Cleveland and Randolph Area Groundwater Study

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Prepared for:

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1.0 Introduction

Numerous City of St. Paul property owners within the Cleveland-Randolph Groundwater Study Area (see Figure 1.1), routinely experience high groundwater issues at their properties. This condition has resulted in reports of wet basements, constantly running sump pumps, property damage, and infrastructure (street and utility) damage.

The Capitol Region Watershed District (CRWD) adopted rules in 2006 that require developments to control the runoff volume from a one-inch storm on their property. Most commonly, volume control practices using infiltration satisfy this requirement. However, recent developments by the University of St. Catherine's and the Sisters of St. Joseph of Carondelet prompted the City of St. Paul to alert the CRWD of the groundwater problem and the possibility that additional infiltration in this area could increase the groundwater level and worsen the reported high water issues. The CRWD subsequently approved the proposed developments with minor amounts of infiltration (filtration was primarily used) because they did not want to exacerbate existing problems.

The CRWD, in partnership with the City of St. Paul, initiated a study of the groundwater conditions in the area near Cleveland and Randolph Avenues (Study area). This report presents the results of the study.

Goals of the Study

The following goals were established for the Cleveland and Randolph Groundwater Study (CRGS):

1. **Document/understand the scope of high groundwater levels.** Property owners, public works departments, and local institutions in the area have a significant amount of anecdotal evidence of high groundwater, but the area has never been specifically identified. Therefore, the first priority is to understand where high groundwater levels are a nuisance to property owners and may affect streets and utilities.

2. **Identify areas unsuitable for infiltration.** Future development or redevelopment within the sub-watershed will happen and will be subject to the CRWD volume control standard. Therefore, the CRGS will help the CRWD staff and permit applicants identify where infiltration practices are not recommended due to a potential to worsen current areas of high groundwater or to create new high groundwater concerns.

3. **Develop management options for existing conditions and future development.** The CRGS will identify alternatives to mitigate or partially mitigate the existing high groundwater levels. This may include a solution at one location or a list of solutions applicable to existing conditions and/or future development or redevelopment in the sub-watershed. Possible solutions will consider the potential negative effects on properties if groundwater levels were to recede.

2.0 Field Work

2.1 PIEZOMETER INSTALLATIONS

Twelve piezometers were installed across the Study area to enable measurement of groundwater elevations. Figure 2.1 shows the locations of the piezometers (labeled PZ-“X”). In addition, three monitoring wells from a previous investigation in the area of Fairview Avenue and Randolph were also available (labeled MW-“X”).

The piezometers were constructed with one-inch diameter PVC casings and five or ten-foot PVC well screens. The piezometers were installed using direct-push drilling technology. At each location core samples were collected prior to installing the well casing to identify the soil types and determine the depth to the water bearing soils. Appendix A contains the logs of the soil conditions and piezometer construction details.

In general, soils within the Study area consist of silty sands, silts, and clay (glacial till). Occasional gravel seams were encountered. Groundwater was generally found in sand seams at various depths across the site. Peat was found at PZ-6, indicating the historical presence of wetlands in this area. The soils are consistent with the glacial and alluvial origins of the landforms in the area. The western portion of the Study area, below approximately 890 feet above Mean Sea Level (AMSL), is an ancestral river terrace and the presence of peat and sands are consistent with alluvial and lacustrine terrace deposits. The Historic Water Features Map in Appendix E also identifies some of the streams and wetlands that existed near the study area prior to development.

Groundwater was found within the glacial and terrace soils across the site. In general, water bearing permeable seams of sand or gravel were encountered within the less permeable clay tills.

At location PZ-7, in the north east portion of the Study area, three piezometers were installed at different depths (PZ-7a, PZ-7b and PZ-7c) to more accurately determine where the water bearing zone was located. PZ-7b has always been dry (see discussion in 3.1).

Bedrock (Platteville limestone) was reached at piezometer locations PZ-2 and PZ-5. Both of these locations are on the ancestral river terrace where bedrock is closer to the surface. Groundwater was found perched at the bedrock surface at these two borings. It appeared that just west of this area there was no longer groundwater in the soils above the bedrock, suggesting the perched water table has entirely entered the Platteville in the western portion of the Study area.

