City of River Falls
North Kinnickinnic River Monitoring Project

2013 Report

Report prepared by SEH Inc., for the

City of River Falls Engineering Department
December 2013

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Project Introduction:

The Kinnickinnic River is one of the premier, naturally sustaining trout fisheries in the Upper Midwest, primarily producing brown trout. There has been a lot of concern about how new development in River Falls may affect the river, especially due to storm water runoff from impervious surfaces in these urbanizing areas. Not only can storm water runoff contribute chemicals from lawns, cars, etc., but the thermal impacts of untreated storm water are also a concern, as described on the North Kinnickinnic River Monitoring Project website (see "The Thermal Impact of Untreated Storm Water").

In 2002, the City adopted a new Storm Water Ordinance, which is designed to protect the Kinnickinnic River from the negative impacts of storm water runoff associated with new development. For new development and re-development projects, the City of River Falls Storm Water Management Ordinance requires that, for a 1.5-inch, 24-hour rainfall event, the post-development runoff volume and peak flow rate must not exceed the pre-development runoff volume and peak flow rate. To achieve this requirement, developers must provide on-site infiltration of storm water. Standards adopted under the ordinance require that a safety factor of two be used for designing infiltration areas. The result is that infiltration basins, at the time of acceptance by the City, will be able to infiltrate twice the additional runoff generated by a 1.5-inch rain event.

To take an active role in sustaining the river's health and well-being, the City of River Falls implemented the North Kinnickinnic River Monitoring Project in 2004. The goal of the project is to evaluate the effectiveness of our Storm Water Management Ordinance for preventing degradation of the Kinnickinnic River due to new City development. The project scope includes four primary monitoring elements:

- Temperature Monitoring
- Water Quality Monitoring
- Base Flow Surveys
- Macroinvertebrate Monitoring

The City is examining the long-term results of each of these four monitoring elements to determine whether the Storm Water Management Ordinance is protecting the river as new development occurs. The project uses an "upstream/downstream" approach to determine if storm water management practices in the Sterling Ponds subdivision protect downstream river conditions. We are also taking a focused look at the performance of the on-site storm water management practices that are incorporated into new developments. Our hope is that, due to the ordinance requirements, the thermal, water quality, water quantity, and biological impacts of new development will be undetectable or greatly reduced.

River Falls Precipitation:

Due to the major influence of precipitation on river flow, temperature, and water quality, an analysis of seasonal precipitation is conducted as a part of this project. Two rain gauges reside within or near the North Kinnickinnic River Monitoring Project Area.

The primary project rain gauge, operated by the City of River Falls, is an electronic tipping-bucket rain gauge that measures 15-minute precipitation amounts in 0.01-inch increments. This rain gauge is part of an Onset HOBO U30 Weather Station that began operating in December 2010. The weather station is located at the River Falls City Hall (222 Lewis Street), in relatively close proximity to all six North Kinnickinnic River monitoring stations. The City of River Falls weather station also serves as a source of 15-minute air temperature and relative humidity data, thereby allowing determination of daily mean, minimum, and maximum air temperatures in River Falls.

The secondary project rain gauge, operated by the United States Geological Survey (USGS), is located at the USGS Kinnickinnic River monitoring station (number 05342000) at County Highway F, near Kinnickinnic State Park, approximately five miles west of River Falls. The USGS gauge is an electronic tipping-bucket rain gauge that measures 15-minute precipitation amounts in 0.01-inch increments. Since the USGS rain gauge is five miles away from River Falls, it does not always accurately reflect rainfall in the North Kinnickinnic River Monitoring Project Area. This tends to be particularly true during larger, convective summer rain events, which can generate localized and quite variable rainfall patterns. Nonetheless, the USGS rain gauge generally provides a good estimate of rainfall in the project area.

In addition to measuring daily rainfall amounts, the City of River Falls and USGS rain gauges provide very helpful information on the timing and intensity of rain events.

Throughout the 2013 monitoring season, the City of River Falls rain gauge operated very reliably and generated all of the daily and 15-minute rainfall data used in this report. However, the USGS provided the daily rainfall data generated by the gauge at the Kinnickinnic River monitoring station, and these data are available upon request.

A total of 20.80 inches of precipitation was recorded in River Falls (by the City of River Falls weather station) during the April-September 2013 period, 0.89 inch less than the normal total of 21.69 inches for the April-September time period (Figure 1). For comparative purposes, April-September rainfall amounts for prior North Kinnickinnic River Monitoring Project years (2004-2012) are also presented in Figure 1. “Normal” monthly and seasonal rainfall amounts are based upon measurements made by the National Weather Service at the Twin Cites International Airport during the “climate normal period” of 1981-2010. Although slightly drier than normal, the April-September 2013 period (20.80 inches of rain) was the fourth-wettest April-September period since the start of the North Kinnickinnic River Monitoring Project in 2004. Since project monitoring began, seven monitoring years (2004, 2006, 2007, 2008, 2011, 2012, and 2013) have been drier than normal, while three monitoring years (2005, 2009, and 2010) have been wetter than normal.

Daily rainfall amounts during the April-September 2013 period are presented in Figure 2. Rain fell on 69 days, or 38% of the April-September 2013 period.

Monthly rainfall amounts during the April-September 2013 period, with a comparison to normal monthly rainfall amounts, are presented in Figure 3. April, May, and June were all much wetter than normal, with rainfall surpluses of 2.26 inches in April, 2.83 inches in May, and 1.98 inches in June. The combined rainfall of 17.34 inches in April, May, and June was 7.07 inches above normal, and accounted for 83% of the total April-September 2013 precipitation. In sharp contrast, July, August, and September were all much drier than normal, with rainfall deficits of 2.99 inches in July, 3.49 inches in August, and 1.48 inches in September. The combined rainfall of 3.46 inches in July, August, and September was 7.96 inches below normal, and accounted for only 17% of the total April-September 2013 precipitation. The largest rain events of the monitoring year occurred on June 21 (1.59 inches), and June 26 (2.31 inches) (Figure 2).

With an extremely dry September 2012, severe drought conditions (DSI = D2) were apparent in the North Kinnickinnic River Monitoring Project Area by mid-October 2012. These severe drought conditions persisted until mid-April 2013, when above-normal precipitation in April, May and June (Figure 3) brought drought conditions to an end. However, with much-reduced rainfall in July and August 2013 (Figure 3), abnormally dry conditions (DSI = D0) were again apparent in the North Kinnickinnic River Monitoring Project Area by mid-August 2013, and moderate drought conditions (DSI = D1) were evident by early September. With a much drier-than normal September 2013 (Figure 3), severe drought conditions (DSI = D2) re-developed in the North Kinnickinnic River Monitoring Project Area by mid-September 2013 and persisted into early October (U.S. Drought Monitor, at http://droughtmonitor.unl.edu/).

Besides being slightly drier than normal, the April-September 2013 monitoring period was slightly cooler than normal. The mean air temperature in River Falls during the April-September 2013 period was 62.2º Fahrenheit (F), 1.5º F lower than the normal mean of 63.7º F for the April-September period, as measured at the Twin Cities International Airport. Monthly mean air temperatures during the April-September 2013 period, with a comparison to normal monthly mean temperatures during the "climate normal period" of 1981-2010, are presented in Figure 4. The months of April, May, June, and July were all cooler than normal, with April (-7.8º F) and May (-2.5º F) experiencing the greatest departures. The months of August and September were both warmer than normal, with temperature departures of +0.5º F and +2.8º F, respectively.

The distribution of River Falls daily rainfall amounts during the April-September 2013 period is presented in Figure 5. On 39 (57%) of the 69 days with measurable precipitation, rainfall amounts were 0.25 inch or less. These 39 days contributed only

18% of the total April-September 2013 precipitation. Twenty-seven of these 39 days occurred in the cooler months of April, May, and September (Figure 6). On 20 (29%) of the 69 days with measurable precipitation, rainfall amounts ranged from 0.26-0.50 inch. These 20 days contributed an additional 35% of the total April-September 2013 precipitation. Twelve of these 20 days occurred in April, May, and September (Figure 6), when air temperatures were cooler. On 5 (7%) of the 69 days with measurable precipitation, rainfall amounts ranged from 0.51-0.75 inch. These 5 days contributed 14% of the total April-September 2013 precipitation, in April, May, June, and September (Figure 6). On 2 (3%) of the 69 days with measurable precipitation, rainfall amounts ranged from 0.76-1.00 inch. These 2 days in May (Figure 6) contributed 9% of the total April-September 2013 precipitation. On 3 (4%) of the 69 days with measurable precipitation, rainfall amounts exceeded 1.00 inch. However, these 3 days contributed 24% of the total April-September 2013 precipitation. Precipitation amounts in excess of 1 inch occurred on May 2 (1.16 inches), June 21 (1.59 inches), and June 26 (2.31 inches) (Figures 2 and 6).

In a very rare occurrence, the precipitation on May 2 (1.16 inches) fell as 10 inches of snow. This snowfall amount greatly eclipsed the previous snowfall record for this date (2.2 inches in 1954), as measured in Minneapolis/St. Paul, MN during the 1871-2013 period-of-record. The 2 largest summer precipitation events, with rainfall amounts in excess of 1.50 inches, occurred on June 21 (1.59 inches) and June 26 (2.31 inches). Both rain events were characterized by convective thunderstorm activity, on days with very warm air temperatures (high temperatures of 84° F and 87° F, respectively). Rainfall on June 21 (1.59 inches) occurred during two waves within an 18-hour period, with peak rainfall rates of 0.45 inch per hour during the first wave (02:45-06:00 CDT) and 0.70 inch per hour during the second wave (19:45-21:00 CDT). According to NOAA Atlas 14, Volume 8 for Wisconsin (2013), an 18-hour rain event of 1.59 inches in River Falls has a recurrence interval of less than 1 year. Rainfall on June 26 (2.31 inches) occurred during a 2-hour period (12:45-14:45 CDT); however, the majority of rain (2.11 inches) fell at a very intense rate during a 1-hour period with thunderstorm activity. According to NOAA Atlas 14, Volume 8, a 2-hour rain event of 2.31 inches in River Falls, Wisconsin has a 6.0-year recurrence interval; however a 1-hour rain event of 2.11 inches has a 9.4-year recurrence interval. These three largest precipitation events in May and June contributed substantially to the above-normal precipitation amounts for these two months (Figure 3). The May 2 snowfall event accounted for 19% of the total precipitation for May, and the June 21 and June 26 rain events accounted for 63% of the total rainfall for June.

Rainfall events in excess of 0.50 inch occurred on 10 days throughout the April-September 2013 period, with 2 events in April, 4 events in May, 3 events in June, and 1 event in September (Figures 2 and 6). These 10 rainfall events in excess of 0.50 inch (14% of the April-September 2013 rain events) contributed 47% of the total April-September 2013 precipitation. Conversely, 59 rainfall events of 0.50 inch or less (86% of the April-September 2013 rain events) contributed 53% of the total April-September 2013 precipitation.

To achieve the requirements of the City's storm water ordinance, developers must provide on-site infiltration of post-development storm water from 24-hour rainfall events of 1.5 inches or less. Of the 69 days with measurable precipitation during the April-September 2013 period, 67 days (97%) had rainfall amounts less than 1.5 inches in 24 hours (a midnight-to-midnight total). Infiltration of these 67 rain events (16.90 inches) would account for 81% of the total April-September precipitation (20.80 inches). Only the rainfall amounts on June 21 (1.59 inches) and June 26 (2.31 inches) exceeded the 1.5-inch infiltration criterion. Even so, the storm water ordinance would require infiltration of the first 1.5 inches of these two rainfall events, thereby accounting for infiltration of 96% (19.90 inches) of the total rainfall (20.80 inches) that occurred during the April-September 2013 period. Figure 7 depicts the annual effectiveness of the River Falls Storm Water Ordinance for infiltrating storm water runoff generated by rainfall during the April-September period. This figure was prepared for illustrative purposes only, and was created with the assumption that the entire 1.5-inch event is infiltrated. This scenario essentially assumes zero pre-development runoff, which may not necessarily be the case.

Kinnickinnic River Flow:

The flow of the Kinnickinnic River is a reflection of strong ground water (spring) contributions, as well as precipitation-induced storm water runoff from predominantly agricultural and urban land uses throughout the 165-square mile Kinnickinnic River Watershed. The United States Geological Survey (USGS) operates a Kinnickinnic River monitoring station (number 05342000) at County Highway F, near Kinnickinnic State Park, approximately five miles west of River Falls. The station measures river stage (water height) and flow at 15-minute intervals, and 15-minute precipitation amounts in 0.01-inch increments. Because accurate monitoring of river stage and flow entails a significant investment in equipment and labor, no continuous measurement of river flow is currently being conducted within the North Kinnickinnic River Monitoring Project Area. For this reason, the Kinnickinnic River flow information provided by the USGS monitoring station is particularly valuable, as it clearly documents when runoff events are occurring and storm water impacts may be apparent. The City of River Falls, Kinnickinnic River Land Trust, and the Kiap-TU-Wish Chapter of Trout Unlimited provide annual cost-share funding to help support the operation of this USGS monitoring station.

