The pages in this document were taken from the "Millers Creek Watershed Improvement Plan" published in April 2004. The entire document can be found at http://www.aamillerscreek.org/Findings.htm.

Millers Creek Watershed Improvement Plan

Excerpt Showing an Example of Identification of Potential Management Strategies

April 2004

6.2 Methodology

6.2.1 Qualitative Feasibility Assessment

The first step in identifying improvement opportunities was to define a set of available watershed improvement tools based on available technology and accepted watershed management practices. **Table 6.1** presents seven categories of watershed improvement tools and several practices that fall within those categories. The categories and practices are discussed below in more detail.

The second step was to identify sites in the watershed where these practices could be applied. This process involved the use of GIS and field reconnaissance. Potential sites were identified based on several observable site characteristics including size, land use, presence of existing storm water features, location, and physical constraints. During the process, the team specifically looked for ways to achieve project goals and objectives through identifiable improvement sites. The process was conservative in terms of omitting sites or failing to identify potential sites. This strategy was used to ensure that we were including opportunities that could be eliminated later through more detailed feasibility analyses rather than omitting sites that might provide a potential benefit(s) to Millers Creek.

Table 6.1 Available Technological Controls, Best Management Practices, and Resource Improvement Methods

Stormwater Practices	Stewardship	Regulatory & Administrative Practices	Stream Enhancement	Land Conservation	Soil Erosion & Sedimentation Control	Native Landscape Restoration
Detention Basin Retrofit	Drain Stenciling	Low/No P Fertilizer Ordinance	Buffer Establishment	Open Space Preservation	Inspection & Enforcement	Reforestation
New Detention Basin	Fertilizer & Pesticide Use Reduction	Detach Roof Drains	Buffer Protection	Park Expansion	Containment	Wetland Restoration
In-line Treatment & Storage	Low P Fertilizer	Detach Footing Drains	Habitat Improvements	Natural Area Protection	Better Site Design	Native Prairie Establishment
Infiltration Swales	Rain Collection	Yard Waste Management Programs	Streambank Stabilization	Better Site Design	Street Sweeping	Invasives Removal
Infiltration Basin	Disconnect Roof Drains	Better Site Design	Daylighting	Sustainable Development		
Structural Improvements	Turf Grass Reduction		Grade Stabilization	Land Acquisition		
Wetland Creation	Tree Planting			Development Rights		
	Volunteer Monitoring					
	Public Education					
	Adopt-a-Stream					

To evaluate relative feasibility, the team used five criteria to assign a feasibility level from 1 to 5, one being most feasible and five being least feasible. This evaluation was not conducted to determine if a project could be implemented, only to assess the relative ease at which one could be implemented based on the five criteria. The five criteria are technological challenges, engineering design requirements (e.g., level of complexity), property ownership and management, public acceptance, and potential site constraints.

In addition to the feasibility assessment, each opportunity was qualitatively assessed based on its agreement with project goals. This assessment ensured that all five goals were thoroughly addressed and indicated which goals the opportunity was most applicable to. **Figure 6.1** shows the location of all the identified improvement opportunities. Refer to **Appendix L** for a brief description of each identified opportunity, the qualitative feasibility ranking and goal attainment assessments, and the modeled alternative number.

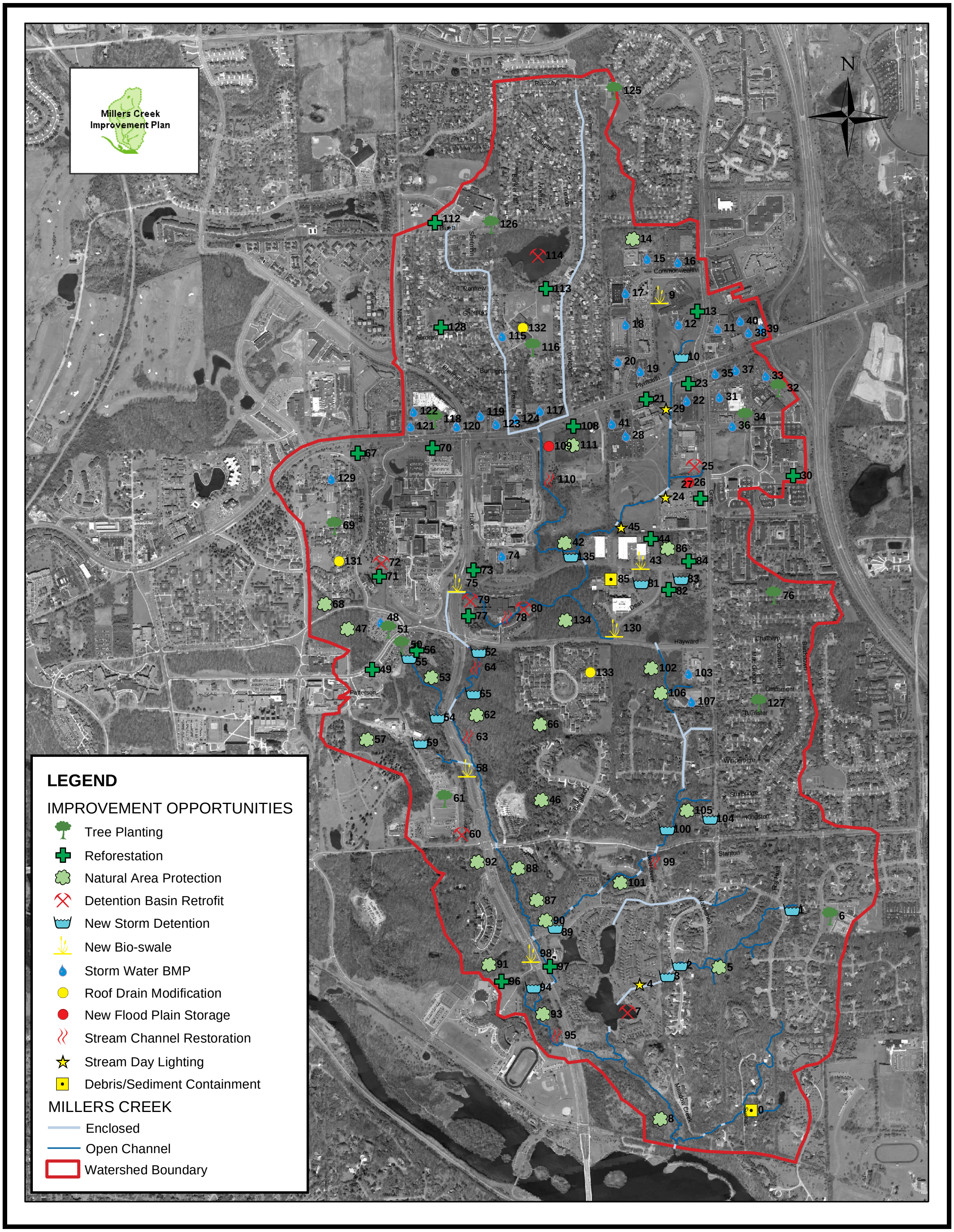

Figure 6.1 Locations of All Identified Improvement Opportunities

A total of 112 opportunities were identified and ranked. The opportunities are identified by watershed tool category and by ID number on **Figure 6.1** and are cross-referenced with the opportunity list in **Appendix F**. **Table 6.2** breaks out the opportunities by watershed tool category.