2.2 GROUNDWATER LEVEL MEASUREMENTS

The piezometer elevations were surveyed to a common benchmark and water levels (depth to groundwater) were measured by both Wenck and CRWD staff approximately once a month from March to November 2009. Appendix B contains the groundwater elevation database and maps of the groundwater elevations.

2.3 BASEMENT CONDITIONS SURVEY

On September 23, 2009 CRWD staff sent a letter and survey card to all residents within the Study area. The letter notified residents of the new piezometers that were installed and asked a series of questions about experiences with water in their basements. A copy of the letter and survey are included in Appendix C.1. The letter invited interested parties to a public information meeting held on October 12, 2009. At this meeting CRWD and Wenck presented and took questions on the purpose of the study, progress at that time, and the reason for the survey.

Figure 2.2 shows the survey responses and Figure 2.3 shows those respondents who reported some degree of wet basement conditions.

2.4 BASEMENT ELEVATION SURVEY

On January 25, 2010, CRWD sent a second mailing to those residents who reported wet basements and were willing to participate in a basement elevation survey. A copy of the mailing is included in Appendix C.2. Approximately 40 residents agreed to assist the Study by measuring the depth of their basement floor slab to an agreed upon benchmark (a window sill). Appendix C.3 presents a tabular summary of the survey responders. Only addresses are given for reasons of privacy. Survey response cards are on-file at the CRWD offices. Wenck personnel then completed GPS surveys of the outside of the homes using the same benchmarks as the residents. This allowed the elevation of the basement floors to be calculated as shown on Figure 2.4.

3.0 Study Results

3.1 HYDROGEOLOGIC SETTING

The Study area is located in a fully developed urban area of St. Paul. Homes in the area typically date to the early 20th century. The drainage in the area is controlled by storm sewers that discharge to the Mississippi River gorge to the west. The study area lies approximately between 850 and 960 feet above mean sea level (AMSL). The topography slopes to the west. The Mississippi River is at approximately 725 AMSL in an 80 to 100-foot deep gorge.

Figure 3.1 is a portion of the Ramsey County water atlas showing the Study area, model domain (discussed in section 4) and regional groundwater contours. The Study area is on a plateau surrounded on the west, south and east by a large bend in the Mississippi River (River). The plateau contains a groundwater divide that runs northeast-southwest along the center of the plateau. Groundwater on either side of the divide flows toward the respective arm of the River bend. Seeps along the River gorge reflect where shallow groundwater discharges to the surface and subsequently to the River. For the purpose of modeling, this allows us to assume that the only source of groundwater within the study is from precipitation.

Shallow groundwater occurs in glacial till (moraine) and outwash soils that cover the area. Closer to the River, approximately below elevation 890, are post-glacial alluvial terrace deposits from the period when the river was at a much higher elevation. The western half of the Study area appears to be on an ancestral terrace, evidenced by a topographic break in slope around Bayard Avenue and Howell Street and extending to the northwest (see topographic contours on Figure 3.2) and by the peat and alluvial soils found in the core sample at PZ-6.

Bedrock is the Platteville Limestone, a horizontally bedded, highly fractured shaley limestone, which is visible in outcrops in the River gorge. The shallow groundwater enters the bedrock via fractures as it moves toward the River and exits in seeps as described above. Some of these seeps occur in other areas throughout the District. Appendix E contains historic and existing springs identified by Greg Brick. These springs occur when the groundwater elevation and surface elevation intersect. The Dew Drop Pond is identified as one such spring. Observations by one resident suggest there is a constant flow of water in the underground pipes leading to the pond and exiting the pond to the municipal storm sewer. This serves as an outlet for groundwater to leave the shallow aquifer. There is also a deeper water table in the bedrock that occurs roughly at the elevation of the River.

Figure 3.2 shows the alignment of a hydrogeologic cross-section through the Study area roughly parallel to the groundwater flow. Figure 3.3 shows the cross section. The cross-section shows the general slope of the ground surface to the west. The water table is also shown on the cross-section and follows surface topography and drainage. The slope of the water table steepens between PZ-4 and PZ-2, in the area which is interpreted as a drop in the bedrock surface. This is where the ground surface drops from the upper glacial till soils to the terrace deposits. At the nested Piezometer PZ-7a, -7b, and -7c the water table makes a slight drop causing PZ-7b to be dry.