The daily mean (average) flow of the Kinnickinnic River at County Highway F during the April-September 2013 period is presented as a hydrograph in Figure 8. Daily rainfall, as measured at the USGS monitoring station, is also presented in Figure 8.

Precipitation patterns help explain the changes that occur in the Kinnickinnic River hydrograph, due to runoff events in the watershed. Daily rainfall amounts in excess of 1 inch and combined rainfall amounts in excess of 1 inch on consecutive (back-to-back) days generally had the greatest influence on the April-September 2013 Kinnickinnic River hydrograph (Figure 8).

The Kinnickinnic River hydrograph suggests that nine significant runoff events occurred during the April-September 2013 period (Figure 8). Peak daily mean flows for all of these runoff events were ≥ 200 cubic feet per second (cfs).

Five of the nine significant runoff events occurred in April, with peak daily mean flows ranging from 200-574 cfs. Much of the April precipitation (4.92 inches) fell as snow, with 18.5 inches of snow recorded during the month in nearby Hudson, WI. As such, the five significant runoff events in April were primarily caused by snowmelt. With very cool air and water temperatures in April, thermal impacts of storm water runoff are generally not a concern, but water quality impacts can be problematic, due to frozen soils and a lack of vegetative cover in the watershed.

Four of the nine significant runoff events occurred in May and June, when thermal impacts of storm water runoff become a concern due to warmer air and water temperatures. A combined 2.12 inches of precipitation fell on May 1-4, including a record snowfall of 10 inches on May 2. The rainfall and rapidly melting snow produced a 6-day runoff event (May 1-6), with a peak daily mean flow of 407 cfs. Shortly thereafter, a combined 2.50 inches of rain during the May 17-20 period produced a 9-day runoff event (May 17-25), with a peak daily mean flow of 270 cfs. A very large rain event on June 21 (1.59 inches), followed by a combined 0.73 inch of rain on June 22-23, produced a 5-day runoff event (June 21-25), with a peak daily mean flow of 698 cfs. Very shortly thereafter, the largest rain event of the summer on June 26 (2.31 inches) produced a 4-day runoff event (June 26-29), with a peak daily mean flow of 363 cfs.

With well-below-normal rainfall, no significant runoff events occurred in July, August, and September, when thermal impacts of storm water runoff remain a concern due to warmer air and water temperatures.

The four runoff events in May and June should be the focus for evaluating possible storm water impacts in the North Kinnickinnic River Monitoring Project Area in 2013, and are further analyzed in this report.

With slightly below-normal rainfall during the April-September 2013 period, Kinnickinnic River base flows generally ranged from 85-126 cfs, as measured at County Highway F (Figure 8). As the April-September 2013 period became increasingly drier (Figure 3), base flows gradually decreased. Base flows tended to be a bit higher (105-126 cfs) during the wetter-than-normal months of April, May, and June, and a bit lower (85-115 cfs) during the drier-than-normal months of July, August, and September.

Temperature Monitoring:

The thermal impacts of untreated storm water discharges on segments of the Kinnickinnic River within the City of River Falls, especially in the downtown and Glen Park areas, have been clearly documented by temperature monitoring research conducted by the local Kiap-TU-Wish Chapter of Trout Unlimited (TU). These thermal impacts are also evident in the South Fork of the Kinnickinnic River. The TU temperature monitoring research can be viewed at:

http://www.kiaptuwish.org/storm-water

A direct storm sewer discharge to the Kinnickinnic River at Division Street

The intent of the City of River Falls Storm Water Management Ordinance is to prevent storm water impacts on the Kinnickinnic River, including thermal pollution, in areas of the city with new development, such as the Sterling Ponds subdivision.

In 2013, temperature monitoring was conducted at seven sites within the North Kinnickinnic River Monitoring Project Area:

Site:	Deployment Period:	Location:
Site 1:	May 1-September 30, 2013	Kinnickinnic River at North Main St.
Site 1A:	May 1-September 30, 2013	Kinnickinnic River at Quarry Road
Site 4A:	May 1-September 30, 2013	Sumner Creek: Mouth
Site 5IN:	May 10-September 30, 2012	Sterling Ponds: Wet Pond Inlet
Site 5P:	May 10-September 30, 2012	Sterling Ponds: Wet Pond
Site 5IB:	May 10-September 30, 2012	Sterling Ponds: Infiltration Basin
Site 5MHW:	May 10-September 30, 2012	Sterling Ponds: Wet Pond Outlet

The Kinnickinnic River monitoring locations at Site 1 (downstream from Sumner Creek) and Site 1A (upstream from Sumner Creek) were established to evaluate any storm water-related impacts of Sumner Creek and the Sterling Ponds subdivision on the Kinnickinnic River.

The Sumner Creek monitoring location at Site 4A (near the mouth of the creek) was established to evaluate any storm water-related impacts of the Sterling Ponds subdivision on Sumner Creek.

To evaluate the thermal performance of the storm water management practices at Site 5 in the Sterling Ponds subdivision, temperature monitoring was conducted at four locations: the wet detention pond inlet (Site 5IN), the wet detention pond (Site 5P), the wet detention pond outlet to the infiltration basin (Site 5IB), and the wet detention pond outfall to Sumner Creek (Site 5MHW).

A more detailed description of the 2013 temperature monitoring sites and the temperature monitoring equipment deployed at these seven locations can be found in the 2012 Technical Report.

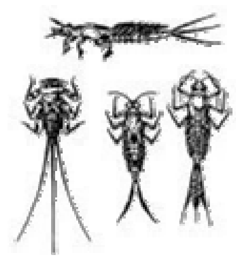
Kinnickinnic River Temperature Monitoring Results:

May-September (summer) 2013 temperature monitoring data were obtained for the Kinnickinnic River at Sites 1 and 1A (Figures 9 and 10). River temperatures at these two monitoring sites averaged 13.8° C and ranged from 3.2-20.8° C over the course of the summer. The 2013 summer average river temperature of 13.8º C was the second-lowest summer average river temperature recorded during the 2004-2013 period. The coolest summer average river temperature (13.7º C) was recorded in 2011, while the warmest summer average river temperature (15.2º C) was recorded in 2007. Summer average river temperatures in 2004-2006, 2008-2010, and 2012 ranged from 13.8º-14.9º C. Below-normal river temperatures probably prevailed in the North Kinnickinnic River Project Area during the summer of 2013, since the 2013 summer average air temperature of 19.2º C (66.6º F) was slightly cooler than the normal summer average air temperature of 19.4° C (67.0° F). The 2013 summer average air temperature of 19.2º C was the third-lowest summer average air temperature recorded in the North Kinnickinnic River Monitoring Project Area during the 2004-2013 period.

The most direct way to determine if any thermal impacts occurred in the Kinnickinnic River as a result of the Sterling Ponds subdivision is to compare the temperature monitoring data at Site 1, located immediately downstream from Sumner Creek, to the temperature monitoring data at Site 1A, located immediately upstream from Sumner Creek. Site 1A serves as control or reference site, since it is not impacted by Sterling Ponds storm water discharges. In 2013, downstream summer temperatures at Site 1 were nearly identical to upstream summer temperatures at Sites 1A, as shown in Figure 11. The 2013 monthly and summer mean (average) temperatures at Sites 1 and 1A were also nearly identical, as indicated in Figure 12. In general, the monthly and summer mean temperatures were slightly (0.1° C) cooler at Site 1, perhaps due to the cooler water contributed by Sumner Creek, just upstream from Site 1 (see *Sumner Creek*, below).

The summer 2013 temperature regime in the Kinnickinnic River at Sites 1 and 1A was generally excellent for coldwater macroinvertebrate and brown trout communities. Approximately 90% of all temperatures recorded at Sites 1 and 1A during the May-

September 2013 period were less than or equal to (≤) 17° C, which is the top of the optimum temperature range for a healthy coldwater macroinvertebrate community. A temperature of 17° C is also considered to be the optimum for brown trout survival. Approximately 98% of all temperatures recorded at Sites 1 and 1A during the May-September 2013 period were ≤ 19° C, which is the top of the optimum temperature range for brown trout growth. Approximately 99% of all temperatures recorded at Sites 1 and 1A during the May-September 2013 period were ≤ 20° C, which is the top of the optimum temperature range for brown trout survival. With a slightly cooler-than-normal summer, river temperatures exceeding 20º C were only recorded on one date in June, two dates in July, and three dates in August (Figures 9 and 10).



During four significant precipitation and runoff events in May and June 2013, thermographs at Sites 1 and 1A can be compared to determine if rapid temperature increases (thermal spikes), which are characteristic of warm storm water discharges, were apparent at Site 1, downstream from Sumner Creek and the Sterling Ponds subdivision.

In May (Figure 13), no thermal spikes were evident at Site 1 during the May 1-6 runoff event (triggered by a combined 2.12 inches of precipitation during the May 1-4 period) (Figure 14) and during the May 17-25 runoff event (triggered by a combined 2.50 inches of rain during the May 17-20 period) (Figure 15).

In June (Figure 16), no thermal spikes were evident at Site 1 during a very large rain event on June 21 (1.59 inch) (Figure 17). However, the largest rain event of the year on June 26 (2.31 inches) produced a notable thermal spike at Site 1 (Figure 17).

Strong, convective thunderstorm activity during the early afternoon of June 26 produced the largest rain event (2.31 inches) of the 2013 monitoring season. When the thermographs for Site 1, Site 1A, and Division Street are compared during the June 26-29 runoff event (Figure 17), a notable thermal spike (0.8º C) was evident at Site 1, downstream from Sumner Creek and the Sterling Ponds subdivision. After a 2-hour period of very intense rainfall (2.31 inches) ended at 14:45 CDT, the river temperature at Site 1 began increasing at 20:00 CDT on June 26 and peaked at 21:00-21:50 CDT. No such increase in river temperature was apparent at Site 1A upstream. For an 11.3-hour period (until 07:20 CDT on June 27), the downstream river temperature at Site 1 was notably higher than the upstream river temperature at Site 1A, perhaps indicating that a warm discharge from Sumner Creek created a downstream thermal impact at Site 1. Indeed, a very prominent thermal spike (6.5º C) was evident at Site 4A (mouth of Sumner Creek) during the June 26 rain event (see Figure 18 and *Sumner Creek*, below). When the river temperature at Site 1 peaked (18.0º C) at 21:00-21:50 CDT, Sumner Creek was contributing markedly warmer water (22.1º C) to the Kinnickinnic River, likely accounting for the notable temperature spike (0.8º C) evident at Site 1. A very prominent thermal spike (4.1º C) was also apparent at Division Street during the June 26 rain event (Figure 17). The thermal impacts of this rain event can be attributed to the high rainfall intensity, a very warm antecedent air temperature (30º C / 87º F), and the timing of the rain event in early-afternoon, when pavement temperatures were also very warm.

With well-below-normal rainfall in July, August, and September, no significant runoff events occurred, and no thermal spikes were evident at Site 1 (Figures 19, 20, and 21, respectively).

While the presence of thermal spikes at Division Street is attributed to the thermal impacts of untreated storm water discharges to the Kinnickinnic River, the lack of thermal spikes at Site 1 during all but one runoff event (June 26) in 2013 could be attributed to several factors, including effective storm water management at the Sterling Ponds subdivision, or simply a lack of Sterling Ponds storm water discharges and/or storm water conveyance down Sumner Creek. The effectiveness of Sterling Ponds storm water management practices during the summer of 2013 (including the June 26 rain event), and possible downstream impacts on Sumner Creek and the Kinnickinnic River, are discussed below (see *Assessment of Sterling Ponds Storm Water Infiltration and Discharge to Sumner Creek*).

Sumner Creek and Sterling Ponds Temperature Monitoring Results:

Sumner Creek

Sumner Creek is a low-gradient tributary of the Kinnickinnic River that exhibits only intermittent flow for the majority of its length. Permanent flow begins in the vicinity of the WI Highway 35 bypass, near the creek confluence with the Kinnickinnic River (Site 4A). From this location, the creek drainage way extends upstream to Radio Road on the far northwest corner of River Falls. The upper portion of the Sumner Creek drainage way, including Sites 4 and 6, conveys no flow for the majority of the year. The headwaters area near Site 6 is a dry run. Downstream, however, rather extensive wetland areas are apparent in the Sumner Creek drainage way through the Sterling Ponds subdivision, and for an appreciable distance downstream of Site 4. Anecdotal evidence suggests that flow occurs in the upper portion of Sumner Creek during the spring snowmelt period, and past temperature monitoring data at Sites 4 and 6 indicate that flow sometimes occurs during large summer rain events. During large summer rain events, however, the wetland areas and dry portions of the Sumner Creek channel likely provide considerable water storage, making it very difficult to determine if and when any upstream flow is conveyed all the way downstream to the Kinnickinnic River.

