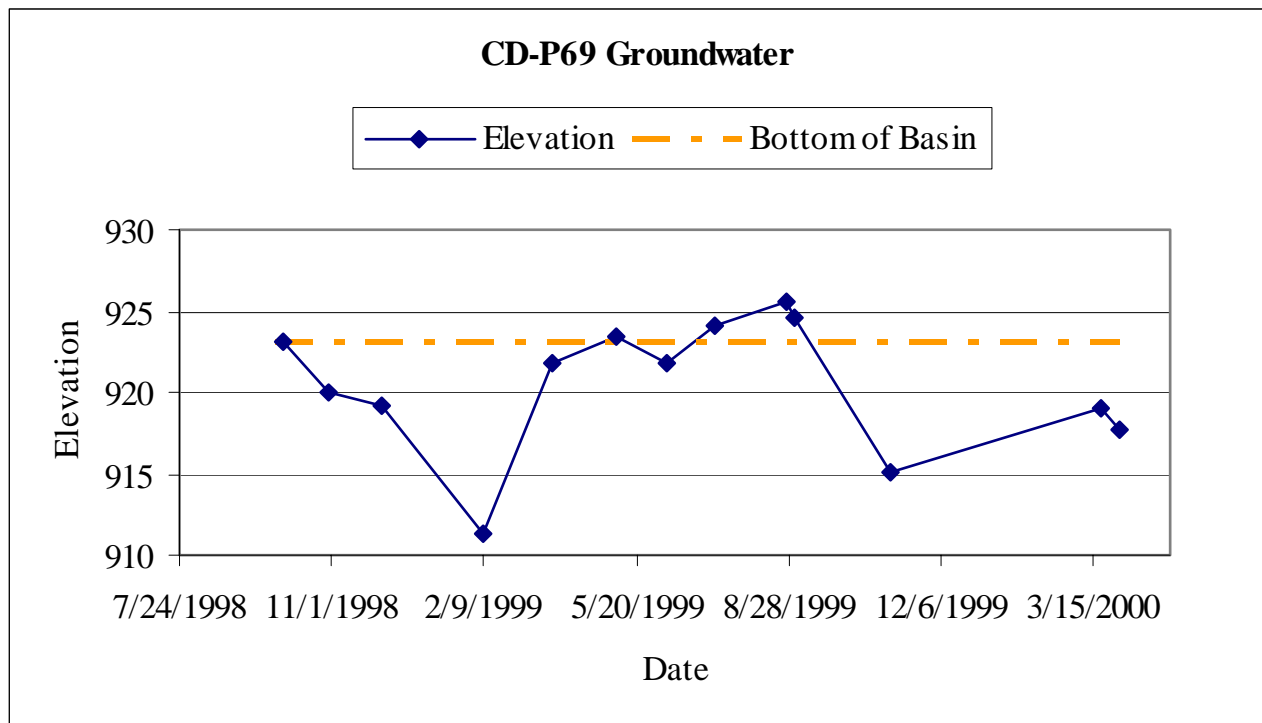
Water Quality

Surface and groundwater quality was not sampled during 2000.

Groundwater Level Monitoring

Groundwater levels at CD-P69 have continued to fluctuate. Recorded groundwater levels intersected the bottom of the basin on several occasions during 1999. The high groundwater levels, those that intersect the bottom of the basin, will impede the surface infiltration rate. The groundwater table did not intersect the bottom of the basin in spring 2000. Figure II-4 is a summary of groundwater levels at CD-P69 since September 1998.

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



CD-P76

Water Quality

Surface and groundwater quality was not sampled for during 2000.

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

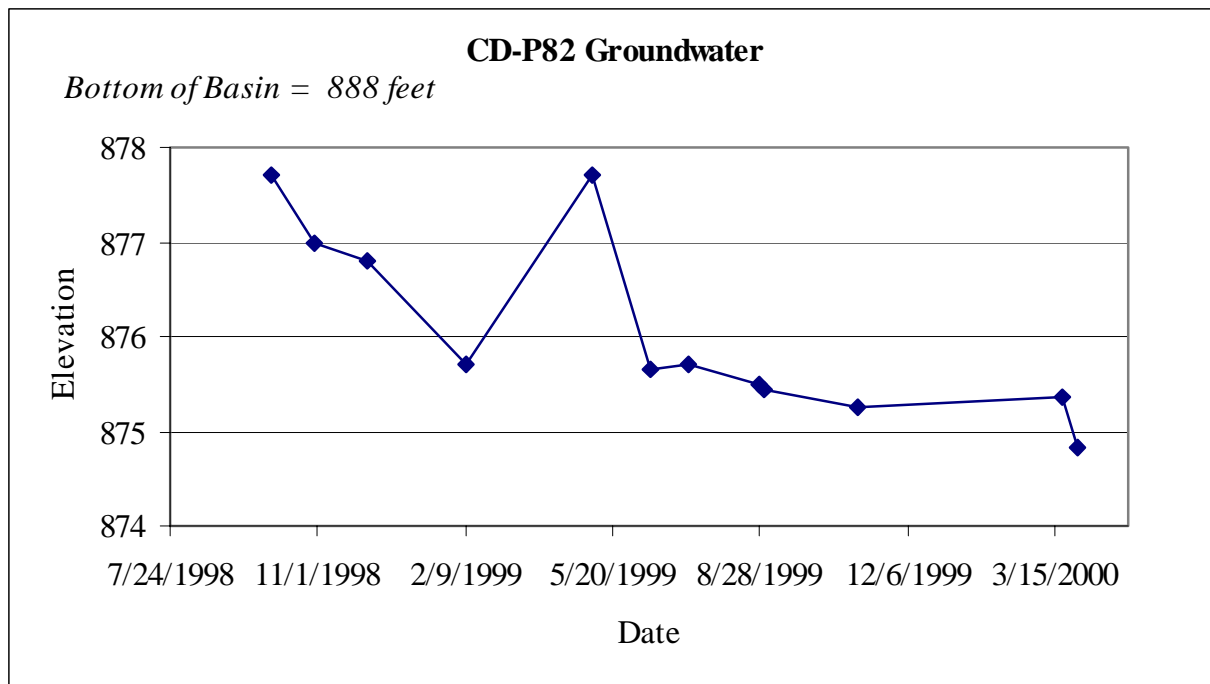
Water Quality

Surface and groundwater quality was not sampled during 2000.

Groundwater Level Monitoring

Figure II-5 represents the changes in groundwater elevations occurring since the installation of the well in 1998. There was no significant increase in the groundwater table during the spring snowmelt event of 2000.

Figure II-5. Water Table Fluctuations at CD-P82



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 2000. 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. Figure II-1 illustrates the location of each of these basins. Regional infiltration basin CD-P85 was monitored for a single pumping event in September of 2000. Appendix B contains a photo log for each of the infiltration events in 2000.

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 2000 monitoring events: American Sigma area/velocity flow meters to monitor flows and Telog water level pressure transducers to monitor water levels in the basins.

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 also taken where feasible and are incorporated into the data analysis.

The equipment used to monitor the spring snowmelt event was installed on February 23 at CD-P76, February 25 at CD-P69, February 26 at CD-P50, and March 1 at CD-P82. All of the

basins were dry at the time of equipment installation except for CD-P82. Water levels were staked in the field and later surveyed at CD-P82 prior to the equipment being installed. Monitoring of the basins occurred until most of the runoff generated by the event had infiltrated in the basin. The equipment was pulled from each of the basins on the following dates: CD-P50 on March 13, 2000; CD-P69 on March 19, 2000; CD-P76 on March 2, 2000; and CD-P82 on March 22, 2000. All of the basins were dry for the remainder of the spring / summer season with the exception of CD-P69. Equipment was re-installed at CD-P69 on June 30, 2000 and removed on August 23, 2000.

The equipment used to monitor the pumping event in CD-P85 was installed on September 14, 2001 and removed on October 6, 2000.

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. Regional infiltration basin CD-P85 was not monitored for the spring snowmelt event due to a lack of runoff. CD-P85 was monitored during April and June as a result of two separate pumping events at the basin. The results of the spring 2000 event and CD-P85 pumping events are 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 February 26, 2000 and removed on March 13, 2000. The bottom of CD-P50 is classified as a Jurisdictional Wetland. The soils up to 3.8 feet in depth are wetland soils, and appear less permeable than the surrounding materials. The basin remained dry for the rest of the field season.