Table 6.2. Number of identified improvement opportunities by watershed tool

Watershed Improvement Tool Category	Number
Stewardship	20
Land Conservation	23
Structural Stormwater Practices	39
Stream Enhancements	9
Native Landscape Restoration	14
Soil Erosion and Sedimentation Control	5
Administrative Practices	2
TOTAL	**112**

6.2.2 Quantitative Goal Assessment

The degree to which the recommended improvements achieved flow and water quality control objectives was assessed with a set of five specific improvement scenarios. For these scenarios major improvement opportunities were grouped together by sets (or class) of improvement attributes and analyzed with the calibrated hydrologic/hydraulic and water quality models. The five alternative simulations, as defined by improvement opportunity classes, are:

1. Build-out conditions
2. Reforestation and Drain Disconnects
3. New Storm Water Detention and Detention Pond Retrofits
4. Additional Storm Water Detention, Detention Pond Retrofits, Proprietary Water Quality BMPs and Huron HS Sediment Trap
5. Construct boulder drops at the 84-inch culvert at the Hubbard site and at the outlet of the curved culvert above the Glazier site

Descriptions of the modeling scenarios are included in Chapter 7 below.

6.3 Watershed Improvement Tools and Practices

Structural Storm Water Practices

Often referred to as “best management practices” or “BMPs,” structural storm water practices are infrastructure designed and constructed to collect, store, infiltrate, and treat storm water. Structural storm water practices are some of the most expensive watershed improvement tools to implement and require perpetual maintenance. According to Schueler and Holland (2000), the cost to maintain a storm water practice over 20 to 25 years can be equal to the initial construction costs. Despite the high construction and maintenance costs, structural storm water practices can be effective tools for pollutant removal, runoff reduction, and peak flow reduction when properly designed, constructed, and maintained. The following practices have been recommended for Millers Creek.

Detention Basins
A detention basin is a constructed basin that receives, temporarily stores, and then gradually releases storm water. Detention basins are designed to pass a large volume of water through the channel network over a longer period, thus reducing the peak in-stream flow. Detention basins can also be designed to treat storm water during storage by removing sediments, nutrients, and contaminants. Older detention basins may no longer function properly due to inadequate maintenance or may lack contemporary improvements that improve function, such as extended detention outlet structures. The function of existing detention basins can be improved by altering the outlet structure, planting vegetation, removing sediment, and altering flow-through patterns. Retrofitting existing detention basins can be cheaper than constructing new detention basins.

Retention Basins
A retention basin is similar to a detention basin but is designed to indefinitely store storm water without a direct outlet to surface water. Detention basins can treat storm water but their effectiveness varies considerably. During storm events, a detention basin may only be able to remove a small percentage of the pollutants. The balance of the pollutants is discharged into the receiving water body. In contrast, retention basins receive and store storm water from a drainage basin without discharging to the receiving water body. Therefore, retention basins can consistently prevent most of the watershed pollutants from reaching the receiving water. Typically, these basins must be significantly larger than detention basins in order to store two back to back 100-year design rain events.

Bio-swale
A bio-swale, or grassed swale, is a type of conveyance channel designed to reduce surface flow velocities and remove pollutants from storm water through settling, adsorption, biological uptake, and infiltration en route to receiving water.

Tree Planting
Tree planting is intended to increase the density of trees in managed landscapes where trees already exist or establish trees where they do not exist. Both residential and commercial landowners can plant trees to increase rainwater interception and lower peak flows in the Creek. Tree planting is a recognized storm water BMP. Trees intercept rain before it hits the ground, help enhance infiltration with their root systems and lower air temperatures in their immediate vicinity. Small tree planting projects can be completed by almost anyone.

Roof Drain Disconnect
Roof drains in residential communities are often directly connected to the storm sewer network or discharge onto impervious surfaces (sidewalks and driveways) that are directly connected to the storm sewer network. Redirecting down spouts onto pervious surfaces or storing rainwater in rain vessels (e.g., rain barrels, rain cisterns) reduces storm water runoff volume.

Proprietary BMPs

Space constraints in developed areas often limit the options for storm water BMPs. This is particularly true around the commercial developments of the Plymouth Road corridor in the Millers Creek watershed. In these instances, below-ground proprietary BMPs can provide some storm water treatment, although they do not provide storage. Proprietary BMPs are pre-manufactured structures, such as concrete vaults or manholes with specialized weirs and filters that are installed as in-line or off-line treatment systems within the storm sewer network. They also include specialized chambers that can be installed in place of existing catch basins. Proprietary BMPs are recommended throughout the older commercial areas along Plymouth Road.

Stewardship Practices/Public Involvement
A stewardship program that includes public education, public participation, and environmentally friendly property management is highly recommended for Millers Creek. The community must support the improvements for the creek if they are to be effective, especially in view of the high costs of the construction and maintenance of structural improvements. Concern and support by the public are immeasurably enhanced by personal experience of the creek. An experience as simple as a tour of Millers Creek elicited one woman to say that while her congregation originally resented the City requirement that her church construct an expensive retention pond when expanding their parking lot, she could now see why it was necessary. People must know about the creek in order to respond to requests for its support. Many people will work hard to help make the community better if they understand what to do and how it will help. Such stewardship reduces the cost of improvements and generates commitment to the project.

The key to successful voluntary programs is effective leadership and organization. HRWC has shown the power of voluntary stewardship in many creeks including the study phase of the Millers Creek project. Residents have already donated approximately $40,300 in labor costs by collecting data on the conditions of Millers Creek. Many people worked in the rain and during odd hours to measure flow during peak flow events. Hundreds of people turned up reliably, regardless of the weather, to monitor the biotic health of the creek. Many of those people changed their yard maintenance practices as a result of their experience and accompanying education by HRWC. Voluntary programs under effective leadership are essential to the improvement of Millers Creek.

Regulatory and Administrative Practices
Local units of government (LUGs) are charged with the task of correcting water quality and water use impacts within their communities. In particular, LUGs have storm water management responsibilities under the federal “National Pollutant Discharge Elimination System” (NPDES) program of the federal Clean Water Act. This program is implemented by the State of Michigan under its Phase I and Phase II storm water permitting authority. In addition, the middle Huron River phosphorus TMDL and the Geddes Pond *E. coli* TMDL require compliance by the affected LUGs. The City of Ann Arbor, Ann Arbor Township, the University of Michigan and Washtenaw County (Drain Commission) are ultimately responsible for implementing storm water improvements that meet these requirements.

One way LUGs address these issues is through regulatory and administrative practices such as storm water and fertilizer ordinances. In contrast to the voluntary action encouraged under stewardship programs, regulatory and administrative practices establish the legal basis for LUGs to require compliance. Enforcement is accomplished through inspections, fees, and penalties. While high voluntary participation through stewardship is more desirable, regulatory and administrative practices are often required to effectively control water quality and use impacts to the extent that LUGs can meet their regulatory responsibilities. The following practices have been recommended for Millers Creek.