May-September (summer) 2013 temperature monitoring data were obtained for Sumner Creek at Site 4A, which is located near the mouth of the creek, 1.5 miles downstream from the Sterling Ponds subdivision (Figure 22). Site 4A is the only Sumner Creek monitoring location with permanent flow throughout the summer. At Site 4A, Sumner

Creek temperatures averaged 12.8° C and ranged from 3.2-22.2° C during the May-September 2013 period. The summer mean temperature of Sumner Creek (12.8º C) was notably colder than the summer mean temperature of the Kinnickinnic River (13.8º C) at Sites 1 and 1A, reflecting strong spring activity. Approximately 96% of all temperatures recorded at Site 4A during the May-September 2013 period were ≤ 17° C. A temperature of 17° C is considered to be the top of the optimum temperature range for a healthy coldwater macroinvertebrate community (Galli, 1990). Approximately 99% of all temperatures recorded at Site 4A during the May-September 2013 period were ≤ 20° C, which is considered to be the top of the optimum temperature range for brown trout survival (Armour, 1994). As such, Sumner Creek potentially provides a good thermal environment for a brook trout fishery, and is an important contributor of cold water to the Kinnickinnic River.

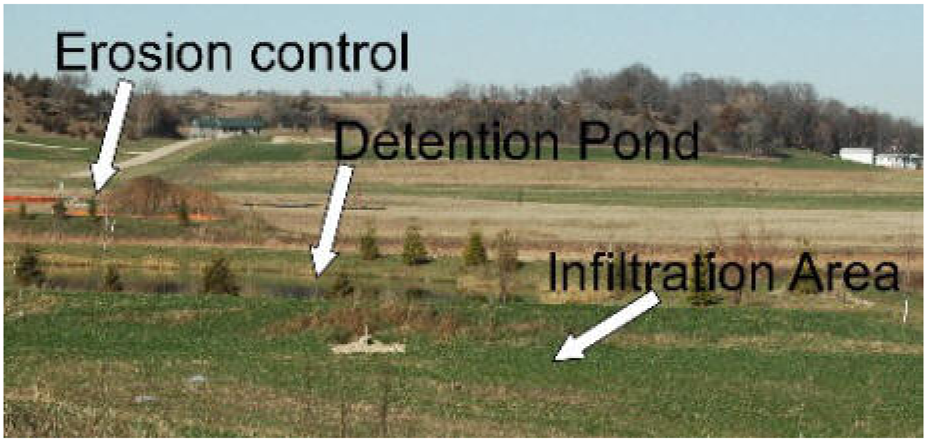
Of concern, however, are the large thermal spikes that occurred at Site 4A during the June 21 and June 26 rain events (Figure 22). A very prominent Sumner Creek thermal spike (6.6º C) occurred after the very large summer rain event (1.59 inches) on June 21, during a warm day (84º F) (Figure 22). During and after this rain event, the Sumner Creek temperature at Site 4A exceeded 17º C for a 33.2-hour period and exceeded 20º C for an 8.2-hour period, reaching a maximum of 21.5º C. A very prominent Sumner Creek thermal spike (6.5º C) also occurred on June 26, after the largest summer rain event (2.31 inches) on a warm day (87º F) (Figure 22). During and after this rain event, the Sumner Creek temperature at Site 4A exceeded 17º C for a 32.5-hour period and exceeded 20º C for a 12.7-hour period, reaching a maximum of 22.2º C.

The Sumner Creek thermal spikes were of even greater magnitude than those observed at the Division Street monitoring site on the same dates (Figure 17). As noted above, the Sumner Creek thermal spikes associated with the June 21 and June 26 rain events exceeded optimum temperature thresholds for macroinvertebrates (17º C) and brown trout (20º C). As such, thermal spikes of these magnitudes and extended durations could have a detrimental impact on aquatic life (especially macroinvertebrates) in lower Sumner Creek. The June 26 thermal spike also caused a notable temperature spike (0.8º C) in the Kinnickinnic River at Site 1 (Figure 18). Storm water discharges at Sterling Ponds likely contributed to the extended durations of the thermal spikes evident at Site 4A after the June 21 and June 26 rain events (see *Assessment of Sterling Ponds Storm Water Infiltration and Discharge to Sumner Creek*). However, both thermal spikes at this location also had a more local cause that needs further investigation.

Numerous thermal spikes were also apparent in lower Sumner Creek (Site 4A) during the summers of 2005-2012. Possible sources contributing to thermal spikes in lower Sumner Creek may include: storm water runoff from WI Highway 35, located immediately upstream from Site 4A; warm water from natural wetland areas in the upper Sumner Creek drainage way; and storm water discharges from the Sterling Ponds subdivision.

Sterling Ponds

Temperature monitoring data for the Sterling Ponds storm water management practices were obtained in the wet detention pond (Site 5P), at the wet pond inlet (Site 5IN), at the wet pond discharge to the infiltration basin (Site 5IB) (see photo below), and at the wet pond discharge to Sumner Creek (Site 5MHW).



Storm water best management practices at Sterling Ponds

The May-September (summer) 2013 temperature monitoring data obtained for the Sterling Ponds wet detention pond at Site 5P are presented as a thermograph in Figure 23. At Site 5P, Sterling Ponds wet detention pond temperatures averaged 22.4° C and ranged from 10.7-33.4° C during the summer period. Approximately 69% of all summer temperatures exceeded 20° C, and wet pond temperatures consistently remained above 20° C from June 13 until September 14. Substantial warming of small, shallow ponds such as this can be expected, especially with no shading or canopy cover. The summer mean temperature of the Sterling Ponds wet detention pond (22.4° C) was substantially higher than the summer mean temperatures of Sumner Creek at Site 4A (12.8º C), clearly demonstrating the potential for thermal impact when the pond discharges to the creek, and emphasizing the importance of the River Falls Storm Water Management Ordinance, which requires storm water infiltration.

Assessment of Sterling Ponds Storm Water Infiltration and Discharge to Sumner Creek

Temperature data from three of the Sterling Ponds monitoring stations (Sites 5P, 5IB, and 5MHW) and the downstream Sumner Creek monitoring station (Site 4A) can be used to evaluate the effectiveness of the Sterling Ponds storm water management practices for infiltrating storm water and minimizing warm storm water discharges to Sumner Creek. Given the warm and relatively stable thermal regime (Figure 23) in the Sterling Ponds wet detention pond (measured at Site 5P), pond discharges to the infiltration basin can be readily identified when the temperature at Site 5IB closely matches that at Site 5P. Similarly, pond discharges to Sumner Creek can be readily identified when the temperature at Site 5MHW closely matches that at Site 5P. Warm storm water discharges to Sumner Creek may be detectable as thermal spikes at Site 4A.

During the summer of 2013, the thermal performance of Sterling Ponds stormwater management practices can be evaluated monthly by comparing the Sterling Ponds and Sumner Creek thermographs. Performance of these storm water management practices during the four significant precipitation and runoff events in May and June is of particular interest, and may help explain the possible causes of the thermal impacts (spikes) observed in lower Sumner Creek (Site 4A) and the Kinnickinnic River (Site 1). Two of these four significant events (May 1-4 and May 17-20) were characterized by 24-hour rainfall amounts less than 1.5 inches, and hence would be expected to meet the infiltration requirement of the River Falls Storm Water Management Ordinance. However, the June 21 and June 26 events were characterized by 24-hour rainfall amounts in excess of 1.5 inches, beyond the infiltration requirement of the ordinance.

May

The comparative Sterling Ponds thermographs for May 2013 are presented in Figure 24. The month of May was cooler (-2.5° F) and much wetter (+2.83 inch) than normal. Precipitation events ranging from 0.01-1.16 inches were recorded on twenty dates (Figure 2), with two of the four significant summer precipitation events occurring on May 1-4 and May 17-20.

Due to very cool and inclement weather during the first week of May, including 10 inches of snow on May 2, the temperature loggers at Sites 5IN, 5P, 5IB, and 5MHW were not installed until May 10. When the loggers were installed, the Sterling Ponds wet detention pond was discharging to the Sterling Ponds infiltration basin (Figure 24), likely due to the first significant precipitation and runoff event on May 1-4. During the May 1-4 period, a combined 2.12 inches of precipitation fell, with daily precipitation amounts as follows: May 1 (0.42 inch), May 2 (1.16 inches, as 10 inches of snow), May 3 (0.33 inch), and May 4 (0.21 inch). With 1.16 inches (55%) of the May 1-4 precipitation falling as snow, and with a gradual snowmelt during the May 2-4 period, it is very likely that all of the May 1-4 precipitation (2.12 inches) was captured in the wet pond and infiltrated. This circumstance would be expected, as all 24-hour precipitation amounts during the May 1-4 period were less than the 1.5-inch infiltration standard set by the River Falls Storm Water Management Ordinance. Wet pond discharge to the infiltration basin, due to the May 1-4 rain events and small rain events on May 8 (0.01 inch), May 9 (0.17 inch), and May 11 (0.01 inch), continued until 03:00 CDT (3:00 AM) on May 13 (Figure 24).

The second of four significant summer rainfall and runoff events occurred on May 17-20. The comparative Sterling Ponds and Sumner Creek thermographs for the May 17-20 rain events, with a combined 2.50 inches of rain, are presented in Figure 25. A small rain event on May 17 (0.13 inch) was captured in the Sterling Ponds wet detention pond. Due to the moderate rain event on May 18 (0.56 inch), the Sterling Ponds wet detention pond began discharging to the Sterling Ponds infiltration basin at 11:10 CDT (11:10 AM) on

May 18 (Figures 24 and 25), shortly after the onset of rainfall at 08:45 CDT (8:45 AM). The large, back-to-back rain events on May 19 (0.90 inch) and May 20 (0.91 inch) were characterized by extended rainfall durations and low rainfall intensities. Both rain events resulted in a continuing but reinforced (increased) discharge from the wet pond to the infiltration basin, as indicated by the nearly identical temperatures at Sites 5P and 5IB at 19:40 CDT (7:40 PM) on May 19 (Figure 25), shortly after the onset of heavier rainfall at 17:00 CDT (5:00 PM). All of the May 17-20 precipitation (2.50 inches) was captured in the wet pond and infiltrated. This circumstance would be expected, as all 24-hour precipitation amounts during the May 17-20 period were less than the 1.5-inch infiltration standard set by the River Falls Storm Water Management Ordinance. No wet pond discharge to Sumner Creek was evident during the May 17-20 event, as documented by the temperature data at Site 5MHW (Figure 25). Wet pond discharge to the infiltration basin, due to the May 18-20 rain events, eight small rain events during the May 21-31 period (a combined 1.38 inches), and a very small rain event on June 1 (0.03 inch), continued until 20:00 CDT (8:00 PM) on June 3 (Figures 24 and 26).

In summary for May, although temperature monitoring at Site 5 did not begin until May 10, it seems likely that the Sterling Ponds wet detention pond continuously discharged to the infiltration basin during the May 1-13 period. All seven precipitation events during this period (a combined 2.31 inches) were infiltrated. A small rain event on May 17 (0.13 inch) was captured in the Sterling Ponds wet pond. The Sterling Ponds wet detention pond continuously discharged to the infiltration basin during the May 18-31 period. All twelve rain events during this period (a combined 3.75 inches) were infiltrated.

June

The comparative Sterling Ponds thermographs for June 2013 are presented in Figure 26. The month of June was cooler (-1.8° F) and wetter (+1.98 inches) than normal. Rainfall events (ranging from 0.02-2.31 inches) were recorded on eleven dates (Figure 2), with two of the four significant summer rainfall events occurring on June 21 and June 26.

As noted above (*May*), the Sterling Ponds wet detention pond was discharging to the Sterling Ponds infiltration basin when the month of June began, due to multiple rain events (a combined total of 3.75 inches) during the May 18-31 period. The very small rain event on June 1 (0.03 inch) was also infiltrated before wet pond discharge to the infiltration basin ended at 20:00 CDT (8:00 PM) on June 3 (Figure 26).

The June 2-11 period was relatively dry. A very small rain event on June 6 (0.02 inch) and a small rain event on June 9 (0.28 inch) were captured in the Sterling Ponds wet pond, where the water infiltrated or evaporated from the pond. The wet pond did not discharge to the infiltration basin during this time period (Figure 26).

Due to a moderate rain event on June 12 (0.60 inch), which began at 09:00 CDT (9:00 AM), the Sterling Ponds wet detention pond began discharging to the Sterling Ponds infiltration basin at 11:00 CDT (11:00 AM) (Figure 26), after 0.47 inch of rain had fallen.

Wet pond discharge to the infiltration basin, due to the June 12 rain event and a small rain event on June 15 (0.28 inch), continued for 6.05 days, until 12:10 CDT (12:10 PM) on June 18.