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 volumetric flow rates were computed by multiplying the rates shown in Table III-1 by the average area of the basin at the corresponding elevations. No additional steps were taken to separate out new inputs from precipitation, so the infiltration rates computed here are lower than actual infiltration rates.

Figure III-1. Depth vs. Time for CD-P50 - Spring 2000

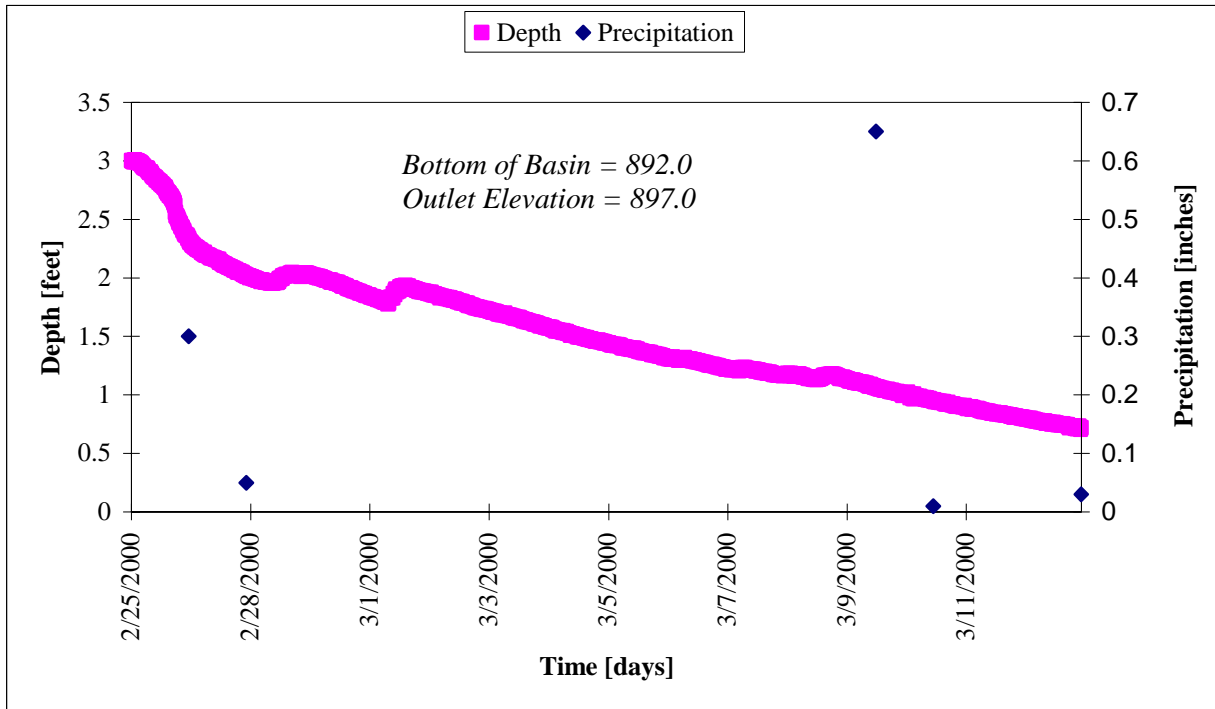


Table III-1. Infiltration Rates at CD-P50 for Spring 2000

Basin Elevation [feet]	Average Area [acre]	Infiltration Rate			Volumetric Infiltration Rate [cfs]
		[ft/hr]	[ft/min]	[inches/hr]	
3.0 – 2.5	3.3	0.024	0.0004	0.29	0.96
2.5 – 2.0	2.8	0.012	0.0002	0.14	0.41
2.0 – 1.5	2.2	0.006	0.0001	0.07	0.16
1.2 – 0.8	1.6	0.004	0.0001	0.05	0.08

Monitoring Results

- Data collected for CD-P50 is consistent with the spring infiltration data for 1999 presented in the IMS Phase II Report, 2000.

- Water levels fell from a depth of 3.0 feet on February 2, 2000 to a depth of 0.8 feet on March 13, 2000.
- Snowmelt infiltration rates ranged from 0.3 inches/hour to 0.05 inches/hour over the spring event.
- The jurisdictional wetland boundary corresponds to an elevation of 895.6 to 895.8, which is a depth of 3.6 to 3.8 feet. Therefore, infiltration data collected in 2000 represents the infiltration capacity of this jurisdictional wetland.

CD-P69 – Pioneer Drive Wetland

Two water level recorders were installed to monitor the water balance for the Pioneer Drive Wetland basin on February 25, 2000. 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 (Figure II-1). Due to low water levels, the pressure transducers were removed at the end of March.

During the spring, a third water level recorder was also installed near the west inlet of the basin to measure additional inflows that may be present. Comparisons were made between the water level elevations at the west inlet to the overflow elevation into the Pioneer Drive basin to determine when water was entering the basin from the west. The water level elevations were below the overflow elevation during the time intervals that the water balance was performed; therefore, west inlet flows were not included in the water balance calculations. More accurate measurements of the west contributing area could be obtained in the future.

To monitor summer infiltration events, one pressure transducer was reinstalled in the Pioneer Drive basin on June 31, 2000 and a second pressure transducer was reinstalled at the Savanna Oaks outlet structure on July 7, 2000. Data was collected through August 23, 2000.

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 rates 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 monitoring season.

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:

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

1. Determine discharge and volume inputs (at 4-hour time intervals, Δt) for Savanna Oaks outlet structure ($Q_{\text{in}}:V_{\text{in}}$)
2. Determine discharge and volume outputs (at 4-hour time intervals, Δt) for Pioneer Drive Wetland V-notch outlet structure ($Q_{\text{out}}:V_{\text{out}}$)
3. Calculate the difference in volume for each time step ($V_{\text{in}} - V_{\text{out}}$)
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 ($(V_{\text{in}} - V_{\text{out}}) + V_{\text{basin}}$)
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 three separate time periods consisting of two periods of 2 days and one period of 4 days. The summer event consisted of three time periods of 4, 7, and 8 day durations. Each period began two days after the last rainfall event and ended immediately preceding the next rainfall event. This approach minimizes any unmeasured inputs to the basin from precipitation or runoff from the immediately surrounding developments. 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 that were not measured, the infiltration rates could be higher than those calculated here.

Figure III-2. Depth vs. Time and Precipitation for CD-P69 - Spring and Summer 2000