County Drain Designation

Millers Creek is not a designated County Drain. However, it is possible that Millers Creek, or portions of the creek, could be designated as a County Drain during implementation of the plan. Drain designation is a legal process where by a drain easement is established along the creek. This process can be controversial, could take years to complete, and would most likely be permanent given the societal needs for storm water conveyance in the Millers Creek watershed. The designation can be removed according to the current drain code, but the drain must no longer serve a useful purpose; this is not likely in Millers Creek. However, drain designation will improve access, allow drain improvement projects to be petitioned by the public, provide for a long-term maintenance program and will provide funding sources through grants and special assessments.

The current Washtenaw County Drain Commissioner, Janis Bobrin, leads a very progressive drain program that has integrated water quality goals, objectives and practices into their design standards. This programmatic philosophy is consistent with the goals and objectives of this project. There is some uncertainty associated with the longevity of this progressive stance because the Drain Commissioner's position is an elected office. However, the history of the County Drain Commissioner's office locally, including Washtenaw, Livingston, Oakland and Wayne Counties, has been a steady improvement of programs oriented towards protecting natural resources. In the opinion of the project team, given this climate it is highly unlikely that any of these programs, including Washtenaw County's, will relax their environmental standards. On the contrary, it is more likely that these programs will continue to improve their standards.

We recommend that LUGs consider petitioning the Drain Commissioner to designate Millers Creek as a County Drain. This will provide a permanent structure for identifying and implementing many of the improvements in this plan. This will also provide permanent administrative and maintenance attention on the creek.

Ordinances

Ordinances provide the legal basis for LUGs to require certain practices within their jurisdictions. Ordinances are used to control and oversee fertilizer application, storm water management, and land development (land use). The City of Ann Arbor has a storm water ordinance that applies to storm water management in Millers Creek. The City of Ann Arbor and Ann Arbor Township have land use ordinances that apply to Millers Creek. The City is also drafting a fertilizer application ordinance for consideration by the City Council. There is also an effort to pass a state-wide no-phosphorus fertilizer bill to control phosphorus at the level of fertilizer suppliers. Effective design and implementation of such ordinances are important to improving Millers Creek. Unless the effort to pass a bill restricting fertilizer phosphorus content at the state level is successful, we recommend that the City continue to pursue a fertilizer application ordinance that controls the use of fertilizers containing phosphorus.

Septic System Inspection Programs

Private, residential septic systems are often not maintained properly, leading to failure. Failed septic systems can leach bacteria and nutrients into ground water or allow these contaminants to be exposed at the surface and washed into receiving streams during storm events. LUGs have dealt with this growing problem by requiring septic inspections during real estate transactions. Improperly functioning systems must be replaced prior to completion of, or as a stipulation of, the real estate transaction. Washtenaw County already requires septic system inspections in rural areas outside the jurisdiction of local municipalities. Ann Arbor Township should consider requiring inspections every 3 to 5 years regardless of property ownership turnover. Ann Arbor Township should also consider requiring dye testing at the time of sale of residential properties. The only residential areas served by private septic systems in the Millers Creek watershed are within the jurisdiction of Ann Arbor Township.

Stream Enhancement

There are two modern paradigms associated with stream improvements today. The second suggests that improvements should be based on controlling impacts to the extent practical and then allowing the stream to adjust to a new set of environmental conditions. This is a more passive approach to stream enhancement that is based on the theory of dynamic equilibrium. That is, one expects a stream channel to adjust until it reaches a certain level of stability under the new environmental conditions. The first paradigm suggests that improvement should be based on controlling impacts to the extent practical, designing stream enhancements to the new set of environmental conditions, and then actively changing the stream channel to establish an expected and/or desired condition. This paradigm is a more active approach that is also based on the theory of dynamic equilibrium, but it attempts to predict the changes that will take place and then create the new condition that is expected to occur in response to the new environmental conditions.

Both paradigms incorporate, to some extent, the notion that urban streams cannot be restored, only improved and enhanced, due to the level of disturbance associated with heavily urbanized areas like Millers Creek. The scientific literature supports this general understanding quite well. The most important aspects for paradigm selection are stream corridor space restrictions and cost, and their forecast benefits.

The two paradigms differ in their implementation strategies that are designed to achieve a desired condition. There are pros and cons to both approaches. For example, the more passive approach involves less risk of failure but requires more time, and patience, to achieve the desired improvements. On the other hand, the more active approach involves more risk of failure but less time to achieve the desired improvements (assuming the efforts are successful).

The Millers Creek Implementation Plan proposes a mix of the two approaches. For example, eroding stream banks that threaten infrastructure should be dealt with regardless of the outcomes of other activities or the anticipated changes that lie ahead. In other cases, it may be desirable to accept some risk in order to hasten the improvement process through physical channel alterations (e.g., fish habitat enhancements). Watershed improvement opportunities that fall within this category should be dealt with on a case-by-case basis as a matter of priority. As appropriate, the activities can be evaluated within the context of the implementation process to determine the appropriate time to implement them. Such decisions should be based on the prevailing philosophies (within the steering body) regarding stream enhancements, public expectations, regulatory pressures, acceptable levels of risk, monitoring results, and available funding. This plan provides a prioritized list of improvements that prioritizes hydrologic control activities first, critical infrastructure needs, including eroding streambanks that threaten infrastructure, second and active channel enhancement last. Refer to Chapter 7 for prioritization and estimated costs.

Land Conservation

The conservation of open space and preservation of natural habitats is important to protecting watersheds and for fostering meaningful personal experience with our natural surroundings. It is especially important in disturbed watersheds where open space and natural habitats have been reduced to small portions of the overall watershed area. Areas contiguous to and part of the corridor are vitally important. Furthermore, natural areas such as forests provide irreplaceable hydrologic functions and wildlife habitat. Millers Creek was most forested prior to European settlement. Logging and farming practices reduced forest cover considerably. Urbanization of the Millers Creek watershed has left only fragments of forests and intact river corridors. Today, approximately 16% of the Millers Creek watershed is forested. The remaining open spaces in the Millers Creek watershed continue to provide critical hydrologic functions and wildlife habitat. Continued pressure to develop the open space will further contribute to storm water and water quality management problems despite efforts over the next ten years to improve the watershed. Although preserving land is preferable, land development is not precluded. In some cases, development will be necessary. Through better site design and sustainable development practices, the impacts of additional development in Millers Creek can be minimized. Natural feature setbacks can be used to protect the important vegetated buffers and development footprints can be minimized to limit natural feature impacts (e.g., tree clearing), and small, distributed BMPs located close to runoff sources enhance treatment and infiltration (where feasible). This type of land development approach is often referred to as "low-impact development." Land use ordinances are an important tool for implementing such land conservation practices.

Soil Erosion and Sedimentation Control (SESC)

The primary source of erosion and sedimentation in developing watersheds is construction sites. Soil erosion and sedimentation is controlled through state legislation and implemented at the local level. In Millers Creek, it is implemented primarily by the City of Ann Arbor. SESC programs are important and need adequate funding and staff. Inspection and enforcement are important and will ensure that SESC practices are properly implemented as designed and maintained in a functional manner. Improving inspection and enforcement capabilities will greatly increase the effectiveness of the SESC program for Millers Creek. The Millers Creek Improvement Plan recommends additional staffing and funding to support inspection and enforcement efforts.