Because of the configuration of the groundwater divide, shown on Figure 3.1, it is evident that the only source of shallow groundwater in the Study area is infiltrating precipitation. There are no upland streams or other bodies of water, for example, contributing to the perched aquifer. The Dew Drop Pond acts as a surface basin for stormwater runoff and campus building foundation drainage systems. Therefore, the pond does not act as a source of groundwater, but may cause some lateral shift in groundwater mounding from the east, towards the river. Infiltration on the plateau forms a shallow perched aquifer in the glacial soils and flow follows the natural topography toward the River gorge.

The infiltration and ultimate seepage into the bedrock and River gorge are at equilibrium. Changing the infiltration rates or distribution, via constructing storm water infiltration projects, has the potential to change the equilibrium resulting in an increase in groundwater levels. This observation formed the conceptual basis for understanding the groundwater flow system and setting up the computer model discussed in section 4.

3.2 WATER TABLE MAPPING

The water level measurements collected by CRWD and Wenck were plotted as elevations to map the water table surface and determine the groundwater flow direction and gradients. Figure 3.4 shows the May 2009 contours, which were typical of most measurements. Flow is to the west, consistent with the regional flow patterns discussed earlier. The horizontal gradient steepens in the center of the Study area (shown as closer contour lines). This steepening corresponds to a topographic break in slope onto the terrace deposits to the west. This also appears to reflect a drop in the bedrock surface (likely an erosion feature in the bedrock surface) and is also the area where groundwater is closest to the ground surface.

Figure 3.5 shows the depth to groundwater below the ground surface. The area where groundwater is shallowest (less than 10 feet deep) is highlighted. The area of shallow groundwater largely parallels the break in slope between the till and the terrace deposits discussed above. This is the area where infiltration is most likely to cause a rise in the water table that could lead to, or worsen, wet basement issues.

Appendix B contains a series of maps showing groundwater elevation and depth to groundwater at various times.

Figure 3.6 shows the water elevations at the piezometers with the precipitation records for the same period. There was little change observed between readings or seasonally. This suggests the equilibrium between precipitation and the groundwater is stable. It should be noted that both

2008 and 2009 were drier than average years (according to University of Minnesota climate data). It is possible that groundwater levels fluctuate annually based on precipitation amounts. Long term monitoring is needed to assess how annual fluctuations in precipitation may affect groundwater levels.

3.3 BASEMENT ELEVATION SURVEY

Figure 3.7 shows the results of the basement elevation survey superimposed on the groundwater contour map. Basements within approximately five feet of the groundwater are highlighted. These highlighted areas are the most sensitive to storm water infiltration in the area. This evaluation indicates that most basements, those outside of the shaded area on Figure 3.7, are likely above the stable shallow water table.

The basement elevation evaluation helps distinguish areas with wet basements that are related to a high water table from areas where the wet basements are due to conditions other than stable high groundwater. The purpose is to identify those basements that are at or near the water table and therefore susceptible to increases in storm water infiltration.

Based on the survey it appears that most of the reported wet basements are located physically above the water table. This suggests that most are more likely to have wetness issues due to local drainage and soil conditions, such as poor local soil drainage or poorly controlled surface drainage. It is beyond the scope of this study to diagnose the cause of each wet basement issue. However, the piezometer borings indicated a mix of clays and sand that are likely prone to creating and holding local perched water that may exist during wet periods. The presence of peat at one boring shows that at least some of the area was historically wetland. Some anecdotal reports from residents also support the presence of wetlands prior to development.

In addition to the overall poor soil drainage the individual problems may be exacerbated by lots sloping inward, rain gutters discharging too close to the foundation, poor foundation drainage, or winter clogging of frozen storm drain inlets creating ponded water. Some residents on Bayard Avenue near the St. Catherine's campus have observed stormwater bypassing drain inlets due to inconsistent structure and ground elevations. The occurrence of wet basements from these types of situations would likely increase during years in which large rainfall events were more frequent. Addressing these issues would require property-specific evaluations to identify a solution to improve drainage while not causing settlement or other foundation issues.