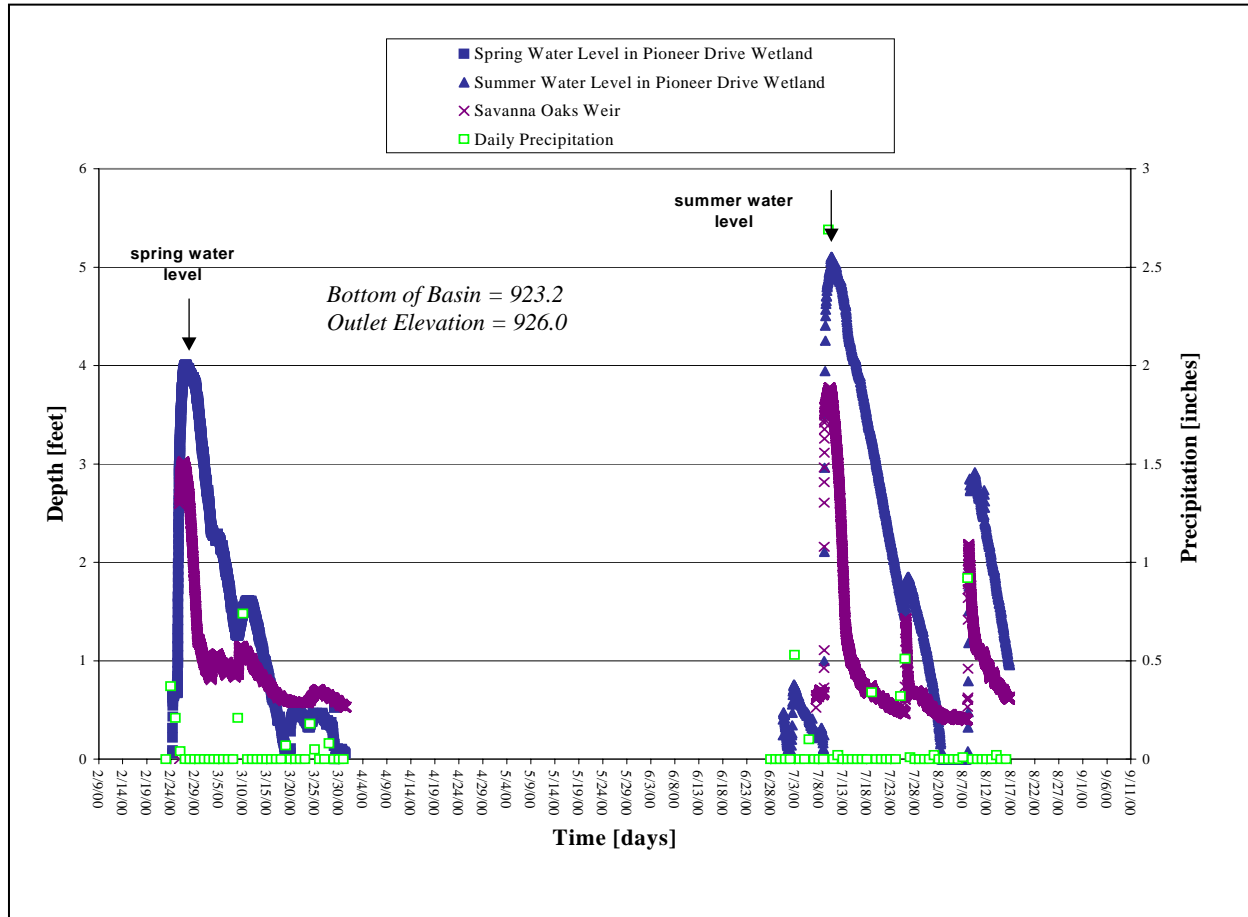


Table III-2a. Infiltration Rates at CD-P69 for Spring 2000

Basin Depth [feet]	Average Area [acre]	Infiltration Rate			Volumetric Infiltration Rate [cfs]
		[ft/hr]	[ft/min]	[inches/hr]	
3.5 – 2.5	4.6	0.029	0.0005	0.35	1.65
2.0 – 1.5	4.0	0.028	0.0005	0.34	1.45
1.5 – 0.5	4.0	0.031	0.0005	0.37	1.44

Table III-2b. Infiltration Rates at CD-P69 for Summer 2000

Basin Depth [feet]	Average Area [acre]	Infiltration Rate			Volumetric Infiltration Rate [cfs]
		[ft/hr]	[ft/min]	[inches/hr]	
3.5 – 3.0	4.6	0.010	.0002	0.12	0.71
2.5 - 1.0	4.0	0.023	.0004	0.27	1.17
1.0 - 0.5	4.0	0.015	.0003	0.19	0.85

Monitoring Results

a. Spring Infiltration Data

- Spring infiltration rates of approximately 0.35 inches/hour were calculated for depths of 3.5 feet to 0.5 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 stage/discharge curve for the Savanna Oaks outlet structure was calibrated based on flow data collected during the summer of 1999. This produced higher predicted flow levels into the basin for a given elevation and resulted in increased infiltration rates when compared with 1999 data.
- The slightly higher infiltration rates calculated at lower elevations are attributed to the lack of accurate inflow monitoring into CD-P69, both at the Savanna Oak outlet structure and the other two major inlets to the wetland. Unmeasured inflow from upstream snowmelt and local precipitation would mean that the infiltration rates calculated for this report are lower than the actual infiltration rates.

b. Summer Infiltration Data

- Average summer infiltration rates of 0.2 inches/hour were calculated in the basin at depths of 0.5 to 4.5 feet.
- The rates shown in Table III-2b could be lower than the actual rates due to unmeasured inputs into the basin.
- Groundwater mounding, as shown in Figure II-4, appears to be partially controlling the summer infiltration rates of the basin vs. free vertical infiltration with no limiting factor below the basin.

CD-P76 – Mile Drive Basin

Infiltration Rates

A single water level recorder was installed in CD-P76 on February 23, 2000. The water level recorder was removed on March 2, 2000. The basin remained dry for the rest of the field season.

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 ($\Delta \text{Depth} / \Delta \text{Time}$) 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. No additional steps were taken to separate out new inputs from precipitation, so the infiltration rates computed here are lower than actual infiltration rates.

Figure III-3. Depth vs. Time at CD-P76 for Spring 2000

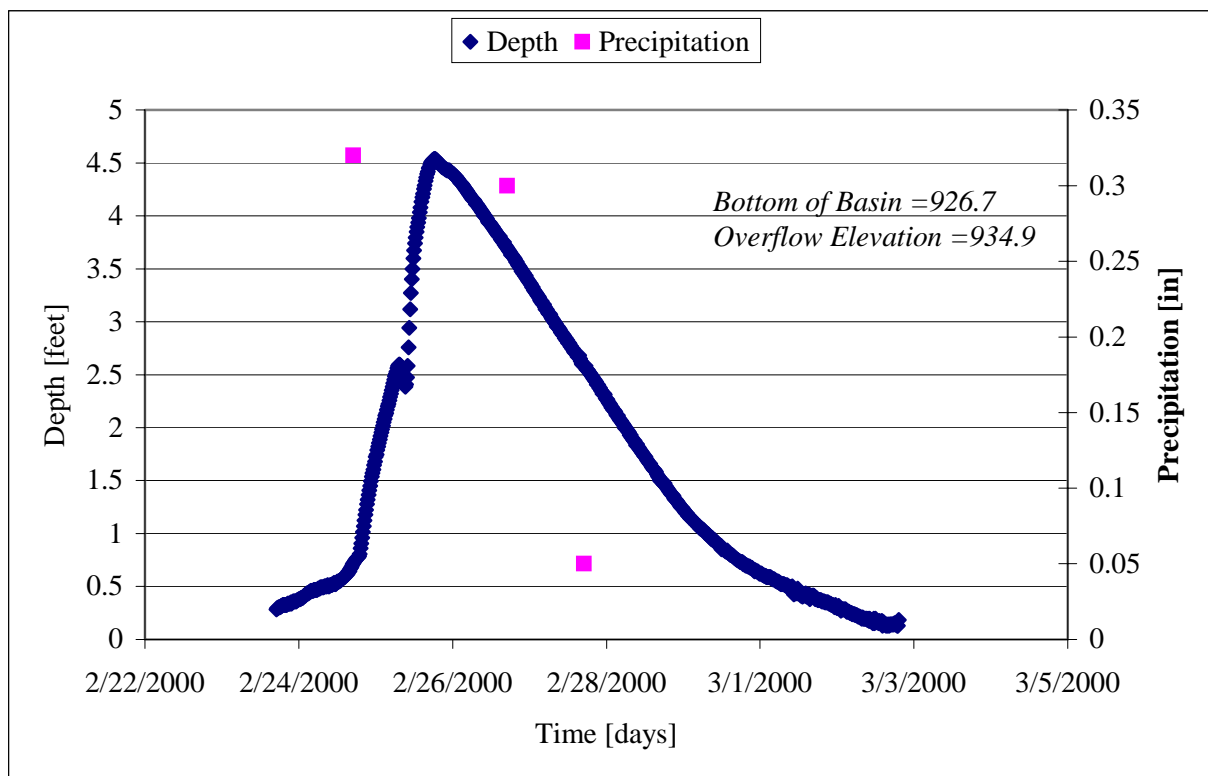


Table III-3. Infiltration Rates at CD-P76 for Spring 2000

Basin Depth [feet]	Average Area [acre]	Infiltration Rate			Volumetric Infiltration Rate [cfs]
		[ft/hr]	[ft/min]	[inches/hr]	
4.5 - 4.0	9.0	0.04	0.0007	0.48	4.57
4.0 - 3.5	8.4	0.04	0.0007	0.48	4.27
3.5 - 3.0	7.4	0.05	0.0008	0.60	4.30
3.0 - 2.5	6.4	0.04	0.0007	0.48	3.25
2.5 - 2.0	5.4	0.05	0.0008	0.60	3.14
2.0 - 1.5	4.5	0.05	0.0008	0.60	2.61
1.5 - 1.0	3.5	0.03	0.0005	0.36	1.27
1.0 - 0.5	2.3	0.02	0.0003	0.24	0.50
0.5 - 0.0	0.9	0.01	0.0002	0.12	0.13

Monitoring Results

- Data collected for CD-P76 is consistent with the spring infiltration data for 1999 presented in the IMS Phase II Report, 2000.
- Snowmelt infiltration rates ranged from 0.48 inches/hour to 0.12 inches/hour over a 4.5-foot range in depth.
- Based on the elevation of the natural overflow, the maximum depth of the basin is 10.5 feet.