Native Landscape Restoration

Manicured open space habitats or areas where natural habitats have been lost can be restored. Open space in City parks, housing complexes, commercial and industrial properties, and along Millers Creek contain opportunities to establish forests and prairies. Such native species would replace managed turf grass with communities that provide important wildlife habitat and hydrologic functions. These native plant communities reduce storm water volumes by intercepting precipitation, increasing evaporation, and increasing infiltration.

<u>Reforestation</u>

Forested communities are important for storing precipitation on the landscape. Leaf litter and organic matter on the forest floor act like a sponge while the leaf and bark surface area intercepts rainwater. Reforestation also reduces consumptive turf grass management practices. Reforestation differs from tree planting in that it entails high density planting and abandonment of managed turf grasses to allow the development of a natural forest floor community with its inherent functions.

Stream Buffers

The vegetation along the stream corridor is important to overall stream health. It provides many functions including pollutant filtering, stream shading, wildlife habitat, flow control, sediment trapping and soil stabilization. The stream corridor should be vegetated to the waters edge with native vegetation. Trees and shrubs are preferred on stream banks for shading and erosion control. Vegetated stream buffers should be established along Millers Creek where development has encroached and natural vegetation removed. The buffer should be as wide as site constraints and land management requirements allow.

Native Prairie

Prairies are similar to forests in many functional respects but are dominated by grasses and forbs rather than woody species. Mature prairies can be established over much shorter time frames than mature forests. Consequently, the benefits from their functional values are realized much sooner.

Native Vegetation Management

While the natural areas in the Millers Creek watershed provide a host of important wildlife habitat functions, those functions can be negatively impacted by the presence of invasive plant species. Some invasive plant species displace native species and decrease forest understory productivity. Many of the natural areas in the Millers Creek watershed have invasive plant species that are impacting the functional values of those natural features. Controlling the invasive plant species and encouraging propagation of native species will improve the value of natural features in the watershed.

7. ALTERNATIVES EVALUATION

Five alternative scenarios were developed to evaluate the range of benefits the key improvement recommendations could achieve. The alternatives and their analysis are structured as a series of incremental improvements. Each alternative scenario builds upon the cumulative improvements recommended in all previous scenario(s). For example, Alternative 1 looks at the impacts on a completely built-out (developed) watershed. Alternative 2 considers the impacts of reforestation and drain disconnects on build-out conditions. The first four alternative scenarios were designed to provide increasing levels of flow and water quality control with structural controls. The last alternative examined the use of non-structural water quality controls and the impact of stream bed grade changes on erosion potential. The rationale for approaching controls as incremental improvements was based on five key assumptions:

1. The primary problem for the poor in-stream habitat, widening banks, deepening channel bed, and impoverished macroinvertebrate population is extreme hydrologic disruption by development and lack of comprehensive storm water management measures in the watershed.

2. Any recommendations for stream bed and stream bank restoration should be made and analyzed after understanding the impact of other recommendations aimed at stabilizing hydrology.

3. Conditions in the creek and watershed are so extreme that achieving some semblance of earlier pre-built out conditions is effectively impossible. Therefore, there is no effective limit on the number of BMPs that could be installed in an attempt to recover earlier conditions.

4. Establishing the alternatives as side-by-side comparisons of two or more sets of completely different choices would not be an efficient process. Structuring the alternative scenarios as a set of incremental improvements establishes both the relative improvement effectiveness of different classes of improvements and the overall effectiveness of all the alternatives at the same time.

5. Due to the extreme conditions, some reliance has to be placed upon the capacity of the stream to recover a flow and sediment transport balance on its own.

An important provision of this analysis is that although some of the recommended improvements were not analyzed, that does not imply they would provide no benefit to the creek. On the contrary, every recommended improvement in this plan would have some positive impact. Some representative reasons that certain recommended improvements were not included in the modeled alternatives analysis include:

1. No existing quantitative basis for judging impacts is available; e.g., the impacts of public education on fertilizer use.

2. The number of deployment sites appears to be limited and therefore did not warrant analysis effort; e.g., bioretention areas appear to be limited by the predominance of clay loam soils in the watershed.

3. In addition, some assumptions of existing conditions are very conservative. For instance, when estimating a soil's infiltration rate, the limiting soil layer value in the

column was assumed. Because of this assumption, a significant area of coverage by a top layer of hydrologic soil type B was re-classified because a lower soil layer had a lower infiltration rate. We recommend that each site's soils should be field tested before definitively ruling out the use of infiltrative practices.

4. Although some literature exists on impacts, it is either limited, done in another region or both; and, acceptance of these impacts has not been proven locally; e.g., planting native vegetation increases localized infiltration rates with time.

5. Although there are a high number of opportunity areas, density of application within the opportunity area is low; for example, low density tree planting areas (as opposed to reforestation areas) such as parking lot islands.

Undoubtedly, opportunities not described in this plan that can benefit the watershed will also arise. Before implementation of improvements not specifically identified in this plan, each proposed improvement should be judged on how it meets the spirit and intent of this plan.

7.1 Alternative Modeling Scenarios

The five alternative modeling scenarios created to judge the success of the recommended improvements for meeting flow and water quality objectives are:

1. Build-out conditions
2. Reforestation and Drain Disconnects
3. New Storm Water Detention and Detention Pond Retrofits
4. Additional Storm Water Detention, Detention Pond Retrofits, Proprietary Water Quality BMPs and Huron HS Sediment Trap
5. Street sweeping; No-Phosphorus Fertilizer Ordinance; Construct boulder drops at the 84-inch culvert at the Hubbard site and at the outlet of the curved culvert above the Glazier site

Build-out land use is shown in **Figure 7.1**. Locations of the individual modeled improvements are shown in **Figure 7.2.** The alternatives analysis was structured as a series of incremental improvements. Each alternative built upon the cumulative improvements recommended in all previous scenario(s). The hydrologic and hydraulic events modeled included the first flush, 1-year, 2-year, 5-year, 10-year and 100-year design events.

For the water quality analysis, only the first flush, 2-year and 10-year events were simulated. Only two kinds of pollutant concentration removal mechanisms were simulated in the water quality model: 1) removal of total suspended solids (TSS) and total phosphorus by settling, and assumed removal rates by proprietary BMPs. Other removal mechanisms, such as adsorption or biological uptake were not quantified. This approach should yield a conservative estimate of TSS and TP removals.

Descriptions of the alternative scenario modeling techniques and assumptions are summarized below.

Alternative 1: Build-out Conditions

The future development projections for undeveloped parcels in the watershed were based on the City of Ann Arbor's Northeast Area Plan (NAP, 2003). The NAP identifies these parcels as Study Sites and provides recommendations for future built-out land use. These recommendations extend to the UM North Campus as well. Because the UM Master Plan was undergoing revision during this project, only the NAP recommendations were used to estimate build-out conditions for sites on UM property. In addition, it was assumed that any re-development within the campus would provide storm water management that would meet or exceed current conditions. Build-out recommendations from the NAP include areas of open space conservation, re-development areas and conversion of open space to new Ann Arbor parkland, new residential, new commercial and new industrial developments.