A very large rain event on June 21 (1.59 inches), followed by a combined 0.73 inch of rain on June 22-23, produced the third of four significant summer rainfall and runoff events. The comparative Sterling Ponds and Sumner Creek thermographs for these three rain events (a combined 2.32 inches) are presented in Figure 27. Rainfall on June 21 (1.59 inches) occurred in two "waves", from 02:45-06:00 CDT and 19:45-21:00 CDT. Rainfall amounts during these two waves were very similar, with 0.83 inch falling during the first wave and 0.76 inch falling during the second wave. Both waves were associated with severe thunderstorm activity, which produced high winds and peak rainfall intensity rates of 0.45-0.70 inch per hour. During the first wave of rainfall, the Sterling Ponds wet detention pond began discharging to the infiltration basin at 04:40 CDT (4:40 AM) (Figure 27), after 0.72 inch of rain had fallen. Sterling Ponds wet pond discharge to the infiltration basin was still in progress when the second wave of rainfall began at 19:45 CDT (7:45 PM). With 0.76 inch of rain falling in a 75-minute period from 19:45-21:00 CDT, a reinforced discharge from the wet pond to the infiltration basin began at 20:40 CDT (8:40 PM), and the Sterling Ponds wet detention pond began discharging to the Sumner Creek drainage way at 20:50 CDT (8:50 PM), as indicated by the rapidly-increasing temperature at Site 5MHW (Figure 27). By this time, 1.52 inches of rainfall had occurred on June 21, indicating that the Sterling Ponds wet pond had sufficient capacity to capture the majority of the June 21 rain event (1.59 inches) before discharge to the Sumner Creek drainage way began. This capacity was gained via wet pond drawdown (to the infiltration basin) after the June 12 and June 15 rain events, which was complete on June 18 (above). Wet pond discharge to the Sumner Creek drainage way continued for 7.2 hours, until 04:00 CDT (4:00 AM) on June 22. During this 7.2-hour period, the wet pond discharge temperature averaged 20.6º C and ranged from 19.2-22.9º C. Field observations during a large rainfall event in July 2008 indicated that some opportunity exists for infiltration, evaporation, and wetland storage (in the Sumner Creek drainage way) of storm water discharged from the Sterling Ponds wet pond outlet. Furthermore, the presence of dense wetland vegetation severely restricts storm water flow through the drainage way. An initial thermal spike (4.3º C) evident near the mouth of Sumner Creek (Site 4A) at 23:50 CDT (11:50 PM) on June 21 (Figure 27) cannot be attributed to the Sterling Ponds storm water discharge, since the temperature increase at Site 4A, located 1.5 miles downstream, was already occurring before the Sterling Ponds storm water discharge began. It seems apparent that the initial thermal spike at Site 4A had a more "local" cause, perhaps including storm water runoff from WI Highway 35. However, the extended discharge (7.2 hours) of warm storm water from the Sterling Ponds wet pond to Sumner Creek may have contributed to a secondary thermal spike (1.0º C) evident at Site 4A at 05:30 CDT (5:30 AM) on June 22, as well as to the extended duration (21.0 hours) of warmer-than-normal water at Site 4A, until 17:10 CDT (5:10 PM) on June 22, when a peak temperature of 21.5º C occurred. It is likely that warm water flowing from natural wetland or storage areas in the upstream Sumner Creek drainage way also contributed to the extended presence of warmer water at Site 4A. Although the Sterling Ponds storm water discharge to Sumner Creek on June 21-22 may have contributed to the very prominent thermal spike (6.6º C) present at Site 4A, this spike had no downstream thermal impact on the Kinnickinnic River at Site 1 (Figure 17), as noted above (***Kinnickinnic River Temperature Monitoring Results***).

Shortly after the June 21 rain event ended at 21:00 CDT (9:00 PM), a small-moderate rain event occurred on June 22. Sterling Ponds wet pond discharges to the infiltration basin and to the Sumner Creek drainage way were still in progress when rainfall began at 02:30 CDT (2:30 AM). With 0.44 inch of rain falling in a 4.0 hour period (until 06:30 CDT), a reinforced discharge from the wet pond to the infiltration basin began at 06:00 CDT (6:00 AM). Although the Sterling Ponds wet detention pond stopped discharging to the Sumner Creek drainage way at 04:00 CDT (4:00 AM), the June 22 rain event caused the wet pond to resume discharging to the Sumner Creek drainage way at 06:10 CDT (6:10 AM), as indicated by the rapidly-increasing temperature at Site 5MHW (Figure 27). Wet pond discharge to the Sumner Creek drainage way continued for 1.3 hours, until 07:30 CDT (7:30 AM) on June 22. During this 1.3-hour period, the wet pond discharge temperature averaged 20.4º C and ranged from 19.8-20.6º C. The unexpected wet pond discharge to Sumner Creek during the June 22 rain event can be attributed to the very large antecedent rain event on June 21, which utilized all of the Sterling Ponds wet pond capacity. With the June 22 rain event closely following the June 21 rain event, wet pond inflow simply exceeded outflow to the infiltration basin, with the excess water discharged through the outlet structure. Although relatively short in duration (1.3 hours), the storm water discharge to Sumner Creek due to the June 22 rain event may also have contributed to the extended duration (21.0 hours) of warmer-than-normal water at Site 4A.

The Sterling Ponds wet pond was still discharging to the infiltration basin when a small rain event occurred on June 23 (0.29 inch) (Figure 27). Wet pond discharge to the infiltration basin, due to the June 21-23 rain events (a combined 2.32 inches), continued until the June 26 rain event began.

The largest rain event of the summer on June 26 (2.31 inches) produced the fourth (and final) of four significant summer rainfall and runoff events. The comparative Sterling Ponds and Sumner Creek thermographs for this rain event are presented in Figure 27. Due to the June 21-23 rain events (a combined 2.32 inches), Sterling Ponds wet pond discharge to the infiltration basin was still in progress when the June 26 rain event (2.31 inches) began at 12:45 CDT (12:45 PM). With very intense rainfall starting at 13:00 CDT (1:00 PM) and 2.02 inches of rain falling in a 45-minute period from 13:00-13:45 CDT, a reinforced discharge from the wet pond to the infiltration basin began at 13:10 CDT (1:10 PM), and the Sterling Ponds wet detention pond began discharging to the Sumner Creek drainage way at 13:50 CDT (1:50 PM), as indicated by the rapidly-increasing temperature at Site 5MHW (Figure 27). Wet pond discharge to the Sumner Creek drainage way continued for 14.7 hours, until 04:30 CDT (4:30 AM) on June 27. During this 14.7-hour period, the wet pond discharge temperature averaged 23.0º C and ranged from 21.4-24.5º C. The lengthy wet pond discharge to the Sumner Creek drainage way was certainly influenced by the great magnitude of the June 26 rain event (2.31 inches). However, the antecedent rainfall (2.32 inches) on June 21-23 was also a likely influence. When the Sterling Ponds wet pond discharge to the Sumner Creek drainage way ended after the June 22 rain event, wet pond discharge to the infiltration basin continued for 4.2 days, providing a considerable opportunity for much of the combined June 21-23 rainfall to be infiltrated before the June 26 rain event began. Nonetheless, these antecedent rain events utilized wet pond storage capacity that could have been used to capture a greater proportion of the June 26 rain event, resulting in a reduced wet pond discharge to the Sumner Creek drainage way. Additional wet pond storage capacity would also have been helpful for abatement of any "first-flush" temperature and water quality impacts. With the majority of the June 26 rainfall (2.02 inches) occurring in a 45-minute period, and with the wet detention pond still discharging to the infiltration basin after the June 21-23 rain events, the wet pond was quickly inundated with storm water. Wet pond inflow simply exceeded outflow to the infiltration basin, with the excess water discharged through the outlet structure. Some storage of this storm water discharge likely occurred in the wetland that comprises the creek drainage way upstream from Site 4. Field observations during a large rainfall event in July 2008 indicated that some opportunity exists for infiltration, evaporation, and wetland storage (in the Sumner Creek drainage way) of storm water discharged from the Sterling Ponds wet pond outlet. Furthermore, the presence of dense wetland vegetation severely restricts storm water flow through the drainage way. The very prominent initial thermal spike (5.8º C) evident near the mouth of Sumner Creek (Site 4A) at 16:20 CDT (4:20 PM) on June 26 (Figure 27) cannot be attributed to the Sterling Ponds storm water discharge, since the temperature increase at Site 4A, located 1.5 miles downstream, was already occurring before the Sterling Ponds storm water discharge began. It seems apparent that the thermal spike at Site 4A had a more "local" cause, perhaps including storm water runoff from WI Highway 35. However, the extended discharge (14.7 hours) of warm storm water from the Sterling Ponds wet pond to Sumner Creek may have contributed to a secondary thermal spike (1.2º C) evident at Site 4A at 22:10 CDT (10:10 PM) on June 26, as well as to the extended duration (9.0 hours) of warmer-than-normal water at Site 4A, until 22:10 CDT (10:10 PM) on June 26, when a peak temperature of 22.2º C occurred. It is likely that warm water flowing from natural wetland or storage areas in the upstream Sumner Creek drainage way also contributed to the extended presence of warmer water at Site 4A. As discussed above (<u>*Sumner Creek*</u>), the much warmer-than-normal water at Site 4A had a notable downstream thermal impact (0.8º C) on the Kinnickinnic River at Site 1 (Figure 18). Sterling Ponds wet pond discharge to the infiltration basin, due to the June 26 rain event, a very small rain event on June 28 (0.05 inch), and a small rain event on June 29 (0.34 inch), continued until 12:30 CDT (12:30 PM) on July 3 (Figures 26 and 28).

In summary for June, the June 1-11 period was relatively dry. A very small rain event on June 1 (0.03 inch) was discharged to the Sterling Ponds infiltration basin. A very small rain event on June 6 (0.02 inch) and a small rain event on June 9 (0.28 inch) were captured in the Sterling Ponds wet pond. A moderate rain event on June 12 (0.60 inch) and a small rain event on June 15 (0.28 inch) were discharged to the Sterling Ponds infiltration basin. The Sterling Ponds wet detention pond continuously discharged to the infiltration basin during the June 21-30 period. A small rain event on June 23 (0.29 inch), a very small rain event on June 28 (0.05 inch), and a small rain event on June 29 (0.34 inch) were all infiltrated. A very large rain event on June 21 (1.59 inches), a moderate rain event on June 22 (0.44 inch), and a very large rain event on June 26 (2.31 inches) caused wet pond discharges to Sumner Creek, with discharge durations of 7.2 hours, 1.3 hours, and 14.7 hours, respectively. It seems likely that the majority of the combined June 21-22 rain events (2.03 inches) was infiltrated. Although wet pond discharges to the Sumner Creek drainage way occurred on June 21-22, the duration of these wet pond discharges to Sumner Creek (a combined 8.5 hours) was much shorter than the duration of the discharge to the infiltration basin (5.3 days). It also seems likely that the majority of the June 26 rain event (2.31 inches) was infiltrated. Although a wet pond discharge to the Sumner Creek drainage way occurred on June 26-27, the duration of this wet pond discharge to Sumner Creek (14.7 hours) was much shorter than the duration of the discharge to the infiltration basin (7.0 days).

July

The comparative Sterling Ponds thermographs for July 2013 are presented in Figure 28. The month of July was slightly cooler (-0.7° F) and much drier (-2.99 inches) than normal. Rainfall events (ranging from 0.02-0.34 inch) were recorded on eight dates (Figure 2). None of the four significant summer rainfall events occurred in July.

As noted above (*June*), the Sterling Ponds wet detention pond was discharging to the Sterling Ponds infiltration basin when the month of July began, due to multiple rain events (a combined total of 2.70 inches) during the June 26-29 period, including the largest rain event of the summer on June 26. After the Sterling Ponds wet pond discharge to the infiltration basin ended at 12:30 CDT (12:30 PM) on July 3, no further wet pond discharges to the infiltration basin occurred during the remainder of the month. All eight rain events in July (a combined 1.05 inches) were captured in the Sterling Ponds wet pond (Figure 28).

August

The comparative Sterling Ponds thermographs for August 2013 are presented in Figure 29. The month of August was slightly warmer (+0.5° F) and much drier (-3.49 inches) than normal. Rainfall events (ranging from 0.01-0.50 inch) were recorded on only four dates (Figure 2). None of the four significant summer rainfall events occurred in August. All four rain events in August (a combined 0.81 inch) were captured in the Sterling Ponds wet pond, with no wet pond discharges to the infiltration basin (Figure 29).

September

The comparative Sterling Ponds thermographs for September 2013 are presented in Figure 30. The month of September was warmer (+2.8° F) and drier (-1.48 inches) than normal. Rainfall events (ranging from 0.01-0.59 inch) were recorded on seven dates (Figure 2). None of the four significant summer rainfall events occurred in September. All seven rain events in September (a combined 1.60 inches) were captured in the Sterling Ponds wet pond, with no wet pond discharges to the infiltration basin (Figure 30).

Effectiveness of Sterling Ponds Storm Water Management Practices:

2013 Performance Assessment

During the May-September (summer) 2013 period, the extent of storm water discharge to the Sterling Ponds infiltration basin could be readily determined, as temperature monitoring of the basin (Site 5IB) was conducted throughout the summer. The extent of storm water discharge to Sumner Creek could be directly determined via temperature monitoring at the wet pond outlet (Site 5MHW) and/or indirectly determined by the presence of thermal spikes in Sumner Creek (Site 4A).