CD-P82 – County Road 19 Basin

Infiltration Rates

A single water level recorder was installed in CD-P82 on March 1, 2000. In addition to the water level recorder, a number of data points were obtained by surveying the water level in the basin over the course of the infiltration event. The data points obtained from the water level recorder and the surveyed data points are graphically presented in Figure III-4. Monitoring equipment was removed from the basin on March 22, 2000. The basin remained dry for the rest of the field season (infiltration rates exceeded rainfall and runoff rates).

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 2000

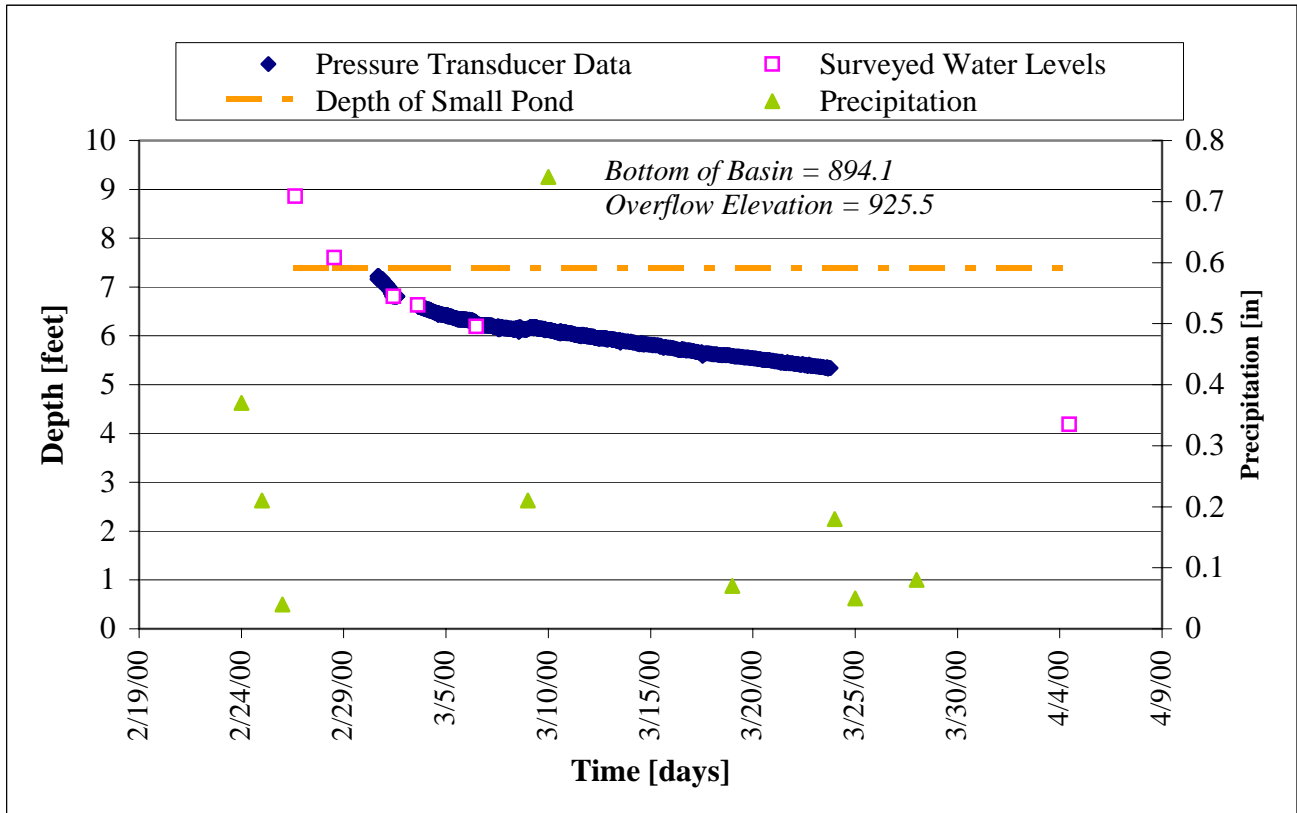


Table III-4. Infiltration Rates at CD-P82 for Spring 2000

Basin Elevation [feet]	Average Area [acre]	Infiltration Rate			Volumetric Infiltration Rate [cfs]
		[ft/hr]	[ft/min]	[inches/hr]	
9.0 - 7.5	9.1	0.028	0.0005	0.34	3.1
7.5 - 7.0	8.4	0.011	0.0002	0.13	1.1
7.0 - 6.5	8.1	0.006	0.0001	0.07	0.6
6.5 - 6.0	7.7	0.006	0.0001	0.07	0.6
6.0 - 4.0	6.7	0.003	0.0000	0.04	0.2

Monitoring Results

- Data collected for CD-P82 is consistent with the spring infiltration data for 1999 presented in the IMS Phase II Report, 2000.
- Snowmelt infiltration rates ranged from 0.34 inches/hour to 0.04 inches/hour over a 4.7-foot range in depth.
- The bottom 7.4 feet of the basin consists of a small depression that often contains standing water. Above this depth, gradual slopes extend out and the area is typically dry and used for agricultural purposes.

CD-P85 – Regional Infiltration Basin

Infiltration Rates

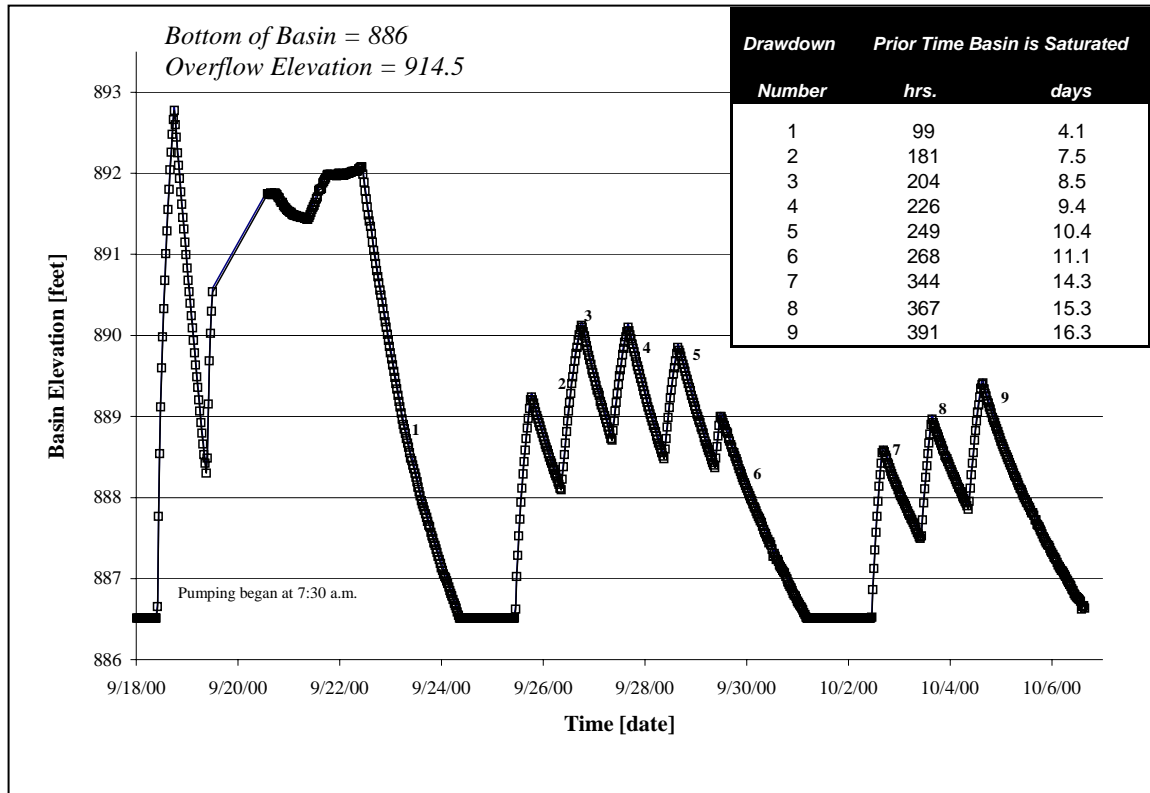
The monitoring data gathered in 2000 includes data from the September 2000 pumping event. Data collected during this event represents the infiltration capacity of the basin after one year with improvements. These improvements, infiltration tubes and infiltration trenches, are presented in detail in both of the Infiltration Management Studies (Phase I and II). A complete description of background information on CD-P85 is provided in the Infiltration Management Study (IMS) reports (Phase I and II).