In areas recommended for conservation or areas of re-development, it was assumed that the land use, particularly in terms of directly connected impervious area (DCIA), was effectively unchanged. In areas where new low and medium density residential housing was recommended, it was assumed that the build-out condition would be reached, so to speak, one house at a time. In these areas, changes to the existing conditions model entailed increasing the DCIA percentage of the affected subwatershed. The increase in DCIA was based on estimates of DCIA from existing, comparable land uses.

For proposed future high-density residential housing and commercial/industrial development in the watershed, we assumed that the Washtenaw County Drain Commissioner's (WCDC) requirements for on-site storm water detention would have to be met. For these proposed development areas, a DCIA based on similar existing developments in the watershed was assumed, and detention pond and outlet structure were sized per WCDC rules and standards.

Pond and outlet sizing, and routing of runoff into and out of the proposed pond, was calculated outside of SWMM using a custom pond model (See **Appendix A**). The pond model calculates runoff using a curve number approach, then uses an iterative technique to determine pond and outlet sizes necessary to meet WCDC rules and standards. The model then uses a numeric technique (a 4^{th} order Runge-Kutta calculation) to route the runoff inflows into and out of the pond. Output from the pond model was used as input to the SWMM EXTRAN model for the alternatives analysis. This pond model, and the output used in this analysis, is included as an appendix to this report. Usually, the proposed development was only a portion of the land within a given subwatershed. Therefore, the drainage area associated with each proposed build-out development site was subtracted from the total subwatershed area in the SWMM RUNOFF model so that site runoff was not double-counted.

Alternative 2: Reforestation and Drain Disconnects

To account for the recommended reforestation efforts, the runoff parameter "pervious storage" was modified. When pervious area is occupied by forest instead of lawn, a much greater amount of rainfall is intercepted by tree and understory branches and trunks and stored in the more variable topography created by the roots, depressions and fallen timber in a forest. For instance, natural forests' canopy interception ranges from 15% to 40% of annual precipitation in conifer stands and from 10% to 20% in hardwood stands (Zinke, 1967). Experiments on a lone oak tree found interception losses of 50% and 20% respectively for rainfall depths of 0.18 inches and 0.59 inches (Xiao, et al., 2000). For this alternative, only the pervious storage for the area of recommended reforestation within a subwatershed was changed to 0.5 inches.

The University of Michigan has two high-density, family-housing developments in the Millers Creek Watershed. Half the roof drains from these developments are connected directly to storm drains that empty into Millers Creek. By disconnecting these drains and storing the water on-site via rain gardens and/or rain barrels, U of M would effectively decrease the impervious area for those subwatersheds. Assuming the roof drains would be disconnected, the roof area for each development was subtracted from the total impervious area of their respective subwatersheds.