The performance of Sterling Ponds storm water management practices during the summer of 2013 is presented in Figures 31 and 32. With the exception of two very large rain events on June 21 (1.59 inches) and June 26 (2.31 inches) and a small-moderate rain event on June 22 (0.44 inch), all summer (May-September) rainfall events were fully infiltrated, as required by the River Falls Storm Water Management Ordinance. These 47 rain events, ranging in magnitude from 0.01-1.16 inches, represent a total of 11.54 inches of precipitation, or 73% of the total summer rainfall amount (15.88 inches). Of these 47 rain events, 22 events, ranging in magnitude from 0.01-0.59 inch and totaling 3.89 inches of precipitation (25% of the total summer rainfall amount) were entirely stored in the Sterling Ponds wet detention pond, with the storm water infiltrating in the pond or evaporating. The 25 remaining summer rain events, ranging in magnitude from 0.01-1.16 inches and totaling 7.65 inches of precipitation (48% of the total summer rainfall amount), were diverted into the Sterling Ponds infiltration basin. Due to below-normal rainfall (-3.15 inches) and a reduced frequency of rainfall during the May-September (summer) 2013 period, the Sterling Ponds wet detention pond discharged to the infiltration basin for 46.7 days, or 31% of the summer period.

Twenty rainfall events in May were stored in the Sterling Ponds wet detention pond or diverted to the Sterling Ponds infiltration basin (Figure 32). These events ranged from 0.01-1.16 inches in magnitude and represented a monthly total of 6.19 inches, or 39% of the total summer rainfall amount. Eight rain events in June, ranging from 0.02-0.60 inch and totaling 1.89 inches, were either infiltrated or stored in the wet detention pond (Figure 32). These June rain events represented 12% of the total summer rainfall. Eight rain events in July, ranging from 0.02-0.34 inches and totaling 1.05 inches, were stored in the wet detention pond (Figure 32). These July rain events represented 7% of the total summer rainfall. Four rain events in August, ranging from 0.01-0.50 inch and totaling 0.81 inch, were stored in the wet detention pond (Figure 32). These August rain events represented 5% of the total summer rainfall. Seven rain events in September, ranging from 0.01-0.59 inch and totaling 1.60 inches, were stored in the wet detention pond (Figure 32). These September rain events represented 10% of the total summer rainfall.

The Sterling Ponds wet detention pond only discharged to Sumner Creek during very large rain events on June 21 (1.59 inches) and June 26 (2.31 inches) and a small-moderate rain event on June 22 (0.44 inch). These discharges of storm water to Sumner Creek were directly measured at Site 5MHW.

The Sterling Ponds wet pond discharge to the Sumner Creek drainage way on June 21-22 was triggered by the great magnitude of the June 21 rain event (1.59 inches) and the relatively high rainfall intensity rates (0.45-0.70 inch per hour) during two waves of rain that fell in an 18-hour period. This rain event slightly exceeded the 1.5-inch, 24-hour infiltration standard set by the River Falls Storm Water Management Ordinance. The Sterling Ponds wet detention pond began discharging to the Sumner Creek drainage way near the end of the June 21 rain event, indicating that the wet pond had sufficient capacity to capture the majority of the event before discharge to the Sumner Creek drainage way began. This capacity was gained via wet pond drawdown (to the infiltration basin) after antecedent rain events on June 12 and June 15 (a combined 0.88 inch), which was complete on June 18. Given the magnitude of the June 21 rain event, the wet pond inflow rate simply exceeded the outflow rate to the infiltration basin, with the excess water discharged through the outlet structure to the Sumner Creek drainage way. However, the length of the wet pond discharge to the Sumner Creek drainage way (7.2 hours) was likely minimized by the extended duration of the rain event (18 hours) and the significant available capacity of the wet pond when the June 21 rain event occurred.

The Sterling Ponds wet pond discharge to the Sumner Creek drainage way during the small-moderate rain event on June 22 (0.44 inch) can be attributed to the very large antecedent rain event on June 21, which utilized all of the Sterling Ponds wet pond capacity. In fact, wet pond discharge to Sumner Creek (due to the June 21 rain event) was just ending as the June 22 rain event began. With the June 22 rain event closely following the June 21 rain event, there was insufficient time for the wet pond to drain to the infiltration basin and regain enough capacity to store the June 22 rain event. Wet pond inflow simply exceeded outflow to the infiltration basin, with the excess water discharged through the outlet structure. However, the length of the wet pond discharge to the Sumner Creek drainage way (1.3 hours) was short due to the relatively small magnitude of this rain event.

It seems likely that the majority of the combined June 21-22 rain events (2.03 inches) was infiltrated. Although wet pond discharges to the Sumner Creek drainage way occurred on June 21-22, the duration of these wet pond discharges to Sumner Creek (a combined 8.5 hours) was much shorter than the duration of the discharge to the infiltration basin (5.3 days).

The Sterling Ponds wet pond discharge to the Sumner Creek drainage way on June 26-27 was primarily triggered by the great magnitude of the June 26 rain event (2.31 inches) and the very high rainfall intensity. With the majority of the June 26 rainfall (2.11 inches) occurring in a one-hour period, and with the wet detention pond still discharging to the infiltration basin after the June 21-23 rain events, the wet pond was quickly inundated with storm water. The wet pond inflow rate simply exceeded the outflow rate to the infiltration basin, with the excess water discharged through the outlet structure to the Sumner Creek drainage way. The lengthy wet pond discharge to the Sumner Creek drainage way (14.7 hours) was certainly influenced by the great magnitude of the June 26 rain event (2.31 inches). However, significant antecedent rainfall (2.32 inches) on June 21-23 was also a likely influence. When the Sterling Ponds wet pond discharge to the

Sumner Creek drainage way ended after the June 22 rain event, wet pond discharge to the infiltration basin continued for 4.2 days, providing a considerable opportunity for much of the combined June 21-23 rainfall to be infiltrated before the June 26 rain event began. Nonetheless, these antecedent rain events utilized wet pond storage capacity that could have been used to capture a greater proportion of the June 26 rain event, resulting in a reduced wet pond discharge to the Sumner Creek drainage way. Additional wet pond storage capacity would also have been helpful for abatement of any "first-flush" temperature and water quality impacts. Although an extended wet pond discharge to the Sumner Creek drainage way occurred on June 26-27, the duration of this discharge was relatively short (14.7 hours), compared to the duration of discharge to the infiltration basin (7.0 days). Since the storm water volumes discharged to the infiltration basin and Sumner Creek were not measured, it is not possible to precisely determine the amounts of storm water infiltrated versus discharged. The wet pond discharge to Sumner Creek on June 26-27 was not entirely unexpected, as the magnitude of the June 26 rainfall event (2.31 inches) clearly exceeded the 1.5-inch, 24-hour infiltration standard set by the River Falls Storm Water Management Ordinance.

The temperature data for Site 5P, Site 5IB, and Site 5MHW suggest that the performance of the Sterling Ponds storm water management practices (wet detention pond and infiltration basin) was excellent during 47 summer (May-September) rain events, ranging in magnitude from 0.01-1.16 inches. All runoff from these events was stored or infiltrated (Figures 31 and 32). The very large rain events on June 21 (1.59 inches) and June 26 (2.31 inches) caused storm water discharges to the Sumner Creek drainage way; but the 24-hour rainfall amounts for these two storms were greater than the 1.5-inch infiltration standard set by the River Falls Storm Water Management Ordinance.

A summary of the performance of Sterling Ponds storm water management practices during the entire 2005-2013 project period is presented in Figure 33.

Temperature monitoring of all 2005-2013 summer rain events has revealed some performance issues and possible opportunities for improvement of the current Sterling Ponds storm water management practices and/or revision of the storm water management ordinance. The 2005-2012 performance issues are summarized in the 2012 Technical Report, while the 2013 performance issues are summarized below.

2013 Performance Issues

Temperature monitoring of the Sterling Ponds storm water management practices in 2013 indicated that warm storm water was discharged from the Sterling Ponds wet pond to Sumner Creek during very large rain events on June 21 (1.59 inches) and June 26 (2.31 inches) and a small-moderate rain event on June 22 (0.44 inch). The circumstances contributing to these wet pond discharges to Sumner Creek are detailed in the *2013 Performance Assessment* above.

The great magnitude of rainfall on June 21 (1.59 inches) and June 26 (2.31 inches) was a major factor contributing to the wet pond discharges to Sumner Creek during these rain events. Given that the 24-hour rainfall amounts on these dates exceeded the 1.5-inch infiltration standard set by the River Falls Storm Water Management Ordinance, it is understandable that Sterling Ponds storm water management practices were inadequate to ensure complete infiltration of storm water under these circumstances. Past monitoring has documented that wet pond discharges to Sumner Creek commonly occur when 24-hour rainfall amounts exceed 1.5 inches (Appendix A). During the 2005-2013 monitoring period, wet pond discharges occurred during 18 rain events ranging from 1.59-4.00 inches. On average, two such rain events occur each summer.

In addition to great rainfall magnitudes, high rainfall intensity rates and short rainfall durations also contributed to the wet pond discharges to Sumner Creek during the June 21 and June 26 rain events. Both rain events were characterized by convective thunderstorm activity that produced periods of very intense rainfall, with peak rainfall rates of 0.70 inch per hour during the June 21 storm and 2.11 inches per hour during the June 26 storm. Rainfall durations during these two rain events were relatively short. The majority (1.15 inches) of the June 21 rainfall (1.59 inches) occurred during a two-hour period. The majority (2.11 inches) of the June 26 rainfall (2.31 inches) occurred during a one-hour period. These high-intensity, short-duration storms rapidly delivered storm water to the Sterling Ponds wet pond, quickly overwhelming the capacity of the pond. The wet pond inflow rate simply exceeded the outflow rate to the infiltration basin, with the excess water discharged to Sumner Creek.

Wet pond discharges to Sumner Creek during the June 22 and June 26 rain events were also significantly affected by antecedent rainfall, with 1.59 inches of rain (June 21) preceding the June 22 rain event and a combined 2.32 inches of rain (June 21-23) preceding the June 26 rain event. These antecedent rain events significantly reduced the storage capacity in the wet detention pond, and provided relatively short periods of time for storm water discharge to the infiltration basin before the onset of additional rainfall. As such, the Sterling Ponds wet detention pond was still discharging to the infiltration basin when the June 22 and June 26 rain events began.

An extended discharge lag (16.2 hours) was apparent during the June 21 rain event; however, very short discharge lags of 10 minutes and 40 minutes were evident during the June 22 and June 26 rain events, respectively (Appendix A). Discharge lags, defined as the time lag between the onset of discharge to the infiltration basin and the onset of discharge to Sumner Creek, provide a limited opportunity for first-flush abatement of temperature and water quality impacts. For this reason, longer discharge lags are desirable when rain events ≥1.5 inches result in Sterling Ponds wet pond discharges to Sumner Creek. During the 2005-2013 monitoring period, wet pond discharge lags ranging from none (instantaneous) to 17.5 hours were associated with the 18 rain events ranging from 1.59-4.00 inches (Appendix A). The 16.2-hour discharge lag during the June 21 rain event was the second-longest recorded during the 2005-2013 monitoring period. This very extended discharge lag can be attributed to two waves of thunderstorms on June 21, with an intervening 13.8-hour period between these two storms. The early morning storm on June 21 (0.83 inch of rain) likely used much of the available capacity of the Sterling Ponds wet pond and resulted in a discharge to the infiltration basin at

04:40 CDT (4:40 AM). With the wet pond still near capacity when the evening storm (0.76 inch of rain) began on June 21, the discharge to Sumner Creek commenced at 20:50 CDT (8:50 PM). The extended discharge lag on June 21 provided a significant opportunity for first-flush abatement of the temperature and water quality impacts associated with the first storm on June 21. In contrast, the discharge lags during the June 22 and June 26 rain events were very short (10 minutes and 40 minutes, respectively). The very short lag time on June 22 (10 minutes) can simply be attributed to the very large antecedent rain event on June 21 (1.59 inches), which utilized all of the Sterling Ponds wet pond capacity, thereby providing no ability to store the June 22 rain event (0.44 inch), in spite of its small-moderate size. The very short lag time on June 26 (40 minutes) can be attributed to the great magnitude of the rain event (2.31 inches), a high rainfall intensity rate (2.11 inches per hour), a short rainfall duration (2 hours), the timing of heavy rainfall at the front end of the storm, and considerable antecedent rainfall on June 21-23 (2.32 inches), which reduced the capacity of the Sterling Ponds wet pond before the June 26 rain event began. The very short discharge lags on June 22 and June 26 provided very little opportunity for first-flush abatement of temperature and water quality impacts.

Sterling Ponds wet pond discharge times to Sumner Creek during the June 21 and June 26 rain events were 7.2 hours and 14.7 hours, respectively (Appendix A). During the 2005-2013 monitoring period, wet pond discharge times ranging from 2.5-34.5 hours were associated with the 18 rain events ranging from 1.59-4.00 inches (Appendix A and Figure 34). For these rain events ≥1.5 inches, reduced wet pond discharge times are clearly more desirable than extended discharge times.