On September 18, 2000, the City of Woodbury began pumping water from South Bailey Lake into regional infiltration basin CD-P85. Water levels in the basin were recorded with a pressure transducer located in the southern portion of the basin. The pressure transducer was installed before the pumping event began. Staff gauge readings were taken as often as possible to verify the datalogger readings. Figure III-5 represents the water levels in CD-P85 over the course of the pumping event. As Figure III-5 illustrates, the pumps were turned on and off each weekday for a period of approximately two weeks resulting in a total of nine recession curves over the entire pumping event.

The data collected during the September 2000 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 during the course of the event. This adjustment

was performed by adjusting the receding portions of the curve to datum elevations using water levels measured on a staff gage in the field.

Figure III-5. Depth vs. Time at CD-P85 for September 2000 Pumping Event



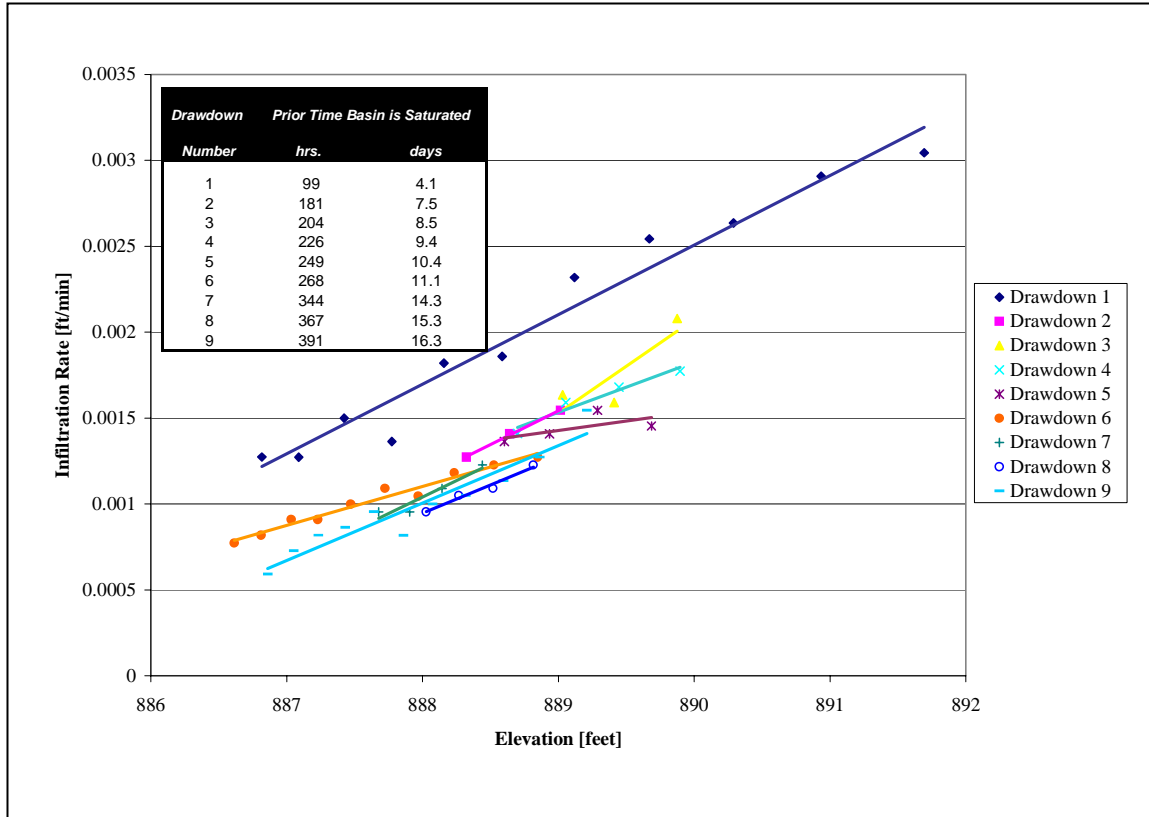
Infiltration rates for the September 2000 event were determined by calculating the slope of the depth vs. time curve (Figure III-5) averaged over a four hour time period for the corresponding elevation intervals. The slope ($\Delta \text{Depth} / \Delta \text{Time}$) is equivalent to the overall basin 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 nine recession curves (identified in Figure III-5) to compare the change in infiltration rates over the 16-day pumping event. The results of this analysis are presented in Table III-5. The data points plotted in Figure III-6 represent the 4-hour average infiltration rates at various elevations for all nine drawdowns and the data points plotted in Figure III-7 represent the 4-hour average volumetric infiltration rates for all nine drawdowns. In both figures, all nine drawdowns were fit with a linear trendline to establish a "best-fit" line. To gain a better understanding of how the basin reacts to being

saturated over time, tables showing the amount of time the basin was saturated before each drawdown begins are also included in Figures III-5 thru III-9.

Table III-5. Infiltration Rates and Volumetric Flow Rates for CD-P85 (September 2000 Pumping Event)

Basin Elevation	Average Area	Drawdown 1 Infiltration Rate			Drawdown 1 Volumetric Infiltration Rate	Drawdown 9 Infiltration Rate			Drawdown 9 Volumetric Infiltration Rate
		[ft/hr]	[ft/min]	[inch/hr]		[ft/hr]	[ft/min]	[inch/hr]	
[feet]	[acre]	[ft/hr]	[ft/min]	[inch/hr]	[cfs]	[ft/hr]	[ft/min]	[inch/hr]	[cfs]
892.0	8.9	0.183	0.0030	2.19	19.38	-	-	-	-
891.5	7.9	0.175	0.0029	2.09	16.63	-	-	-	-
891.0	7.2	0.158	0.0026	1.90	13.59	-	-	-	-
890.5	6.4	0.157	0.0025	1.83	11.62	-	-	-	-
890.0	5.7	0.139	0.0023	1.67	9.52	-	-	-	-
889.5	4.7	0.123	0.0021	1.48	7.17	-	-	-	-
889.0	4.1	0.112	0.0019	1.34	5.66	0.085	0.0014	1.01	4.22
888.5	3.4	0.109	0.0018	1.31	4.44	0.068	0.0011	0.82	2.80
888.0	2.9	0.082	0.0014	0.98	2.95	0.060	0.0010	0.72	2.11
887.5	2.2	0.090	0.0015	1.08	2.40	0.057	0.0010	0.69	1.52
887.0	1.8	0.076	0.0013	0.92	1.70	0.044	0.0007	0.52	0.96
886.5	1.4	0.076	0.0013	0.92	1.32	-	-	-	-

Figure III-6. Infiltration Rate Curves for September 2000 Pumping Event for CD-P85



As Figures III-6 and III-7 illustrate, the infiltration rates for the September 2000 pumping event fit within a range. This range is bracketed by the infiltration rates exhibited for the first drawdown event (Drawdown 1) and the infiltration rates exhibited by the last drawdown event (Drawdown 9). To simplify the discussion of this infiltration rate analysis, this range of infiltration rates will be referred to 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 infiltration rate envelope.