4.0 Groundwater Modeling

A groundwater model was run as an aid to understanding how future stormwater infiltration projects may affect the observed wet basement issues in the area. The model used was Multi-Layer Analytic Element Model (MLAEM), 1998, developed by Dr. Otto Strack of the University of Minnesota. The model provides a reasonable approximation of the future conditions based on the available input knowledge. For the purposes of this study a number of simplifying assumptions were made regarding the geologic structure and groundwater flux. For example, one parameter that was not defined in the model was the effect of individual sump pumps on the groundwater elevation. The model set up and simulation results are discussed below.

4.1 MODEL DOMAIN SET UP

MLAEM is an analytic element model that solves the groundwater flow equations directly based on the geometry and properties of prescribed "elements" within the model domain. Figure 4.1 shows the model domain selected for the model superimposed on the hydrogeologic atlas map for the area. The domain was selected to match known hydrogeologic features in the area. The east boundary is the groundwater divide in the center of the plateau. The north and south boundaries are along flow lines. The west boundary is the area where groundwater appears to enter the bedrock. Since the domain is bounded by groundwater divide and natural flow lines, we were able to assume that all water flowing in the aquifer was the result of infiltration within the domain. That is, there is no groundwater entering the area from outside sources.

To reflect the geologic structure of the aquifer, three elevations were established for the bedrock surface, which forms the base of the model. The basis was a combination of soil borings and background knowledge of the area. The base of the eastern portion of the domain was set at 890 feet AMSL. The area at the break in slope down to the terrace deposits was set at 860 feet AMSL and the western area was set at 845 feet AMSL. Since the model is inherently infinite in extent, the elements were established approximately twice the size of the domain as shown in Figure 4.1. By making the elements large, any spurious effects around the edges of the element blocks become insignificant in the central area of interest.

To estimate the infiltration rate into the Study area, GIS land cover information was reviewed (Appendix D.1). The total domain is approximately 779 acres in size. Of this, approximately 308 acres are pervious surfaces. We assumed all precipitation on impervious surfaces is carried out of the area via storm sewers. Of the annual average precipitation of 29 inches, we calculated that 24 inches is removed via runoff through the storm sewers and evapo-transpiration, based on the soil types and land cover. The remaining 5 inches of precipitation results in 123.2 acre-feet of annual infiltration, or 14,700 cubic feet per day. This was interpreted to be the total groundwater flux through the domain.

The model is a “steady state” model meaning that the infiltration rates are assumed to be constant over time and the system eventually reaches equilibrium. There is insufficient data to support a “transient” model where, for example, individual storm events could be modeled.

The model was run through a series of trial and error simulations where the background hydraulic gradient and aquifer hydraulic conductivity were varied in an attempt to match the hydraulic gradient and flow pattern measured in the field. At the same time, the groundwater flux through the domain was checked against the estimated infiltration into the domain. Calibration of the model was considered to be successful when the gradients and flux were similar to the field estimates.

The actual heads in the aquifer were considered secondary to the flux and gradient since the result of interest is the difference in head between ambient conditions and the simulated storm water ponds. Because the interest is in the difference in head, the absolute head is not as crucial as the overall groundwater flux.

Once satisfactory results were obtained for the ambient conditions, a series of simulations were run to evaluate representative infiltration projects in the area. Appendix D.1 contains print outs of the data files created as input for the model. These data files can be used with the MLAEM software to re-create the simulations discussed below.

4.2 AMBIENT GROUNDWATER FLOW SIMULATION RESULTS

Figure 4.2 shows the groundwater elevation contours for the ambient condition simulations. The flow pattern and gradient generally match the field measurements shown in Figure 3.4 and Appendix B. The hydraulic conductivity of the aquifer arrived at through the trial and error process in this simulation is 10 feet/day (typical value for silty sands). The groundwater flux across the domain is 13,000 to 15,000 ft^3/day which agrees well with the estimated infiltration rate of 14,700 ft^3/day.

Given the available data, this aquifer configuration was considered accurately calibrated for the purpose of running representative simulations of storm water infiltration in the area.