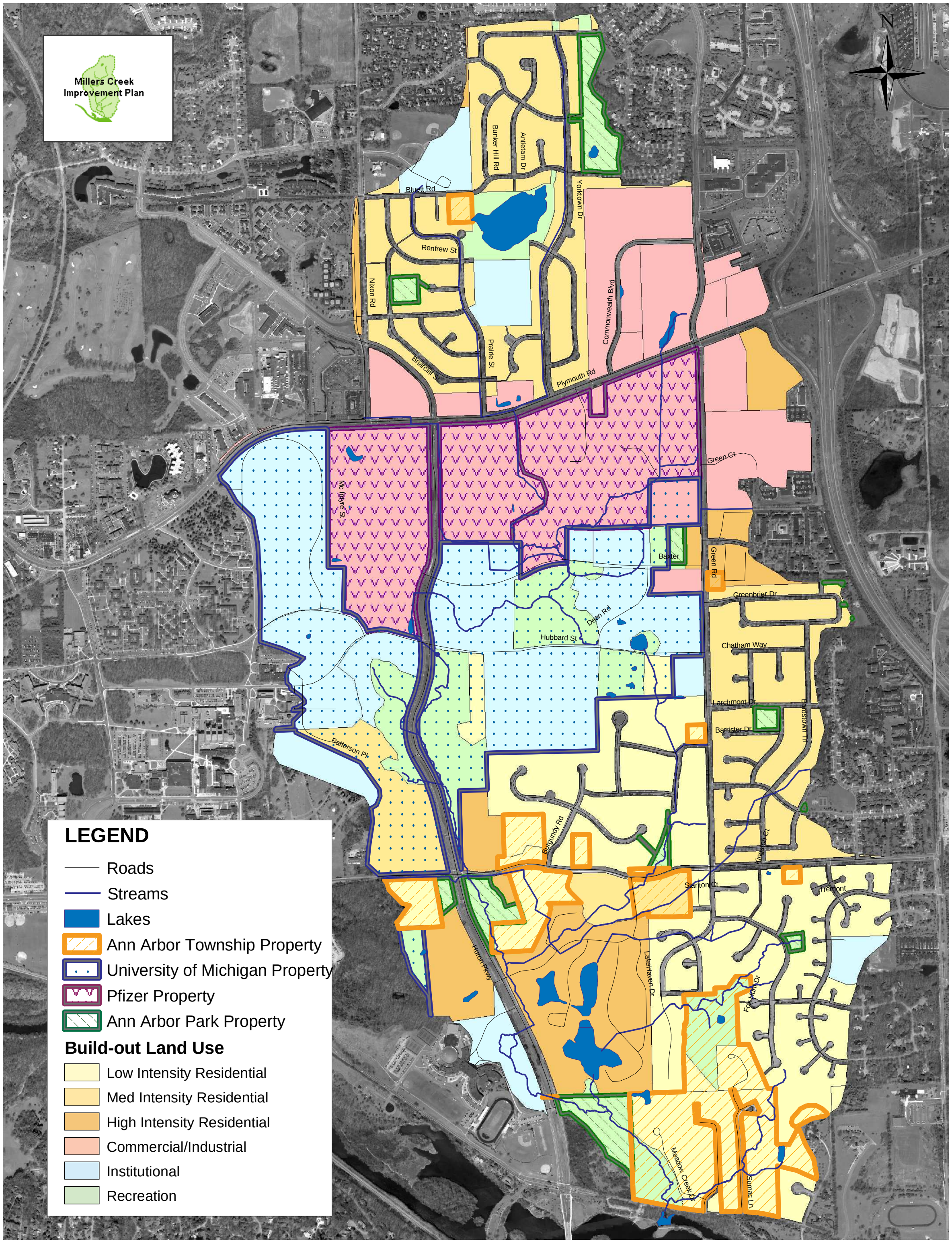

Figure 7.1 Assumed Land Use for Built-Out Conditions

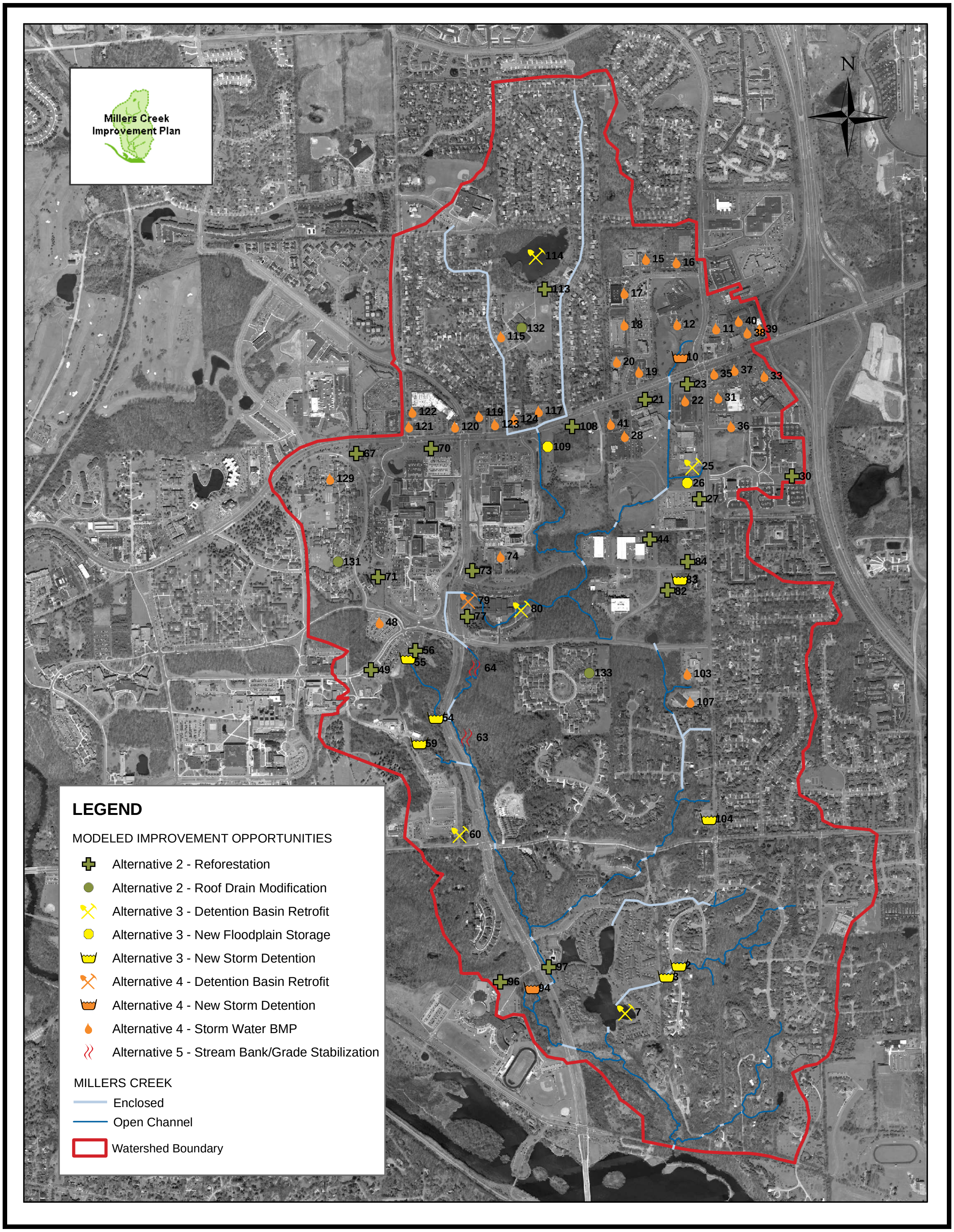

Figure 7.2 Locations of the Individual Recommended Improvements for Modeling Scenarios 2-5

Alternative 3 - New Storm Detention, Regional Off-Line Detention and Pond Retrofits

In order to simulate all of the detention recommendations in the model, several different techniques were utilized. The first involved two sites that currently have no detention basins but have appropriate areas for on-site detention. These two sites are located in the portion of the watershed that was not directly represented in SWMM, meaning that there were no direct links or nodes that could be modified in the model. Consequently, the pond model was used to size appropriate detention basins and create outflow hydrographs that were entered directly into the closest node in the hydraulic mode of SWMM (EXTRAN). As in Alternative 1, the corresponding areas were subtracted from their respective subwatershed areas in the SWMM RUNOFF model to avoid double-counting the drainage areas.

Four locations were recommended for off-line regional detention basins to reduce peak flows. Conceptually, these basins can be visualized as created wetland basins that have engineered inlet and outlet weirs to re-direct stream flows into and out of these basins during high flows. As shown in **Figure 7.3**, these basins were modeled as a storage node and connected to the model channel with inlet and outlet weirs. When the water level in the stream rises to a certain elevation during a storm event, water will begin to flow into the offline detention pond from the stream channel. As the water level continues to rise, water will exit the pond downstream and flow back into the channel. For this level of analysis, the inlet weirs for all four off-line basins were set to overflow into the basin at or above the first flush storm event (0.5 inches of rain in 6 hours).

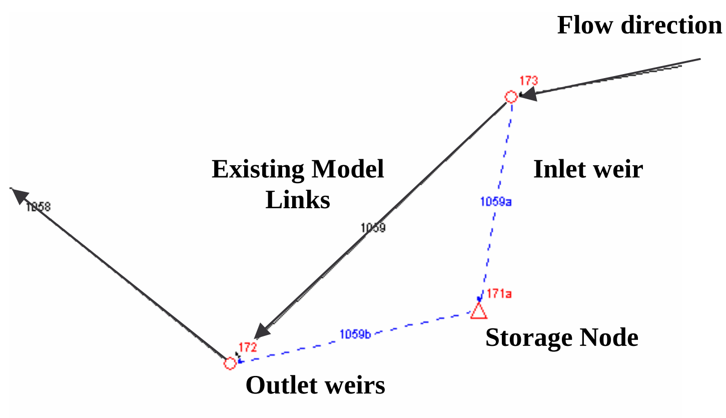

Figure 7.3 SWMM Schematic of Offline Detention

Recommended detention pond retrofits were simulated in five areas where water is already detained to varying degrees. The retrofits included using outlet structures comprised of a row of orifices at first flush event water elevations in addition to a 3-foot diameter standpipe overflow, which was simulated in the model with a weir. The addition of the outlet structure allows storm water to back up to a greater extent, and thus a much greater volume of water is detained for a given storm event.

Additional recommendations were modeled under Alternative 3. The University of Michigan recently constructed a retention pond for their maintenance area on the west side of the watershed. To account for this in the model, the drainage area for the new pond was subtracted from the total subwatershed area, effectively removing that water volume from the system altogether. Similarly, when the Millers Creek project began, the Geddes Lakes outlet structure was not built to detain smaller rainfall events. In Summer 2003, the structure was altered to achieve extended detention in the lakes. The storage node in the SWMM model for Geddes Lakes was modified to reflect the recent outlet structure retrofit.

Finally, Alternative 3 included changes in how Thurston Pond was modeled. Thurston Pond originally proved difficult to model due to conflicting records on the elevations of the inlet and outlet structures. In order to more correctly simulate the function of the pond, additional survey points were taken, and the updated elevations were incorporated into the SWMM model. In addition, a storm sewer pipe carrying a portion of the runoff from Clague Middle School that currently bypasses the Thurston Pond outlet during most rain events was turned off in the model, enabling approximately 30% of the school's runoff to flow directly into Thurston Pond.