The comparatively short wet pond discharge time associated with the June 21 rain event (7.2 hours) can be attributed to a rainfall magnitude (1.59 inches) that only slightly exceeded the 1.5-inch, 24-hour infiltration standard set by the River Falls Storm Water Management Ordinance. The wet pond also had sufficient capacity to capture the majority of the June 21 rain event, due to little antecedent rainfall (only a combined 0.88 inch on June 12 and June 15), which was entirely infiltrated by June 18. Considering all rain events ≥ 1.5 inches during the 2005-2013 monitoring period, the wet pond discharge time (7.2 hours) associated with the June 21 rain event (1.59 inches) was the fourth-shortest recorded. A comparison of the June 21, 2013 rain event to similarly-sized rain events in the 1.50-2.00 inch rainfall range indicates that four slightly larger rain events in 2005 (1.76 inches), 2006 (1.80 inches), 2007 (1.72 inches), and 2011 (1.78 inches) produced wet pond discharge times ranging from 4.0-16.0 hours (Appendix A and Figure 34).

The extended wet pond discharge time associated with the June 26 rain event (14.7 hours) can be primarily attributed to the great magnitude of rainfall that inundated the wet pond. Rainfall magnitude on June 26 (2.31 inches) significantly exceeded the 1.5-inch, 24-hour infiltration standard set by the River Falls Storm Water Management Ordinance. However, substantial antecedent rainfall during the June 21-23 period (2.32 inches) also played a key role by greatly reducing the capacity of the wet pond before the June 26 rain event occurred. In addition, the June 21-23 rainfall amount was not entirely infiltrated by

June 26. Considering all rain events ≥ 1.5 inches during the 2005-2013 monitoring period, the wet pond discharge time (14.7 hours) associated with the June 26 rain event (2.31 inches) was the eighth-shortest recorded. A comparison of the June 26, 2013 rain event to similarly-sized rain events in the 2.00-2.50 inch rainfall range indicates that two slightly smaller rain events in 2012 (2.05 inches and 2.27 inches) produced longer wet pond discharges (19.3 hours and 14.8 hours, respectively). Three slightly larger rain events in 2005 (2.49 inches), 2010 (2.43 inches), and 2011 (2.46 inches) produced wet pond discharge times ranging from 14.0-20.0 hours (Appendix A and Figure 34).

The rainfall amount on June 22 (0.44 inch) was much less than the 1.5-inch, 24-hour infiltration standard set by the River Falls Storm Water Management Ordinance, yet this small-moderate rain event delivered warm storm water to Sumner Creek. The wet pond discharge to the creek was clearly due to the very large antecedent rain event on June 21 (1.59 inches), which utilized all of the Sterling Ponds wet pond capacity. In fact, wet pond discharge to Sumner Creek (due to the June 21 rain event) was just ending as the June 22 rain event began. With only a short separation (5.5 hours) between the June 21 and June 22 rain events, there was insufficient time for the wet pond to drain to the infiltration basin and regain enough capacity to store the June 22 rain event, in spite of the fact that rainfall on June 22 occurred over an extended period (4.0 hours), at a low intensity rate. Wet pond inflow simply exceeded outflow to the infiltration basin, with the excess water discharged through the outlet structure. On a positive note, the 1.3-hour wet pond discharge to Sumner Creek on June 22 was the shortest wet pond discharge measured during the 2005-2013 monitoring period (Appendix A and Figure 34). In total, eight rain events ≤ 1.5 inches produced wet pond discharges to Sumner Creek during the 2005-2013 monitoring period. The wet pond discharge times associated with these eight rain events (0.44-1.49 inches) ranged from 1.3-14.7 hours.

As observed throughout the 2005-2013 monitoring period, the seasonal timing of Sterling Ponds wet pond discharges to Sumner Creek can greatly influence the potential for downstream thermal impacts. The June 21 and June 26 rain events were both characterized by strong convective thunderstorm activity. On June 21, air temperatures were relatively warm, ranging from 18-29° C (64-84° F). As such, the temperature of the wet pond discharge to Sumner Creek on June 21-22 averaged 20.6º C and ranged from 19.2-22.9º C during the 7.2-hour discharge period. In comparison, air temperatures on June 26 were slightly warmer, ranging from 19-30° C (66-87° F). As a result, the temperature of the wet pond discharge to Sumner Creek on June 26-27 was also slightly warmer, averaging 23.0º C and ranging from 21.4-24.5º C during the 14.7-hour discharge period. The average Sterling Ponds wet pond discharge temperatures on June 21-22 (20.6º C) and June 26-27 (23.0º C) were notably higher than pre-rainfall temperatures in Sumner Creek (Site 4A) on June 21 (14.9° C) and June 26 (15.7° C), indicating the strong potential for downstream thermal impacts during both rain events. In fact, the June 21-22 wet pond discharge may have contributed to a secondary thermal spike (1.0º C) evident at Site 4A, as well as to the extended duration (21.0 hours) of warmer-than-normal water at Site 4A, until 17:10 CDT (5:10 PM) on June 22, when a peak temperature of 21.5º C occurred. The June 26-27 wet pond discharge may have contributed to a secondary thermal spike (1.2º C) evident at Site 4A, as well as to the extended duration (9.0 hours) of warmer-than-normal water at Site 4A, until 22:10 CDT (10:10 PM) on June 26, when a peak temperature of 22.2º C occurred. The much warmer-than-normal water at Site 4A had a notable downstream thermal impact (0.8º C) on the Kinnickinnic River at Site 1.

The extended time (6.1 days) needed to infiltrate a moderate rain event on June 12 (0.60 inch) and a subsequent small rain event on June 15 (0.28 inch) seems excessive for the combined rainfall (0.88 inch) and the 2.5-day time period between these two rain events. Similarly, the extended time (12.0 days) needed to infiltrate the combined precipitation during the May 1-11 period (2.31 inches) seems excessive, especially since the majority of this precipitation (2.12 inches) occurred during May 1-4 period. Finally, the extended time (16.4 days) needed to infiltrate the combined rainfall during the May 18-June 1 period (3.78 inches) seems excessive, especially since the majority of this precipitation (2.48 inches) occurred during May 18-22 period, including two large rain events on May 19 (0.90 inch) and May 20 (0.91 inch). Although rainfall occurred on a nearly-daily basis during the May 24-June 1 period (a combined 1.30 inches), all eight rain events were very small-small (0.03-0.37 inch). The three instances (above) of overly-extended wet pond discharges to the infiltration basin in 2013 suggest that the wet pond outlet to the infiltration basin may have been partially plugged, perhaps by pond vegetation at the wet pond end (entrance) of the pipe leading to the infiltration basin, or perhaps by organic material in the pipe itself.

2005-2013 Performance Summary

Temperature monitoring of the Sterling Ponds storm water management practices during the 2005-2013 period indicates that storm water discharges to Sumner Creek are occurring:

- During rain events larger than 1.5 inches (2005-2007 and 2009-2013);
- During back-to-back rain events, when rainfall amounts range from 0.44-1.5 inches and time periods between rain events are less than 48 hours (2006, 2007, 2011, and 2013);
- During very intense rain events, when rainfall amounts range from 1.0-1.5 inches (2008).

A summary of the 2005-2013 Sterling Ponds storm water discharges to Sumner Creek, including discharge dates, rainfall amounts, discharge lags, and discharge times, is provided in Appendix A. Figure 34 compares rainfall amounts to Sterling Ponds wet pond discharge times during the 2005-2013 period.

In June 2007, River Falls Engineering Department staff conducted modeling of the Sterling Ponds storm water management practices, to further investigate performance issues and determine if any corrective action was necessary. Modeling results suggested that the control structure for the wet detention pond outlet should be raised by 6 inches. This adjustment provided more storm water storage in the wet pond and allowed the discharge of more storm water volume to the infiltration basin, without affecting the rate control needed to achieve the target pollutant removal efficiencies (80%) for total suspended solids (TSS) and total phosphorus (TP). As such, the modification should be beneficial for the back-to-back rain events and very intense rain events ≤1.5 inches that are occasionally causing wet pond discharges to Sumner Creek. More storm water storage capacity in the wet pond should also increase discharge lags and reduce the discharge times associated with rain events larger than 1.5 inches.

The modification made to the control structure for the Sterling Ponds wet pond outlet to Sumner Creek seemed to improve storage and infiltration capacity for these types of events in 2007, 2008, and 2009, but was not particularly helpful for the very large rain events (10 events ≥1.5 inches) that occurred in 2010, 2011, 2012, and 2013. Rain events larger than 1.5 inches exceed the intent of the River Falls Storm Water Management Ordinance, so storm water discharges to Sumner Creek might be expected. However, storm water discharges to Sumner Creek during back-to-back or very intense rain events, when rainfall amounts are less than the 1.5-inch ordinance requirement, may need further attention. For back-to-back rain events, more rapid delivery of storm water to the infiltration basin may be desirable between rain events, to ensure substantial infiltration of the first rain event within a 24-hour period. This could be accomplished by increasing the diameter of the pipe (currently 8 inches) leading to the infiltration basin. However, the size of the pipe and rate of storm water delivery to the infiltration basin should also be balanced against the need for adequate water residence time in the wet pond, to achieve target removal efficiencies (80%) for total suspended solids (TSS) and total phosphorus (TP). Another option would be to increase wet pond delivery to the infiltration basin, which currently has significant available capacity, at the potential expense of reduced removal efficiencies for TSS and TP (ordinance permitting). The impacts of such modifications (increasing the rate and amount of storm water delivery to the infiltration basin between large rain events) on wet pond pollutant removal efficiencies could be directly determined by monitoring TSS and TP concentrations at Sites 5IN and 5IB during targeted rain events in the 1.0-1.5-inch range. In addition, perhaps some provision should be made in the River Falls Storm Water Management Ordinance to ensure adequate infiltration of back-to-back 1.5-inch, 24-hour rain events. More capacity in the wet pond may be helpful for capturing more storm water volume during very intense rain events, but the increased volume in the pond could require more infiltration time, which may prove problematic when large, back-to-back rain events occur.

Given the frequent number of rain events ≥1.5 inches during the 2004-2013 monitoring period (24), including 18 that resulted in wet pond discharges to Sumner Creek during the 2005-2013 period, perhaps an ordinance amendment should be considered to require infiltration of all 24-hour rain events ≤2.0 inches. Such an ordinance modification would have covered 10 (42%) of the 24 rain events ≥1.5 inches during the 2004-2013 monitoring period, and potentially would have resulted in 6 fewer rain events with wet pond discharges to Sumner Creek.

The extended Sterling Ponds wet pond discharge times to the infiltration basin after rain events during the May 1-11, May 18-June 1, and June 12-15, 2013 periods suggest possible partial plugging of the pipe conveying wet pond storm water to the infiltration basin. Figure 35 compares rainfall amounts to Sterling Ponds wet pond infiltration times during the 2011-2013 period. Six additional rain events in 2011-2012 (ranging from 0.48-2.13 inches) were also characterized by extended Sterling Ponds wet pond discharge times to the infiltration basin (ranging from 4.7-11.1 days). Given these circumstances in 2011-2013, maintenance work may be needed to clear the pipe between the wet pond and the infiltration basin. The wet pond end (entrance) of the pipe should be checked to ensure that it is not partially plugged by pond vegetation or other organic material. In addition, it may be beneficial to flush the entire length of the pipe.

While this project is primarily focused on evaluating long-term trends, annual performance information is important as well. With the exception of two very large rain events on June 21 (1.59 inches) and June 26 (2.31 inches) and a small-moderate rain event on June 22 (0.44 inch), the storm water management practices at Sterling Ponds prevented thermal impacts on Sumner Creek and the Kinnickinnic River during the May-September (summer) 2013 period. The following should be noted:

- The summer temperature regime in the Kinnickinnic River at Sites 1 and 1A (above and below the Sumner Creek confluence) was generally excellent for coldwater macroinvertebrate and brown trout communities.
- The performance of the Sterling Ponds storm water management practices (wet detention pond and infiltration basin) was excellent during 47 rain events, ranging in magnitude from 0.01-1.16 inches and totaling 11.54 inches of precipitation (73% of the total summer precipitation). All storm water runoff from 47 rain events ≤1.5 inches was infiltrated, as required by the River Falls Storm Water Management Ordinance. Monitoring and analysis of storm water conveyance from the Sterling Ponds wet pond to the infiltration basin will continue in the future, to determine if the intent of the ordinance is being met.
- Smaller rainfall events (less than one inch) caused no thermal impacts on Sumner Creek (see Appendix B). However, during very large rain events on June 21 and June 26, the Sterling Ponds wet detention pond discharged warm water to the Sumner Creek drainage way, for extended time periods (7.2 and 14.7 hours, respectively). The warm storm water discharges during these two rain events may have contributed to secondary thermal spikes (1.0º C and 1.2º C, respectively) in Sumner Creek at Site 4A, as well as to extended durations (21.0 hours and 9.0 hours, respectively) of warmer-than-normal water at Site 4A. The much warmer-than-normal water at Site 4A on June 26 had a notable downstream thermal impact (0.8º C) on the Kinnickinnic River at Site 1. The presence, intensity, and frequency of thermal spikes will continue to be monitored in the years to come.
- "First-flush" thermal spikes were also observed in lower Sumner Creek (Site 4A) during the June 21 and June 26 rain events. These "first-flush" thermal spikes (4.3º C on June 21 and 5.8º C on June 26) seemed to have a local cause. Possible sources contributing to these thermal spikes may include storm water runoff from WI Highway 35, located immediately upstream from Site 4A, and/or warm water from natural wetland areas located a short distance upstream in the upper Sumner Creek drainage way.