4.3 REPRESENTATIVE INFILTRATION SCENARIOS

After establishing the groundwater model for existing conditions, Wenck created a future conditions groundwater model to estimate the impact of future infiltration scenarios on groundwater levels. Wenck and CRWD staff identified eight potential projects (Table 4.1) in the study area that would likely require a CRWD permit, and thereby, likely infiltrate storm water runoff. These projects represent the types of projects that could be contemplated in the Study area. These are only meant to be representative for purposes of running the model and gaining an understanding of the relative effect actual projects could have on the groundwater system.

Table 4.1. Representative Infiltration Projects

Project ID	Project Name	Area of Disturbance (ac)	Impervious Area (ac)	Volume Infiltrated (acre-ft / yr)
1	St. Paul Academy – Juno Block Redevelopment	3.9	3.5	6.7
2	Sisters of St. Joseph – 2009 Expansion Project	7.37	3.8	7.2
3	2010 RSVP – Fairview to Snelling, St. Clair to Jefferson	4.2	4.2	8.0
4	2011 RSVP – Fairview to Snelling, Jefferson to Randolph	6.9	6.9	13
5	Park at Macalester & Palace	1.9	1.7	3.2
6	Southeast Corner of St. Catherine's	1.8	1.8	3.5
7	Northwest Corner of St. Catherine's	6.3	5.0	9.5
8	St. Catherine's 2006 South Campus Addition	Not Permitted by CRWD	1.8	3.5

Project 2 was approved with filtration practices (no stormwater runoff enters the ground) because of poor soils in the area of the project and Project 8 was not required to comply with CRWD volume reduction standards because it was constructed before CRWD adopted Rules. For this study, however, Wenck assumed that infiltration practices were constructed for each of these projects in order to predict the effect on groundwater levels.

The other six future projects were chosen based on the best-available information to Wenck and CRWD staff. The City of St. Paul provided information for two residential street reconstruction projects planned for 2010 and 2011 (Projects 3 and 4). CRWD attempted to contact St. Paul Academy and the University of St. Catherine's, but received no response in terms of future projects that may require a CRWD permit. Therefore, the remaining four projects were selected by Wenck and CRWD staff and are estimates of future development for use in the groundwater model. The four selected projects do not reflect proposed projects by the land owners.

4.4 SIMULATION RESULTS

To simplify these scenarios for modeling, each was simulated as a circular pond with areas based on the amount of impervious surface and the corresponding volume reduction requirements shown in column 4 of table 4.1 and an average annual infiltration rate shown in column 5. Figure 4.3 shows the simulated pond locations. Since the only source of water in the Study area is precipitation, conceptually the water added to the ponds can be considered to be from water that presently is removed by the storm sewer system.

Appendix D.2 contains the results of each of the eight simulations. Each is labeled by the pond number in Figure 4.3. For each simulation the difference in water level between the ambient simulation and the given pond simulation were plotted in increments of 0.25 feet. Each plot therefore shows only the groundwater mound (i.e. the difference in head between Figure 4.2 and the Simulation) formed by each simulated pond.

In general the height of the groundwater mounds was up to 1.5 feet immediately around the higher rate ponds (Pond 1, Pond 2, Pond 4, and Pond 7) with mounds extending several hundred feet radially around the ponds. Mounding heights are plotted on the figures out to 0.25 feet. Mounds of less than one-foot formed under the lower rate ponds (Pond 3, Pond 5 and Pond 6).

Figure 4.4 shows a composite of the 0.5-foot groundwater mound radius for all eight ponds. This figure is not a simulation of all the ponds operating together, but is meant to give the reader one figure to compare the eight simulations. This figure gives a sense of the radius of influence these representative ponds would create.

The worst-case groundwater mounds were on the order of 1.5 feet above ambient groundwater levels. This indicates that storm water infiltration ponds in the range of the eight simulations are of concern for nearby basements currently within 1.5 feet of the water table. In areas where the basements are many feet above the water table, these types of ponds would not be expected to cause wet basement conditions.

5.0 Conclusions and Recommended Stormwater Management Options

Based on these evaluations Wenck makes the following conclusions:

1. The water table in the Study area is seasonally stable and at equilibrium with the infiltration in the area. Long term monitoring could provide additional information regarding annual fluctuations due to wet or dry years.