Alternative 4 - Additional Storm Detention, Detention Pond Retrofits and Sediment Traps
Alternative 4 primarily analyzed the improvements of recommended water quality improvements. These improvements include the installation of 33 individual proprietary stormwater BMPs, such as the *Stormceptor* by Rinker Materials. The units were preliminarily sized for an average annual TSS removal of 80%. Removals for the first flush water quality event was assumed to be 100%; 80% for the two-year recurrence interval design storm event and 60% for the 10-year recurrence interval design storm.

Four other structure recommendations were incorporated into the SWMM model.

1. An additional offline detention pond was added at the UM Administration Building, just upstream of the culvert carrying flow under Huron Parkway and under the Pfizer mitigation wetland, using the method described under Alternative 3.

2. An outlet control structure was simulated just downstream from the Ave Maria wetland to detain additional runoff. Part of the runoff flowing through the storm sewer in Commonwealth Boulevard was also re-directed into this retrofit basin.

3. The Georgetown Boulevard inlet for Thurston Pond, which currently receives storm water only during big rain events, was increased in diameter to handle a greater amount of the overflow runoff from the Georgetown Boulevard storm sewer.

4. An energy dissipation box/sediment trap, similar to the one upstream of the Glazier sampling site, was modeled in the Huron High School reach of Millers Creek.

Alternative 5 – Boulder drops, street sweeping and enactment of no-phosphorus fertilizer ordinance
For alternative 5, boulder drops, serving as energy dissipation structures were simulated at the outlet of the 84-inch culvert at the Hubbard site and at the outlet of the curved culvert above the Glazier site.

In addition, based on two field and modeling analyses of runoff TSS loads and removals (Sutherland and Jelen, 2003 and TetraTechMPS, 2001), a removal rate was assumed for recommended street sweeping procedures and applied directly to calculated TSS loads.

A projected TP mass removal rate was also applied to calculated loads based on a recent field experiment looking at the impacts of banning the use of phosphorus in fertilizers (University of Minnesota, Duluth, Natural Resources Research Institute, et al., 2003).

7.2 Results
Quantitative assessment measures used to gauge the success of the alternative improvements included:

1. Peak flow reduction, over all design recurrence interval storm events,
2. Peak shear stress reduction, over all design recurrence interval storm events,
3. Peak velocity reduction, over all design recurrence interval storm events,
4. Peak water surface elevation reduction, over all design recurrence interval storm events
5. Total reduction of total suspended solids (TSS) loads, for the first flush, 2-year and 10-year design recurrence interval storm events and
6. Total reduction of total phosphorus (TP) loads for the first flush, 2-year and 10-year design recurrence interval storm events

Peak Flow Reductions

The peak flow reduction goals were aimed at the bankfull events. The bankfull event in most reaches was defined as the 2-year design recurrence interval event. In the reaches where the stream still reaches its floodplain, the bankfull event was somewhere at or above the 1-year design recurrence interval event. Peak flow reductions for the 1-year design recurrence interval event ranged between 37% at Geddes to 54% at Glazier and Hubbard. Peak flow reductions for the 2-year design recurrence interval event ranged between 35% at Plymouth to 42% at Meadows (**Figure 7.4**). By reducing the peak flows 40% to 50% for the storm events doing the most work to shape the channel, the peak flow reduction goals for the project were met. Note that these reductions are for alternative four and were designed to be conservative estimates of reductions. These results are conservative because all model assumptions tended to be conservative, and not every possible improvement, as noted above, was modeled.

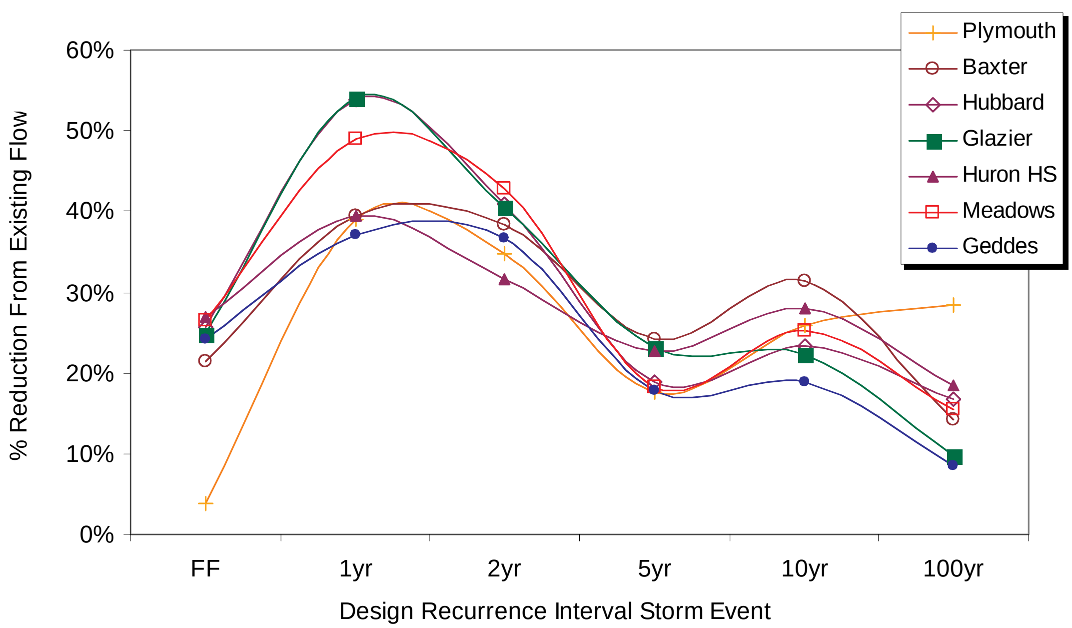

Figure 7.4 Comparison of Peak Flow Reductions between Existing Conditions and Alternative 4

Peak Shear Stress Reductions

In most sections, the largest reduction in peak shear stress is about 20% (**Figure 7.5**). Peak flow reductions do not correspond in a one-to-one fashion to peak velocity or peak shear stress reductions. Shear stress is a function of the channel's hydraulic radius and channel bed slope. The hydraulic radius is the ratio of the area of flow to the wetted perimeter across a channel section. The wetted perimeter is the length across the section that is contact with the moving water. It is this contact region that induces the primary energy loss. The hydraulic radius changes as the flow depth changes, and flow depth changes in proportion to flow raised to the 3/5^{ths} power.

However, in the reach between Hubbard and Glazier below the baffle box, we have specified stream bed stabilization (grade control) measures to decrease the bed slope. This results in a roughly 40% reduction in shear stress in this section – a significant improvement. Although this reduction is not quite enough to meet bed stabilization goals, we believe the channel in time will reach an equilibrium that will stabilize the channel. The bed stabilization improvements should hasten the stability and help stabilize the eroding stream banks in this area as well.