Figure III-7. Volumetric Infiltration Rate Curves for September 2000 Pumping Event for CD-P85

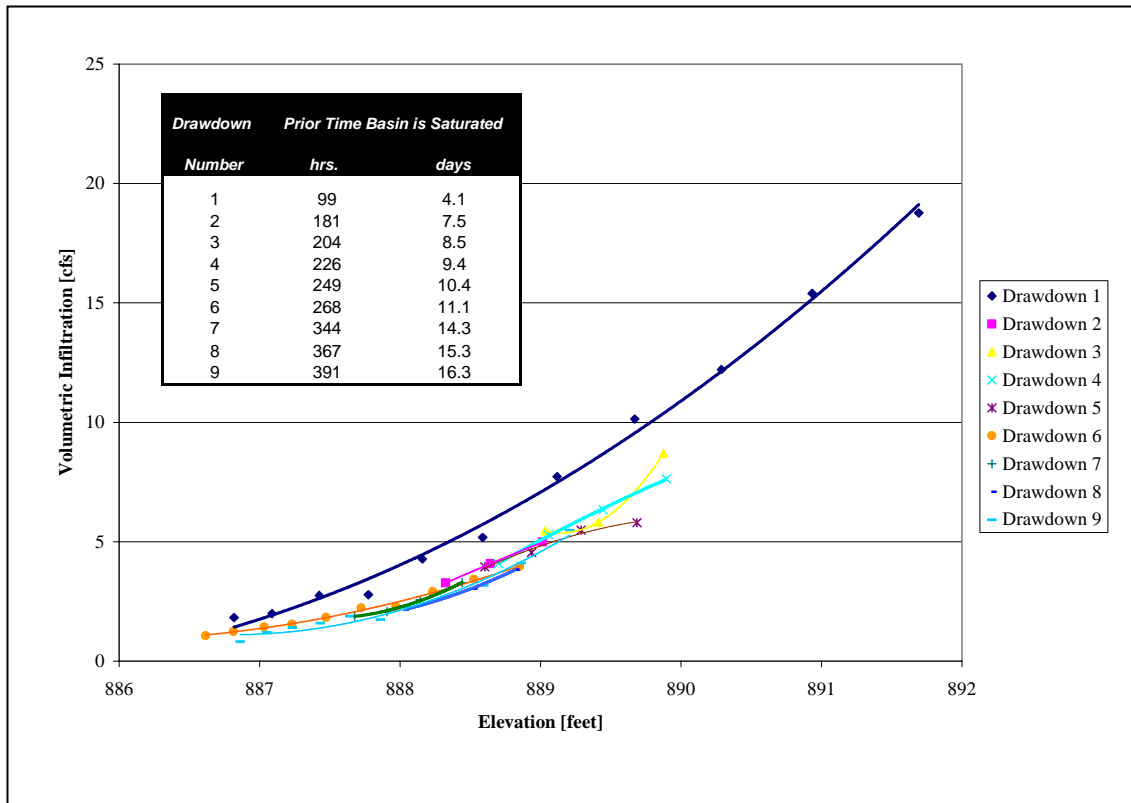


Figure III-8. Infiltration Rate Envelope for September 2000 Pumping Event for CD-P85

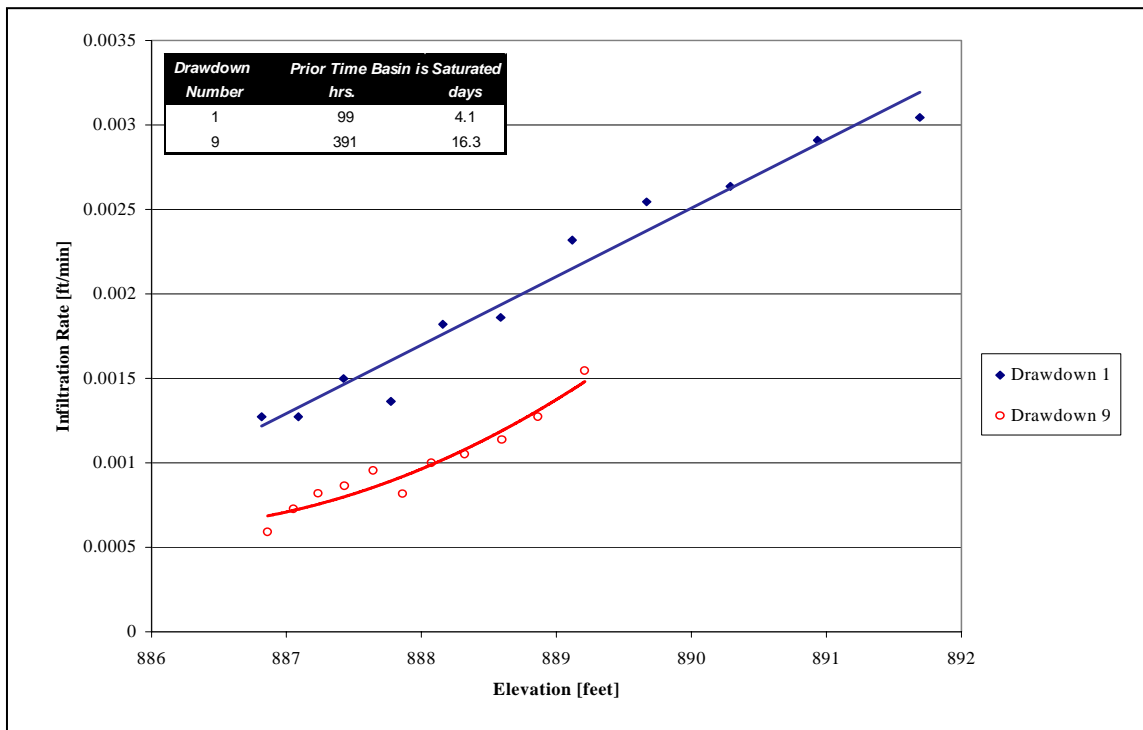
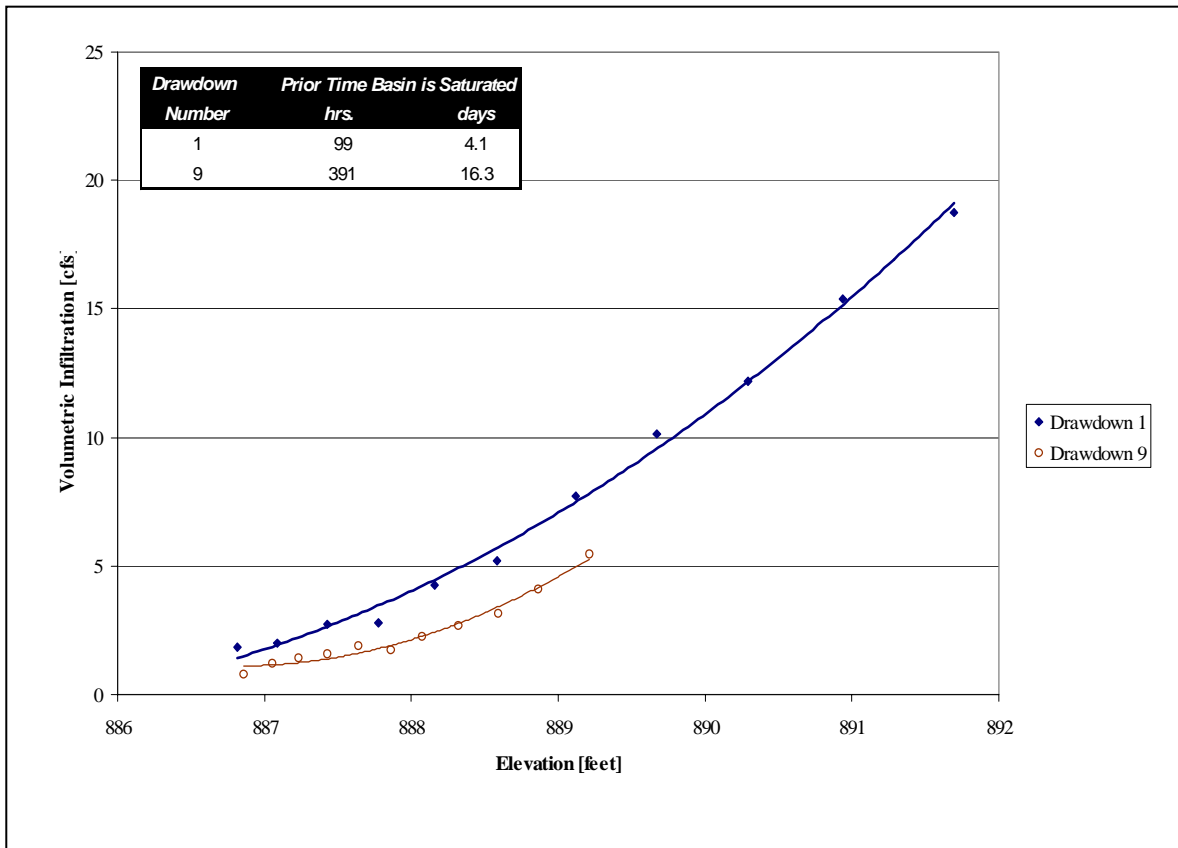