2. The local aquifer is perched within the glacial and alluvial sediments deposited on the plateau surrounded by the large bend in the Mississippi River.

3. The only source of water to the perched aquifer is infiltration. The aquifer discharges to seeps along the bluffs of the Mississippi River.

4. There is an area of shallow groundwater along the break in slope running roughly from the vicinity of Bayard Avenue and Prior northwest to Randolph and Cleveland avenues. This area appears related to the step in the bedrock surface and transition from the glacial till to the east and the terrace deposits to the west. Many of the reported wet basements appear to be related to this feature.

5. Simulations of storm water infiltration suggest groundwater level increases of up to 1.5 feet immediately around the larger ponds simulated. Allowing a safety factor of 3 on this estimate, suggests storm water should not be infiltrated near areas where basements are within 4.5 feet of the water table.

6. The widespread presence of wet basements well above the saturated water table indicates the soils have poor drainage in general across the study area. These observations indicate there are zones of perched water within the glacially derived and largely clayey soils observed in the borings. These perched areas do not appear to be contiguous given the wide range of basement elevations measured.

Based on these evaluations Wenck makes the following recommendations:

1. Figure 5.1 shows the recommended area, within the Study area, where infiltration should not be used for storm water management. This area represents an approximately 500 foot buffer around the area where basements were found to be sensitive to groundwater levels. Future projects inside the buffer should follow the Alternative Compliance portion of the CRWD rules. This would involve using various filtration technologies (e.g. rain gardens with under drains) and discharge to the storm sewer to protect these areas from increased water levels.

2. Many of the reported wet basements are well above the water table. This suggests, in general, poor soil drainage and the presence of localized perched water. The soil borings support this interpretation. Decisions to place storm water infiltration structures near these homes should be evaluated during future planning and design stages.

3. Mitigation options for the wet basements issues depend on the specific relationship of the basements to the water table. The areas prone to wet basements due to high groundwater levels (shaded areas on Figure 3.7 and 5.1) may be amenable to localized subsurface drainage systems to reduce water levels. This could include a French drain along Bayard Avenue (between PZ-4 and PZ-2) to reduce the high water table in this area. The

system would collect groundwater and discharge to the storm sewer. The drain would create a cone of depression in the groundwater along Bayard Avenue. This would replicate the conditions that may have been present before the sanitary sewers were improved. The old sanitary sewers were not water tight and allowed seepage of groundwater into them and unnecessarily discharged the clean groundwater to the wastewater treatment plant The design of such a system would require testing and predesigned studies to determine the depth, length, estimated flow rate, area of influence, and capacity of existing storm drains to handle the additional flow. Geotechnical soil borings would also be advisable to determine if the soils, which have been historically saturated, are prone to excess settlement if they are dewatered. Implementing such a system would require an evaluation of the feasibility of construction and the cost-benefit of the project.

4. Basements that are clearly above the water table would require case-by-case evaluation to improve foundation drainage or surface drainage. In these cases, a geotechnical evaluation would be needed to design a solution and avoid foundation settlement. Since the widespread wet basements above the water table do not appear contiguous, a regional-scale solution is likely not feasible. However, based on some resident observations, storm drain inlet structures along the south property line of St. Catherine's should be inspected to ensure proper drainage.

5. Continued monitoring is recommended to provide data to determine the effects of annual variability in precipitation. In addition to periodic readings at the existing observation wells, a continuous level logger could be installed to assess how quickly changes in groundwater occur in reaction to rain events. There are also wells on the existing City of St. Paul Sewer easement that may be utilized to obtain additional data near the areas of high groundwater.

Closing Statement:

The findings contained in this report are intended to provide as much information regarding the groundwater conditions within the study area as possible based upon the data collected. The study was not intended (nor was it adequate) to be an assessment of any individual residence in the study area. The inclusions or exclusion of homes or properties within the high groundwater area does not guarantee that these properties will all experience similar conditions regarding wet basements.

The study recommendations are intended as guidance to help CRWD understand the hydrogeologic setting in regards to stormwater and groundwater management. All future projects should be evaluated individually based on the unique scope and site characteristics to ensure that water level and geotechnical problems are not created or exacerbated.