CHAPTER 7– PROJECT SUMMARY

This project was conducted to assess changes in water quality and channel morphology resulting from urban development in the Baird Creek watershed and to assist the Baird Creek Preservation Foundation and the City of Green Bay in making informed land management decisions to protect the unique habitat of the Baird Creek Greenway. Sampling at two upstream locations and the downstream USGS Station at Superior Road isolated impacts from the urbanizing segment of the watershed. Land use, impervious cover, and current construction activity were evaluated for each of the subwatersheds. Concentrations of total suspended solids (TSS), total phosphorus, and total dissolved phosphorus for low-flow and storm event samples were compared between sites. Also, sediment and phosphorus loads were compared between the upstream site on the agricultural tributary and the downstream sampling location. To assist in future research, a relationship was established between continuous turbidity readings and stream sediment concentrations. Finally, channel morphology was assessed at twelve locations established in June 2002 to determine if alterations in watershed hydrology were impacting Baird Creek and its tributaries. This chapter summarizes the overall project results, the implications for future land management, and the potential for further research on Baird Creek.

Summation of Results

As with all rain-dependent research projects, this study was complicated by weather patterns and equipment malfunctions. The 2004 sampling season was characterized by heavy spring flooding followed by a period of late-summer drought. According to the National Weather Service, May 2004 was the second wettest May on record with 210.8 mm of precipitation. Although the Green Bay area received 177.8 mm more rain than the historical average during May and June, July through September precipitation was 154.9 mm below normal (National Weather Service 2004). Because seasonal rainfall distribution did not match historical patterns, additional research may be necessary to fully understand the impacts of seasonality on stream water quality parameters. Failures with the YSI multi-parameter sonde equipment at the upstream sites during May also complicated efforts to estimate loads for the entire sampling period. Unless sampling continues at the upstream sites, use of specific load and concentration values from this study for detailed modeling efforts should be done with hesitation. However, the results from this study can still be used to make generalizations about the impacts of urbanization on Baird Creek, and can also identify opportunities for further study.

Land Use Change and Impervious Cover

The Baird Creek watershed is rapidly transitioning from primarily agricultural to urban land use. By 2022, over 25% of the watershed upstream of Superior Road and over 60% of the South Branch watershed will be in urban development. As of 2005, the majority of the urbanization had occurred in the South Branch and the watershed

downstream of the confluence. Approximately 1% of the total area of the USGS Station watershed was under construction per year from 2003 to 2005. The North Branch and South Branch watersheds experienced 0.1% and 4% rates of construction, respectively.

According to established research, the rapid land use change indicates that Baird Creek is a watershed in peril. Several studies have shown that as impervious cover increases above 10% of the watershed area, streams begin to show signs of stress; when impervious cover exceeds 25%, streams become highly unstable and non-supporting of aquatic life (Schueler and Holland 2000a). Under these guidelines, the Christa McAuliffe Park Ravine and Huron-Sitka Detention Basin Ravine watersheds were already approaching the "non-supporting" designation at 20.0% and 17.9% cover in February 2005, respectively. The results for impervious cover under the Green Bay Smart Growth Plan show that not only will these two tributaries fall into this classification, but the South Branch will also reach 29.5% imperviousness by 2022.

Water Quality

Results for pollutant concentrations and loads indicate that urbanization is adversely impacting the water quality of Baird Creek. Statistical analysis showed that event sediment concentrations were significantly higher on the urbanizing South Branch than on the agricultural North Branch at the 95% confidence level. Although the North Branch contributed 60 to 70% of the total discharge recorded at the USGS Station site during a period of early summer storm events, it only provided 30 to 40% of the total sediment load. The remaining 60 to 70% of the sediment load was attributed to the South

Branch and the watershed downstream of the confluence point. Therefore, although the portion of the watershed actively transitioning to urban land use only comprised 18.5% of the total watershed area, it contributed a disproportionately high amount of the sediment load in Baird Creek.

Despite statistically higher total phosphorus concentrations during storm events on the South Branch, the observed phosphorus load was consistent with the proportion of discharge provided by each branch of the stream. This may be explained by apparently higher dissolved phosphorus concentrations during event flows on the North Branch, although the difference was not statistically significant. However, because discharge was disproportionately higher for the urbanizing segment of the watershed, this area contributed more phosphorus on a per area basis than the agricultural North Branch.