Figure III-9. Volumetric Infiltration Rate Envelope for September 2000 Pumping Event for CD-P85



Monitoring Results

- The maximum depth of water measured in the basin for the September 2000 event was 5.5 feet (compared to the total potential depth of 27 feet) and the corresponding infiltration rate at this depth was 2.19 inches per hour corresponding to a volumetric infiltration rate of 19.38 cfs.
- The infiltration event lasted approximately 18 days and included nine drawdowns over that time period.
- The average percent change in infiltration rates from Drawdown 1 to Drawdown 9 is a 33.2% decrease and the percent change in volumetric infiltration rates from Drawdown 1 to Drawdown 9 is a 32.3 % decrease.
- The highest infiltration rates were exhibited on the Drawdown 1. The pumps had been pumping water into CD-P85 for 4 days prior to calculating these rates, therefore higher rates could have been present for the first 4 days.

- Infiltration rates decreased over the course of the pumping event. The greatest decrease occurred within the first few days as evidenced by comparing the rates calculated for the first and second drawdown.
- Infiltration rates stabilized near the sixth drawdown. Infiltration rates calculated for Drawdown 6, 7, 8, and 9 probably represent a steady-state for the system until or unless another constraining factor, such as groundwater mounding or soil clogging, were to occur. Based on theoretical groundwater modeling, groundwater mounding may not be the limiting factor in the system.
- Note that after the 4.1-day prior saturation curve (Drawdown 1), the subsequent drawdown curves (from 7.5 days to 16.3 days prior saturation) do not vary from each other very much. This indicates that, at least for pulsed delivery of water, once a “fully saturated” condition is established (between 4.1 and 7.5 days) the changes in infiltration rates are small. Further, it appears the infiltration rates are fairly sustainable over at least a 16-day period. Without a pulsed delivery of water with intermediate unsaturated periods (even if brief), the sustained infiltration rates may or may not be attained.

IV. Discussion of Snowmelt 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 typically 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 to it. The assumption in traditional modeling is full delivery of the design event, 7.2 inches per unit area, in the southeast metro 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 to the depressions under study have not been refined.

The topography and landforms of the South Washington Watershed consist of many deep natural basins. Most of the closed or landlocked 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 resulting in their well-drained condition. 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 as part of an on-going monitoring effort.

Winter and Spring Climatic Data For 2000

An analysis of the average monthly temperature records for December through March measured at the Minneapolis/St. Paul Airport in Figure IV-1 shows that the average temperatures for 2000 are above the long-term average for that weather station. This information is provided in order to draw conclusions about the spring snowmelt event as well as the infiltration capacity and conditions of the soils. Figure IV-1 compares the average monthly temperature for 2000 to the average monthly temperatures for the last 50 years. The temperature for the December-March time period was 29 percent above average for the last 50 years with the month of March having the highest deviation from the average.

Figure IV-1. Average Monthly Temperature at Minneapolis/St. Paul Airport for 2000

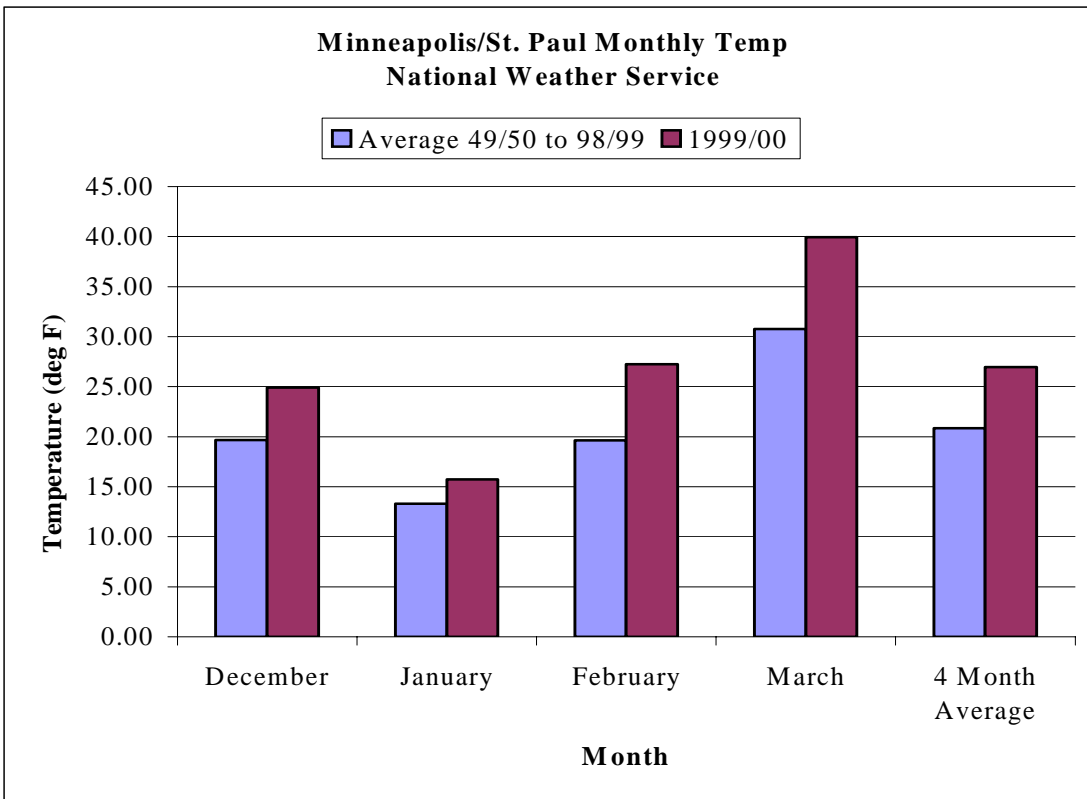


Figure IV-2 shows average total snowfall at the Minneapolis/St. Paul Airport. The graph compares the monthly snowfall for 2000 to the average monthly snowfall over the last 50 years. The average total snowfall for 2000 was fifteen percent below the average for the last 50 years. January received the largest amount of snow for the 1999-2000 season. Average daily temperatures and average snow depth are shown in Figure III-13 for December 1999 through March 2000.

An analysis of the graphs indicates that the volume of snowmelt for the 1999-2000 season was distributed into two separate snowmelt events. The snow pack melted by late February due to above average temperatures and was monitored in CD-P69, CD-P50, CD-P76, and CD-P82. Any snowfall in March melted by mid-March and was monitored in all of the basins.