Based upon the 2005-2013 temperature monitoring results, it appears that the Sterling Ponds storm water management practices are producing long-term positive results that protect the Kinnickinnic River. A summary of the performance of Sterling Ponds storm water management practices during the 2005-2013 period is presented in Figure 33. Note that the number of summer rain events infiltrated far exceeds the number of rain events (partially) discharged to Sumner Creek each year. Also note that the minimum percentage of summer rainfall infiltrated ranged from 60-92% during the 2006-2013 period. Beyond 2013, these same trends will be monitored from year to year, to determine if favorable results are apparent in the future.

Water Quality Monitoring:

A re-evaluation of the North Kinnickinnic River Monitoring Project was conducted at the end of the 2012 monitoring season. Given budget considerations and time constraints, as well as the challenge of operating automated monitoring equipment and/or collecting grab samples during rainfall and runoff events, the water quality monitoring component of the project was discontinued.

As future resources allow, it would be good to obtain water quality information on the performance of the Sterling Ponds storm water management practices. Automated monitoring equipment could be located at Sites 5IN (Sterling Ponds wet detention pond inlet) and 5MHW (Sterling Ponds wet detention pond outlet). Along with automated sampling at these two locations, grab sampling could be conducted at Site 5IB (Sterling Ponds infiltration basin). Water samples could be analyzed (by a certified laboratory) to determine concentrations of total suspended solids (TSS) and total phosphorus (TP). By comparing these pollutant concentrations at Site IN to concentrations at Site IB, Sterling Ponds wet pond pollutant removal efficiencies can be determined for TSS and TP and compared to the target removal efficiencies (80%). In addition, pollutant concentrations at Site 5MHW can be evaluated to better characterize the water quality impacts of any Sterling Ponds wet pond discharges to Sumner Creek. Finally, potential impacts on pollutant removal efficiencies can be determined, if Sterling Ponds storm water management practices are adjusted to provide improved storm water infiltration capability (see "***Effectiveness of Sterling Ponds Storm Water Management Practices: 2005-2013 Performance Summary"***, above). Large rain events (>1.0 inch) of various magnitudes could be targeted for this Sterling Ponds water quality monitoring work.

Base Flow Surveys:

The USGS stream flow gauge located at County Highway F, as described earlier in this report, is used to determine when a base flow condition exists in the North Kinnickinnic River Monitoring Project Area. When 3-4 days of "flat-line" flow are observed at the USGS station, the river is assumed to be in a base flow condition. With slightly below-normal rainfall during the April-September 2013 period, Kinnickinnic River base flows generally ranged from 85-126 cfs, as measured at County Highway F (Figure 8). As the April-September 2013 period became increasingly drier (Figure 3), base flows gradually decreased. Base flows tended to be a bit higher (105-126 cfs) during the wetter-than-normal months of April, May, and June, and a bit lower (85-115 cfs) during the drier-than-normal months of July, August, and September.

Real-time and recent (120-day) stage, flow, and precipitation data for the USGS monitoring station are web-accessible at:

http://waterdata.usgs.gov/wi/nwis/uv/?site_no=05342000&PARAmeter_cd=00065,00060

In past monitoring years (2005-2012), instantaneous measurements of base flow have been obtained at Sites 1-3 in the Kinnickinnic River and at the mouth of Sumner Creek (Site 4A) within the North Kinnickinnic River Monitoring Project Area. Base flow surveys have been conducted in the spring and autumn, using a handheld SonTek® FlowTracker Acoustic Doppler Velocimeter (ADV).

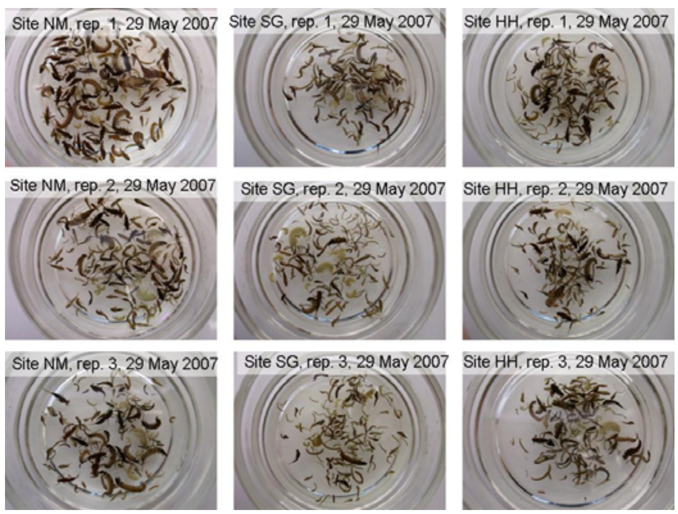
A re-evaluation of the North Kinnickinnic River Monitoring Project was conducted at the end of the 2012 monitoring season. Given budget considerations and time constraints, it was determined that only autumn base flow surveys will be conducted in future monitoring years. However, given time constraints, no autumn base flow survey was conducted in 2013. The results of previous spring and autumn base flow surveys can be found in the 2005-2012 Technical Reports, and in the North Kinnickinnic River Monitoring Project Indicators.

One goal of the River Falls Storm Water Management Ordinance is to maintain strong base flow conditions in the Kinnickinnic River by requiring storm water management practices that promote infiltration of rainfall, thereby maintaining shallow aquifer levels, as well as the springs that provide cold water for the river. During the 2005-2009 period, proportionately similar decreases in spring and autumn base flows occurred at all sites within the project area, including those upstream (Sites 2 and 3) and downstream (Site 1) of Sumner Creek and the Sterling Ponds subdivision. Given this consistent base flow diminution across all sites, it is likely that a regional factor was contributing, rather than a lack of storm water infiltration at Sterling Ponds. Three consecutive summers of below-normal precipitation (2006-2008) and a continuation of moderate-severe drought conditions are the likely causes of the observed base flow reductions through 2009. With above-normal precipitation during the summer of 2010 and only slightly below-normal precipitation during the summer of 2011, base flows rebounded at all sites in the project area. The decreased autumn 2012 base flows in the North Kinnickinnic River Monitoring Project Area were caused by much-reduced rainfall in August and September 2012 and the severe drought conditions that developed by early October 2012. Performance monitoring at Sterling Ponds has demonstrated that the storm water management practices have provided excellent infiltration capacity since 2004, thereby helping to sustain groundwater recharge during any extended dry periods.

Annual autumn base flow surveys will provide an ongoing measure for determining if base flow conditions will be sustained in the future as development progresses in the North Kinnickinnic River Monitoring Project Area.

Macroinvertebrate Monitoring:

Biotic indicators such as macroinvertebrates (aquatic insects and crustaceans) are often used to complement physical and chemical measurements in stream monitoring programs. Biological data add a significant dimension to monitoring procedures because they provide an analysis that measures long-term phenomena. Because many aquatic organisms live in the stream environment for a year or more, they are excellent indicators of past as well as present water quality conditions. During the 2004-2012 period, macroinvertebrate samples were collected annually at Sites 1-3 within the North Kinnickinnic River Monitoring Project Area. Sampling was generally conducted in late May. After collection, the organisms are identified and counted in the laboratory, and various biological indices can then be calculated for each monitoring site. The index values are indicative of water quality, depending upon the pollution tolerances of the macroinvertebrates collected at the monitoring sites.



Site 1 Site 2 Site 3

Triplicate macroinvertebrate samples collected at Sites 1-3 in 2007

The use of benthic (bottom-dwelling) macroinvertebrates to evaluate stream water quality was initiated in Wisconsin with the work of W. L. Hilsenhoff at the University of Wisconsin-Madison. The Hilsenhoff Biotic Index (HBI), which has been modified and refined over a number of years (Hilsenhoff 1977, 1982, 1987), is particularly useful for determining the influence of organic pollution on macroinvertebrates. The Wisconsin Department of Natural Resources has used this index for many years in long-term stream monitoring programs.

Macroinvertebrate HBI determinations follow a sequence of field sample collection, laboratory sorting, identification and enumeration, and index calculation. All macroinvertebrates in each sample are identified to the lowest practical taxon, typically genus, but also species where possible. Each macroinvertebrate taxon has been assigned a specific tolerance value at the genus or species level. These tolerance values range from

0 (extremely intolerant of organic pollution) to 10 (extremely tolerant of organic pollution). The Hilsenhoff Biotic Index (HBI) is calculated for each macroinvertebrate sample, as follows:

$$HBI = \sum T_1 \times TV_1 \ldots. T_n \times TV_n / N$$

Where:

T = number of individuals in the taxon
TV = tolerance value of the taxon
n = number of taxa
N = total number of individuals in the sample

The more intolerant taxa that are present in a macroinvertebrate sample, the lower the biotic index, indicating better water quality, as shown in the table below.

HBI Value	Water Quality	Degree of Organic Pollution
0.00-3.50	Excellent	No apparent organic pollution
3.51-4.50	Very Good	Slight organic pollution
4.51-5.50	Good	Some organic pollution
5.51-6.50	Fair	Fairly significant organic pollution
6.51-7.50	Fairly Poor	Significant organic pollution
7.51-8.50	Poor	Very significant organic pollution
8.51-10.00	Very Poor	Severe organic pollution

HBI values provide the observer with quantitative data that can be used for comparing water quality at various river sites. Additionally, the work yields supplementary metrics useful for further analysis. These metrics include: taxa richness, numerical dominance, and proportions of sensitive groups (Ephemeroptera, Plecoptera, Trichoptera, i.e., EPT index).

The 2004-2009 macroinvertebrate HBI values for triplicate samples collected at Sites 1-3 in the North Kinnickinnic River Monitoring Project Area are presented in Table 1 (below). The mean 2004-2009 macroinvertebrate HBI values at Sites 1-3 are also presented in Figure 36. The 2004-2009 data establish an ongoing baseline for assessing the long-term health of the macroinvertebrate community within the project area.

Table 1. Macroinvertebrate HBI Values in the Kinnickinnic River: 2004-2009

	Sampling Location	2004 HBI Values	2005 HBI Values	2006 HBI Values	2007 HBI Values	2008 HBI Values	2009 HBI Values
Site 1: North Main	50 yards upstream from North Main Street Bridge, River Falls, WI Lat. 44°52'32.1", Long. 92°37'15.6"	2.77 2.86 2.99	3.17 3.04 2.79	3.57 3.57 3.62	3.64 3.85 4.07	2.89 3.95 3.78	4.04 3.85 3.89
	Mean of 3 reps:	2.87	3.00	3.59	3.85	3.54	3.93
Site 2: Swinging Gate (STH 65)	Approx. 1.1 miles upstream from North Main Street Bridge, River Falls, WI Lat. 44°53'12.9", Long. 92°36'40.9"	4.20 3.99 3.85	4.30 4.67 4.45	4.01 3.91 4.13	3.85 3.84 3.62	5.41 4.18 4.52	4.14 4.08 3.66
	Mean of 3 reps:	4.01	4.47	4.02	3.77	4.70	3.96
Site 3: Hebert-Hagen	Approx. 0.4 mile downstream from Quarry Rd., River Falls, WI Lat. 44°53'22.2", Long. 92°36'19.5"	3.37 4.04 3.60	3.65 3.55 3.13	3.88 3.72 3.89	3.65 3.86 3.74	4.44 3.89 3.78	3.66 3.74 3.26
	Mean of 3 reps:	3.67	3.44	3.83	3.75	4.04	3.55

During the 2004-2009 period, mean HBI values at Site 1 were indicative of very good-excellent water quality, mean HBI values at Site 2 were indicative of good-very good water quality, and mean HBI values at Site 3 were indicative of very good-excellent water quality. Mean annual HBI values at Site 1 have been increasing slightly (Figure 43), indicating a slight degradation of water quality. However, the 2006-2009 values were still indicative of very good water quality. In spite of some apparent degradation during the 2004-2009 period, the mean annual HBI values at Site 1 are generally less than or comparable to the mean annual HBI values at Sites 2 and 3, indicating slightly better water quality at Site 1. Mean annual HBI values at Site 2 have been relatively consistent; but values increased in 2005 and 2008, indicating a slight degradation of water quality. However, with the exception of 2008, all annual values during the 2004-2009 period were indicative of very good water quality. Mean annual HBI values at Site 3 were relatively consistent during the 2004-2009 period, and generally indicative of very good water quality.

The comparability of mean annual macroinvertebrate HBI values at Sites 1-3 during the 2004-2009 period indicates that no storm water impacts were apparent at Site 1, downstream from Sumner Creek and the Sterling Ponds subdivision. In fact, the mean 2004-2009 macroinvertebrate HBI values at Sites 1-3 indicate that the best water quality was evident at Site 1. The mean 2004-2009 macroinvertebrate HBI value at Site 1 (3.46) was indicative of excellent water quality, while the mean 2004-2009 macroinvertebrate HBI values at Site 2 (4.16), and Site 3 (3.71) were indicative of very good water quality. The 2004-2009 macroinvertebrate monitoring results nicely corroborate the 2004-2009 Kinnickinnic River and Sterling Ponds temperature monitoring results, which indicated that the summer temperature regimes in the Kinnickinnic River at Sites 1-3 were generally excellent for coldwater macroinvertebrate communities, and the Sterling Ponds storm water management practices were effectively treating storm water, as intended by the River Falls Storm Water Management Ordinance.