Sediment loading from the urbanizing section of the Baird Creek watershed may also explain changes in the aquatic ecosystem. Studies in 1998, 1999, 2003, and 2004 by St. Norbert College and the University of Wisconsin – Milwaukee (UWM) indicated that the composition of the fish population in Baird Creek was shifting towards more tolerant species (Lake Michigan Forum 2004, LFRWMP 2005). Sensitive fish species such as redside dace, fantail darters, and rosyface shiners dramatically declined in abundance between 1998 and 2004. Over the same period, there was a simultaneous increase in the numbers of tolerant species such as green sunfish and blacknose dace. IBI scores for individual fish samples taken in 2004 by UWM at the USGS Station site and on the North and South Branches were 33, 31, and 20, respectively. The scores indicated fair quality ratings for the USGS Station and North Branch sites, but poor quality on the South

Branch. Considering the results of the water quality study, it is unsurprising that the integrity of the aquatic community also appears to be declining.

The Relationship between Sediment Concentration and Turbidity

Continuous turbidity monitoring appears to be a reasonable surrogate for sediment load prediction for Baird Creek, and may provide cost effective, rapidly available information on watershed sediment delivery in future studies. Linear regression analysis showed a strong relationship between sediment concentrations and turbidity readings in Baird Creek at both the USGS Station and North Branch sites, accounting for 97-98% of the model variance. However, no significant difference was found due to event versus low-flow samples or due to hydrograph position. The effect of seasonality was not analyzed due to lack of data from late summer and fall storm events and equipment malfunction.

The relationship between sediment concentrations and turbidity significantly differed between the upstream and downstream sampling sites. We hypothesize that the difference between these two models is directly related to watershed land use and the associated hydrologic response between the primarily agricultural North Branch site and the urban storm water additions above the USGS station. Significant sediment load from urban tributaries and bank erosion enters Baird Creek below the North Branch monitoring station. The higher proportion of large-sized particles (e.g. sand) from these sources may be influencing the refraction of light through the water column and thus the turbidity

sensor response, as compared to that of the silt and clay-sized suspended sediment carried from the agricultural watershed.

Channel Morphology

In July 2004, changes in bankfull width and channel enlargement ratios were assessed at twelve channel cross-sections established in June 2002 on Baird Creek and its tributaries by Applied Ecological Services, Inc. (AES). Land use within the watershed changed substantially between the 2002 and 2004 channel characterization surveys. Although detailed land use data from 2002 were unavailable, 18% of the Christa McAuliffe Park Ravine watershed and 19% of the Huron-Sitka Detention Pond Ravine watershed were under construction as of August 2003. Active construction work at these sites most likely began in late summer 2002 or in spring 2003. Also, as AES ecologists noted in their report, the bridge connecting Huron and Woodside Roads upstream of Site 10 on the South Branch was under construction during the 2002 survey. Any development located off this road obviously occurred after the AES field work.

May 2004 was the second wettest May recorded in Green Bay history; however, atypical weather patterns alone cannot justify the increase in bankfull widths and cross-sectional areas observed at all the channel morphology assessment sites on urbanizing tributaries. Of the eleven sites evaluated for bankfull width, all five sites on the urbanizing tributaries were ranked in the top five sites in terms of percent change. Analysis of variance on the ranks of the data showed that the sites on the urbanizing tributaries significantly increased in bankfull width as compared to the other categories at

the 95% confidence level. However, neither the agricultural or main channel site categories statistically differed from each other. The greatest channel enlargement occurred at Site 1 on the Christa McAuliffe Park Ravine tributary, which increased 1104% in size between 2002 and 2004. Site 9 on the North Branch was the only site to decrease in channel area due to sediment deposition. Of the six sites located on the urbanizing tributaries, four were ranked in the top five sites in terms of percent enlargement. However, analysis of variance on the ranks of the data failed to detect a significant difference in the percent enlargement between categories at the 95% confidence level.