Figure IV-2. Snowfall at Minneapolis/St. Paul Airport for 1999/2000

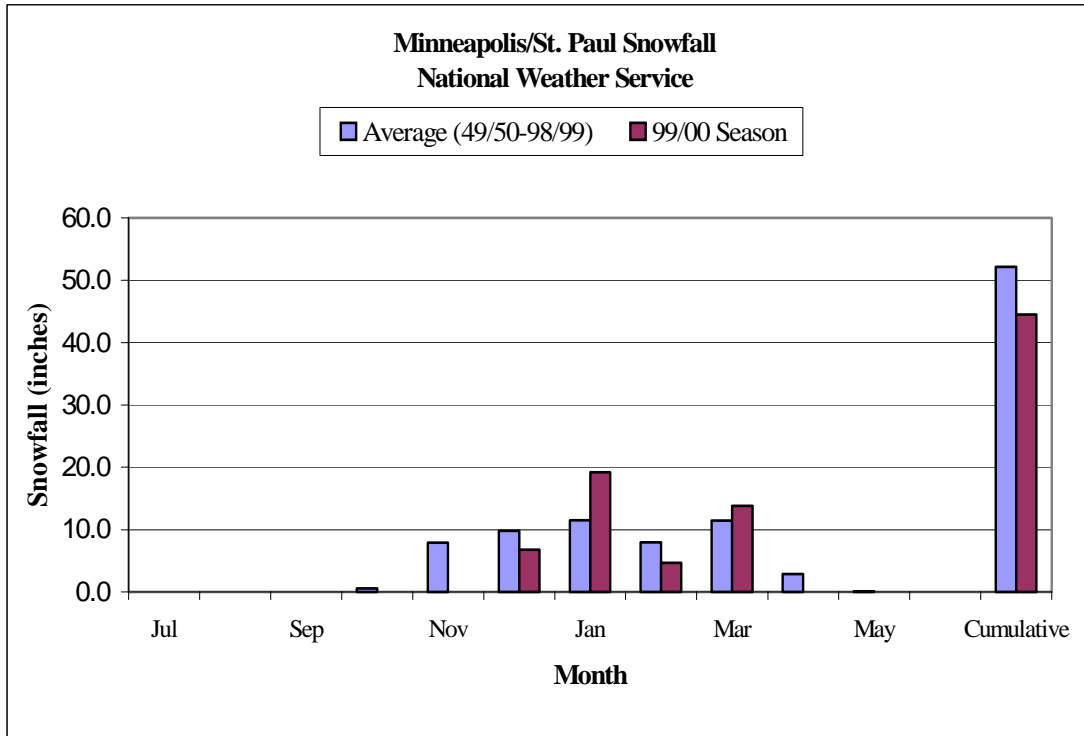
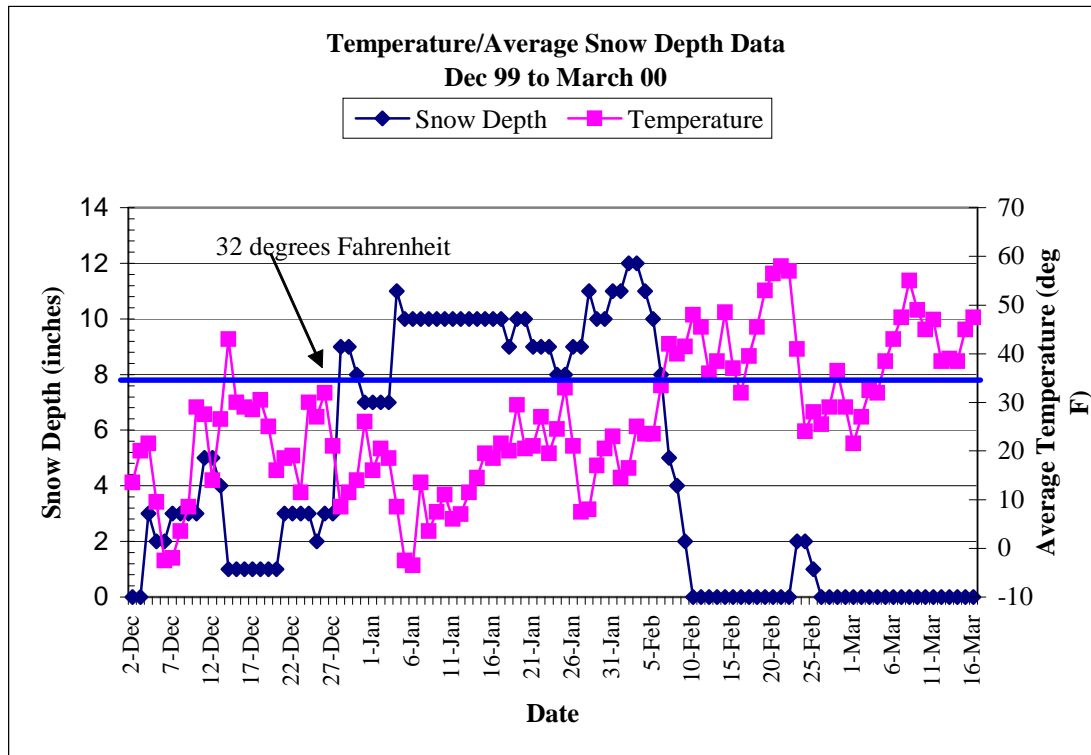


Figure IV-3. Daily Temperature and Precipitation at Minneapolis/St. Paul Airport for 1999/2000



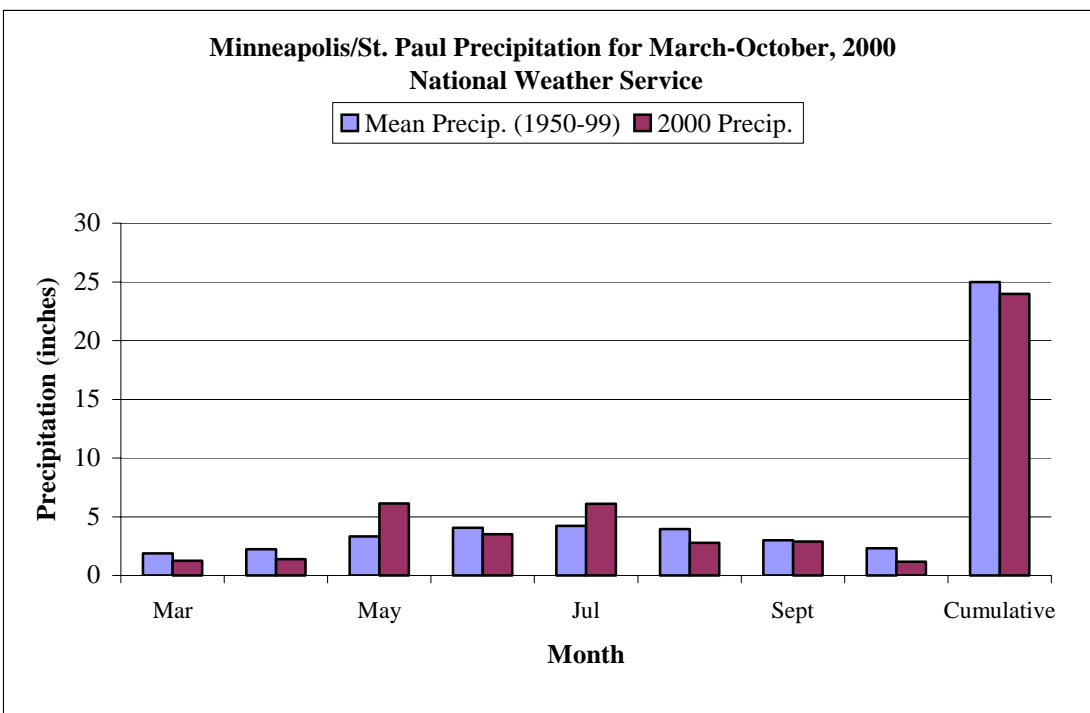
Snowmelt Infiltration Events

Although the metro-area experienced below average snowfall and above average temperatures, the results of the 2000 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 of frost depth, soil moisture, and temperature in the soil will be 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 October of 2000 was slightly below average.

Figure IV-4. Precipitation for Minneapolis/St. Paul Airport for March-October 2000



This graph compares the total monthly precipitation for 2000 to the average monthly precipitation for the last 50 years. Total precipitation for the months of March through October of 2000 was 2 percent below the average for the last 50 years. There was no sustained pond water in CD-P50, CD-P76, and CD-P82 for 2000. However, CD-P69, a regional stormwater

pond subject to multiple inputs from numerous residential areas, did have standing water after June 30, 2000.

As a result of these conditions, 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, 1998, 1999, and 2000 provides the most complete infiltration rates measured under summer conditions in regional basins. CD-P85 has also experienced several improvements to enhance its infiltration capacity over those years. Basin CD-P69 data is also valuable but the record is not as long or as complete as the data set for CD-P85.

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

APPENDIX B

PHOTO LOG



CD-P50: 2-25-2000



CD-P50: 3-03-2000







CD-P69: 2-23-2000



CD-P69: 2-25-2000



CD-P69: 2-28-2000



CD-P69: 3-01-2000





CD-P76 – 2/23/00



CD-P76 – 2/25/00



CD-P76 – 2/28/00



CD-P76 – 2/29/00









CD-P82 – 3/24/00



CD-P82 – 3/30/00



CD-P85: 9-14-2000



CD-P85: 9-19-2000