Macroinvertebrate monitoring was also conducted in May 2010, May 2011, and May 2012, but the taxonomic analysis of these samples has not yet been completed by the University of Wisconsin-Stevens Point laboratory.

A re-evaluation of the North Kinnickinnic River Monitoring Project was conducted at the end of the 2012 monitoring season. Given budget considerations and time constraints, it was determined that future macroinvertebrate monitoring will only be conducted at Sites 1 and 2 on a biennial basis (in even years). As such, no macroinvertebrate monitoring was conducted in 2013. Annual HBI values and other macroinvertebrate indices will continue to be posted as they become available, and long-term trends in these indices will continue to be evaluated, to assess the ongoing health of the Kinnickinnic River macroinvertebrate community.

North Kinnickinnic River Monitoring Project Indicators:

As a part of the North Kinnickinnic River Monitoring Project, key physical and biological indicators have been monitored to evaluate the effectiveness of the River Falls Storm Water Management Ordinance for preventing degradation of the Kinnickinnic River due to development-related storm water impacts. These ten key indicators, which have been monitored since the onset of the project in 2004, include:

- Total rainfall in River Falls during the April-September period
- % April-September rainfall infiltrated, per the River Falls Storm Water Management Ordinance
- Number of summer (May-September) rain events infiltrated and % summer rainfall infiltrated, as measured by monitoring at Sterling Ponds
- Summer (May-September) average air temperature in River Falls
- Summer (May-September) average temperatures in the Kinnickinnic River and Sumner Creek
- % of the summer Kinnickinnic River temperatures favorable for biota
- % of the summer Sumner Creek temperatures favorable for biota
- Spring base flow conditions in the Kinnickinnic River and Sumner Creek

- Autumn base flow conditions in the Kinnickinnic River and Sumner Creek
- Kinnickinnic River macroinvertebrate HBI values

The North Kinnickinnic River Monitoring Project Indicators for the 2004-2013 period can be found on the project website. As monitoring continues in the future, these indicators can evaluate the annual effectiveness of the River Falls Storm Water Management Ordinance and track long-term trends that document protection of the Kinnickinnic River.

Appendix A

Sterling Ponds: Wet Pond Discharges to Sumner Creek
2005-2013

2005:
During six summer rain events in excess of one inch, the Sterling Ponds wet detention pond discharged warm water (17.9-27.2º C) to the Sumner Creek drainage way, often for extended periods (5-14 hours). Three of these rain events (June 11, July 25, and September 21) were less than 1.5 inches.

Date	Rainfall Amount	Discharge Lag	Discharge Time
June 8	1.76 inches	No Data	11 hours
June 11	1.43 inches	No Data	13.5 hours
July 8	4.00 inches	No Data	14 hours
July 25	1.38 inches	No Data	9 hours
Sept. 21	1.49 inches	30 minutes	5 hours
Sept. 24-25	2.49 inches	No Data	14 hours

2006:
During three summer rain events in excess of 1.5 inches, the Sterling Ponds wet detention pond discharged very warm water (23.4-26.5º C during the July 24 event) to the Sumner Creek drainage way, often for extended periods (4 hours during the July 24 event).

Date	Rainfall Amount	Discharge Lag	Discharge Time
July 24	1.80 inches	10 minutes	4 hours
August 2*	2.26 inches	No Data	No Data
August 24*	1.63 inches	No Data	No Data

*Antecedent rain events occurred on August 1 (1.04 inches) and August 23 (0.71 inches)

2007:
The Sterling Ponds wet detention pond only discharged to Sumner Creek during the large, back-to-back rain events on August 27 (1.72 inches) and August 28 (1.04 inches), and during the large, intense rain event on September 20 (1.19 inches).

Date	Rainfall Amount	Discharge Lag	Discharge Time
August 27	1.72 inches	1 hour	4 hours
August 28	1.04 inches	2.5 hours	3 hours
Sept. 20*	1.19 inches	1 hour	5 hours

*An antecedent rain event occurred on September 18 (1.64 inches)

2008:
The Sterling Ponds wet detention pond only discharged to Sumner Creek during the large, intense rain event on July 25 (1.16 inches).

Date	Rainfall Amount	Discharge Lag	Discharge Time
July 25	1.16 inches	20 minutes	3.3 hours

2009:
The Sterling Ponds wet detention pond only discharged to Sumner Creek during the very large, intense rain event on August 8 (3.76 inches).

Date	Rainfall Amount	Discharge Lag	Discharge Time
August 8*	3.76 inches	None	15 hours

*An antecedent rain event occurred on August 7 (0.98 inches)

2010:
The Sterling Ponds wet detention pond discharged to Sumner Creek during three very large summer rain events in excess of 1.5 inches, and twice during a rain event of unknown magnitude on August 8.

Date	Rainfall Amount	Discharge Lag	Discharge Time
June 25*	2.97 inches	50 minutes	2.5 hours
August 8	Unknown	40 minutes	12.5 hours
August 8	Unknown	30 minutes	2.7 hours
August 10-11*	2.43 inches	2 hours	20.0 hours
Sept. 23*	2.58 inches	None	34.5 hours

*Antecedent rain events occurred on June 23 (1.44 inches), August 8 (>0.55 inch), and September 21-22 (2.04 inches)

2011:
The Sterling Ponds wet detention pond discharged to Sumner Creek during two large summer rain events in excess of 1.5 inches, and during a moderate rain event (0.71 inch) on July 16.

Date	Rainfall Amount	Discharge Lag	Discharge Time
June 21*	2.46 inches	17.5 hours	18.2 hours
July 16*	0.71 inch	40 minutes	14.7 hours
August 16*	1.78 inches	1.5 hours	16.0 hours

*Antecedent rain events occurred on June 14-19 (a combined 1.94 inches), July 15 (0.60 inch), and August 13 (1.03 inches)

2012:
The Sterling Ponds wet detention pond discharged to Sumner Creek during two large summer rain events in excess of 1.5 inches.

Date	Rainfall Amount	Discharge Lag	Discharge Time
May 5-6*	2.27 inches	12.2 hours	14.8 hours
June 20*	2.05 inches	10 minutes	19.3 hours

*Antecedent rain events occurred on May 1-4 (a combined 1.46 inches) and June 18-19 (a combined 1.34 inches)

2013:
The Sterling Ponds wet detention pond discharged to Sumner Creek during two large summer rain events in excess of 1.5 inches, and during a small-moderate rain event (0.44 inch) on June 22.
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Date	Rainfall Amount	Discharge Lag	Discharge Time
June 21	1.59 inches	16.2 hours	7.2 hours
June 22*	0.44 inch	10 minutes	1.3 hours
June 26*	2.31 inches	40 minutes	14.7 hours

*Antecedent rain events occurred on June 21 (1.59 inches) and June 21-23 (a combined 2.32 inches)

Discharge Lag is defined as the time lag between the onset of discharge to the infiltration basin and the onset of discharge to Sumner Creek.

Discharge Time is the length of time that discharge occurs to Sumner Creek.

Appendix B

Reasons why small rainfall events (less than one inch) caused no storm water impacts at Sterling Ponds in 2013

Smaller rainfall and runoff events can have significant storm water impacts on the Kinnickinnic River, as was evident by the numerous thermal spikes (Figures 15 and 17) caused by direct (untreated) storm water discharges upstream from the Division Street monitoring site in 2013. However, storm water runoff from the Sterling Ponds subdivision caused no impacts on the Kinnickinnic River during these smaller rainfall events (less than 1 inch) in 2013, due to several factors:

1. Building progress remained very limited in the Sterling Ponds subdivision in 2013, and has only occurred in the southeast and northeast quadrants of the subdivision during the 2004-2013 period.

   In the southeast quadrant, 3 single-family housing units were built by year-end 2003, 19 single-family housing units were built by year-end 2004, 33 single-family housing units were built by year-end 2005, 36 single-family housing units were built by year-end 2006, 48 single-family housing units were built by year-end 2007, 56 single-family housing units were built by year-end 2008, and 58 single-family housing units were built by year-end 2009. No additional single family units were built in 2010 and 2011, leaving the year-end totals at 58 units. In 2012, 1 additional single family unit was built, leaving the year-end total at 59 units. In 2013, 5 additional single family units were built, leaving the year-end total at 64 units.

   In the northeast quadrant, 2 duplex units were complete by year-end 2005, and 2 multi-family (8-plex) units were under construction. By year-end 2006, 1 single-family unit, 2 duplex units, 3 multi-family 8-plex units, and 2 multi-family 10-plex units were complete, for a total of 49 units. By year-end 2007, 3 single-family units, 5 duplex units, 3 multi-family 8-plex units, and 4 multi-family 10-plex units were complete, for a total of 77 units. By year-end 2008, 11 single-family units, 8 duplex units, 3 multi-family 8-plex units, and 4 multi-family 10-plex units were complete, for a total of 91 units. By year-end 2009, 12 single-family units, 9 duplex units, 3 multi-family 8-plex units, and 4 multi-family 10-plex units were complete, for a total of 94 units. In 2010, only two single-family units were built, leaving the year-end total at 96 units, as follows: 14 single-family units, 9 duplex units, 3 multi-family 8-plex units, and 4 multi-family 10-plex units. No additional housing units were built in 2011, 2012, and 2013, leaving the year-end totals at 96 units.

   A build-out total of 600 units is projected for Sterling Ponds. By year-end 2013, a combined 160 units (27% of projected build-out) were complete in the southeast and northeast quadrants of Sterling Ponds.

Maps of Sterling Ponds build-out progress in 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, and 2013 are available on the project website ("Annual Reports"). With 64 (43%) of approximately 150 single family units complete in the southeast quadrant, 96 (64%) of approximately 150 family units complete in the northeast quadrant, and no development occurring in the southwest and northwest quadrants by year-end 2013, impervious surfaces (rooftops, sidewalks, driveways, and streets) still account for a relatively small proportion of the overall Sterling Ponds subdivision area. For example, the percent impervious area in the storm watershed draining to Site 5 in the southeast quadrant of Sterling Ponds (see 2013 build-out map) was only 12.3% (8.2 acres of 66.8 acres) in 2013, reflecting a build-out rate of 39.2% (58 of 148 lots). The percent impervious area and percent build-out rate for each of the ten project years are as follows:

2004:	7.9% Impervious	10.8% Build-out
2005:	9.1% Impervious	18.2% Build-out
2006:	9.5% Impervious	20.9% Build-out
2007:	11.1% Impervious	31.8% Build-out
2008:	11.5% Impervious	33.8% Build-out
2009:	11.7% Impervious	35.1% Build-out
2010:	11.7% Impervious	35.1% Build-out
2011:	11.7% Impervious	35.1% Build-out
2012:	11.8% Impervious	35.8% Build-out
2013:	12.3% Impervious	39.2% Build-out

2. Four wet storm water detention ponds were already in place in 2013, with some capacity for storing storm water runoff from the existing impervious areas, especially during smaller rain events. Two of the four infiltration basins paired with the wet storm water detention ponds were not yet functional in 2013. However, the third infiltration basin (serving the northeast quadrant of Sterling Ponds) and the fourth infiltration basin (serving the southeast quadrant of Sterling Ponds) were functional throughout the April-September 2013 period (see 2013 build-out map). These infiltration basins were designed and constructed to meet the current River Falls Storm Water Management Ordinance infiltration requirements. The Sterling Ponds infiltration basins remained off-line throughout 2004, so that percolation testing could be conducted and native vegetation had an opportunity to become established. The northeast and southeast wet detention ponds and infiltration basins should have provided effective storm water treatment for the northeast and southeast quadrants of Sterling Ponds in 2013, as required by the ordinance. Indeed, monitoring of the southeast storm water management practices in 2013 demonstrated excellent infiltration for 47 summer rain events, ranging in magnitude from 0.01-1.16 inches and totaling 11.54 inches (73% of the total summer precipitation) (see ***Effectiveness of Sterling Ponds Storm Water Management Practices***).

3. The Sterling Ponds subdivision is approximately 1.5 miles from the Kinnickinnic River, with a connection via Sumner Creek. Sumner Creek is a low-gradient tributary that typically exhibits only intermittent flow during larger rain events. Downstream wetland areas that are part of the Sumner Creek drainage way and the Sumner Creek channel itself likely provide some storage of any Sterling Ponds storm water discharges, especially during larger rain events that may exceed the capacity of the wet detention ponds and the functional infiltration basins.

Monitoring at Sterling Ponds in 2013 capably evaluated ordinance effectiveness and identified the storm water impacts related to three large rainfall events in excess of 1 inch (see ***Effectiveness of Sterling Ponds Storm Water Management Practices***). Ongoing annual monitoring and evaluation will be especially important as the Sterling Ponds subdivision continues to develop and impervious area increases.