Although the comparison between assessment sites of changes in bankfull width clearly showed that the urbanizing tributaries were expanding in size, the statistical analysis of channel enlargement was less conclusive. However, the lack of difference between location categories was explained by the drastic enlargement at Site 8 on the main channel downstream of the confluence and the lack of change at Site 2 on the Christa McAuliffe Park Ravine tributary. Site 8 was most likely impacted by flows from the South Branch and Huron-Sitka Detention Basin Ravine. Also, the lack of enlargement at Site 2 was explained by the presence of a large wetland complex just upstream, which dissipated water velocity, stored excess stormwater, and decreased the potential for bank erosion at the downstream site. The inconsistencies in channel enlargement that occurred at Sites 8 and 2 relative to other sites on the main channel and urbanizing tributaries clarified why differences were not statistically found between the location categories. However, considering the results of the bankfull width comparison and the pattern of channel enlargement shown by Figure 5.4, it was concluded that

urbanization has caused substantial changes in the morphology of the urbanizing tributaries of Baird Creek, although fewer impacts have been seen at the sites furthest downstream on the main channel.

Preliminary Evaluation of the L-THIA Watershed Development Assessment Tool

The L-THIA watershed development assessment tool is currently being used by the Bay Lake Regional Planning Commission to assess the potential impacts of changing land use for the portion of the Baird Creek watershed outside the Green Bay City limits. This study assessed the viability of using this nationally-based model to predict local conditions by comparing L-THIA predictions for phosphorus and suspended solids loads under 2004 land use to observations taken at the USGS Station at Superior Road and SWAT model predictions generated by Baumgart (2005). L-THIA predictions were also made for the City of Green Bay Smart Growth 2022 Plan to evaluate the impacts of future land use.

The L-THIA model under-predicted 2004 observed phosphorus loads in Baird Creek by 66% and observed suspended solids loads by 90%. Several reasons for the discrepancies were hypothesized, including deviation of 2004 weather patterns from the 30-year average, differences in annual runoff from model exclusion of baseflow, neglection of bank failure and construction site erosion, and higher phosphorus yields in the Lower Fox River Basin than the national average. Comparisons between L-THIA predictions for existing and future land use showed a reduction in both phosphorus and sediment loads under the 2022 land use plan, which did not agree with previous results

showing elevated sediment and phosphorus loads on a per area basis from the urbanizing sections of the Baird Creek watershed. Model results for the impacts of future land use may be compromised by neglecting bank erosion and by assumptions concerning runoff from agricultural land use that may not hold true for the Baird Creek watershed.

Based on the results, caution is warranted in using the L-THIA model to predict impacts of land use change in the Baird Creek watershed. Although use of L-THIA enables forecasting of the potential water quality impacts of future land use scenarios, the simple model does not provide insight into the effects of urbanization resulting from the transition period, which may impact the stream ecosystem for decades to come. The Advanced Input version of L-THIA may provide more accurate predictions of sediment and phosphorus loads; however, detailed research would first be required to establish event mean concentrations for individual land uses in areas with similar soils and climate as the Baird Creek watershed. In all, this study showed that care must be taken to fully understand the hydrological processes being modeled when evaluating alternative land use planning tools and comparing predictions to actual monitoring data.

Implications for Future Land Management

This project established that urban development and increased impervious cover in the Baird Creek watershed is detrimentally impacting stream water quality and channel stability. This verified conclusions from other research that "protection and reforestation of riparian areas is critical for preventing severe stream degradation, but alone these measures are not adequate to maintain biological integrity in streams draining highly

urban basins" (Morley 2000). Even though the riparian zone for Baird Creek has largely been protected with the Baird Creek Greenway, the aquatic ecosystem is still threatened. Preserving the biotic integrity of Baird Creek under changing watershed land use will require addressing the design of development and impervious surfaces within the watershed.

Research suggests that rewriting municipal subdivision ordinances to specify lot size, frontage, and setback maximums instead of minimums could reduce the overall amount of imperviousness and its effects on stream ecology. For example, reducing lot size from 1-acre to ½-acre parcels, lot frontage from 70-feet to 50-feet, and front setback from 40-feet to 25-feet decreases the impervious cover in residential neighborhoods by 30% (Stone 2004). Street design is also crucial, as blanket design criteria under many ordinances result in travel lanes which are the same width as on interstate highways and on-street parking that provides as many as 4.5 to 6.5 parking spaces per residence (Prince George's County Maryland 1999). Eliminating underutilized parking spaces on one side of the street can reduce overall impervious by as much as 25%. Opportunities also exist to decrease a watershed's effective impervious area by disconnecting rooftops and parking lots with rain gardens and other methods of depressional storage. Including design techniques such as these in future developments could lessen the impacts of the proposed 2022 Smart Growth Plan on Baird Creek.

A recent study by the US Geological Survey in Dane County, WI, concluded that stormwater management and erosion controls implemented in a residential development near Brewery Creek were sufficient to produce no measurable impacts on stream hydrology, ecology, and geomorphology (Selbig et al. 2004). This development

integrated a variety of best management practices (BMPs), including reduced street widths, grassed bioretention swales along roads and in boulevard medians, infiltration basins and stone cribs, vegetated stream buffers, and preservation of existing woodlands. Many of these practices could be retrofitted to existing and proposed development in the Baird Creek watershed to reduce peak storm event runoff and to lessen the potential for stream erosion. In particular, the City of Green Bay could add bioretention swales along flow paths, require rain gardens on individual residential lots, and modify detention basins to provide additional storage, promote infiltration, and retain stormwater from smaller events.

The Brewery Creek study also stressed the importance of maintaining erosion control BMPs on construction sites, noting that Dane County, WDNR, or USGS personnel were at the site on a daily basis during wet periods to assess damages and highlight areas needing repair. As a common problem across the country, the lack of proper installation, maintenance, and code enforcement of erosion control practices can substantially contribute to sediment loading in streams. In 2004, the Baird Creek Watershed Stewardship Assessment found that similar problems may exist locally as the City of Green Bay currently does not have enough available staff time for conducting stormwater-related inspections of construction sites (Lake Michigan Forum 2004). Enforcement of these ordinances already on the books could offer significant protection for the Baird Creek ecosystem.

In conjunction with the City of Green Bay, the Baird Creek Preservation Foundation hired AES to perform an update to the 2002 study that would recommend restoration strategies for the Christa McAuliffe Park and Huron-Sitka Detention Basin Ravines

(O'Leary et al. 2004). AES identified preliminary locations and conceptual details for in-stream channel stabilization techniques to repair failing banks and prevent additional channel degradation in the tributaries. Although the updated report recommended best management practices (BMPs) to promote infiltration in three other subwatersheds of Baird Creek slated for future development, no specific mention was made to implement these practices or other retrofits within the watersheds of the two degraded ravines. As noted by other researchers, focusing all efforts on repairing bank erosion without addressing the underlying cause (i.e. increased flows, impervious surfaces) results in a "band-aid" remedy that will not be sustainable over time (Booth 1991). Instead, solutions such as those utilized in the Brewery Creek study should be considered for these tributaries, as only a watershed-based approach will adequately protect the aquatic integrity of Baird Creek.

Opportunities for Further Research

The Baird Creek watershed will continue to urbanize as the City of Green Bay implements the 2022 Smart Growth Plan. This project provides baseline data for future research to investigate variations in stream water quality and channel morphology as the land use changes. In particular, detailed studies may provide insight on the effectiveness of BMPs in controlling erosion and protecting predevelopment hydrology. Also, revisiting the channel morphology assessment sites in 2006 would provide the biannual evaluation recommended by the 2002 AES study.

For the near future, continuation of sampling at the North Branch site would furnish additional data points for comparison, assist with modeling efforts, and allow assessment of seasonal variability of water quality parameters. Based on the results of the sediment-turbidity relationship, this monitoring could be accomplished by deploying a YSI sonde in conjunction with limited water sampling to maintain the calibration curve. Due to the sampling difficulties and equipment losses experienced at the South Branch site as compared to the relatively stable North Branch, it is recommended that efforts to quantify loads from the urbanizing part of the watershed be accomplished through subtraction of the North Branch contribution from the USGS Station site.

Characterization of particle-size and phosphorus concentrations of bank materials on the North Branch, South Branch, and other tributaries may prove valuable in understanding potential sources of sediment and phosphorus. Establishing the particle size distribution for suspended sediment samples would also assist in understanding site-to-site differences in the sediment-turbidity relationships. The relationships could also be strengthened by selecting samples for sediment analysis based solely on the real-time turbidity data, thus completing the curve with well-spaced samples throughout the full range of observed turbidity values.

In all, this study established the adverse impacts that urban development is having on the aquatic ecosystem of Baird Creek. Continuation of this study would provide the City of Green Bay and the Baird Creek Preservation Foundation with knowledge of stream response to future watershed changes, and allow assessment of alternative development strategies and BMP design. Also, further understanding of the dynamics of stream

discharge and pollutant loads under urbanizing conditions could be applied to other watersheds in the Western Lake Michigan Drainage Basin and throughout Wisconsin.