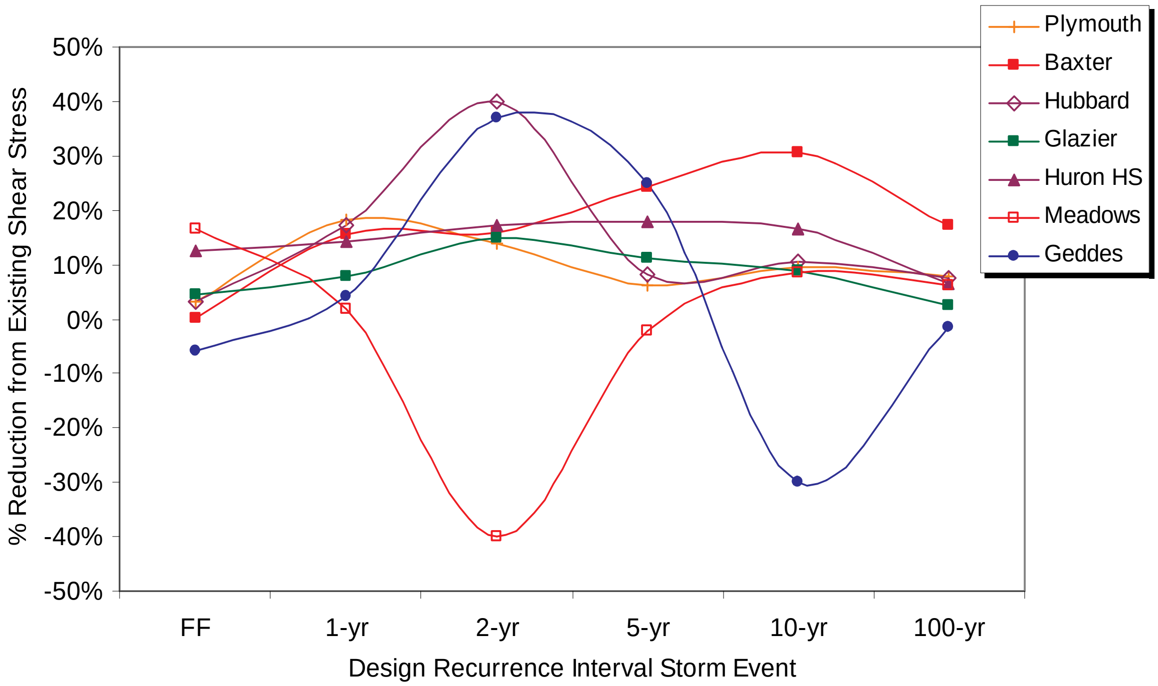

Figure 7.5 Comparison of Peak Shear Stress Reductions between Existing Conditions and Alternative Five (calculated shear stress is the average across the bed)

The negative reductions in shear stress at Meadows and Geddes indicate that the post-improvements shear stress will actually increase in these areas. This is because the lowered peak flows translate into less overbank flow. Overbank flows significantly decrease energy due to friction of moving water downstream. By decreasing the frequency and depth of overbank flows, more water is concentrated at or just below bankfull. Bankfull flow is typically the most efficient flow. It carries the most water per unit area of the channel section and therefore creates the most shear stress per unit area. This reduction in bankfull flows should help to move sediment through the section and forestall the stream's efforts to build up its base level (and slow the filling of the culvert under Huron Parkway with sediment deposits).

Peak Velocity Reductions

Average cross-section velocity is the flow across the section divided by the total area of flow at that section. As flow is reduced, area across the section is reduced. As shown previously in **Chapter 4**, for most cross sections there is little chance for achieving velocity reductions of magnitude similar to peak flow reductions once the 1-year design recurrence interval flows are exceeded (See **Figure 7.6**). Additional peak velocity reductions were achieved in the reach between Hubbard and Glazier by the use of grade control structures.

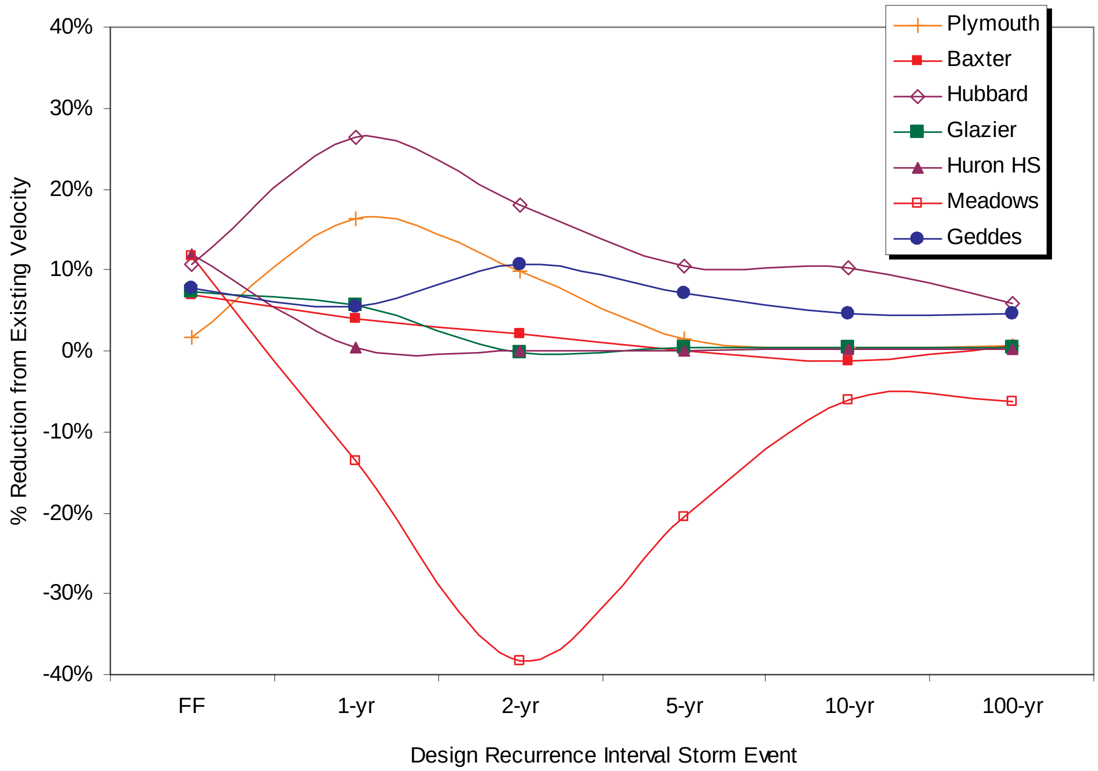

Figure 7.6 Comparison of Peak Velocity Reductions between Existing Conditions and Alternative Five (calculated velocity is the average across the channel)

Once again the results show some negative reductions in velocity but only at the Meadows site. These higher velocities are also the result of lower peak flows resulting in more water in the channel and less flow going overbank.

Total Suspended Solids Reductions

Figure 7.7 shows the cumulative reductions for Alternatives 1-4 and in addition, shows the impact of increasing the frequency and manner of street sweeping. The purchase of a high efficiency or regenerative air sweeping street sweeper is recommended. These are very efficient units and also do an excellent job removing fine particles. Many pollutants are typically attached to and transported via fine particles.

TSS reductions range between 10-15% for alternative two and 27-35% for alternative four. Based on analyses by Sutherland and Jelen (2003), by increasing street sweeping frequency from semi-annually to quarterly and using a high efficiency sweeper, reductions can be increased by approximately another 13%. In a pilot study in Jackson, Michigan, runoff TSS removals reached 50% with monthly high efficiency sweeping and catch basin cleaning (TetraTechMPS, 2001). Although this recommendation would likely necessitate hiring new City personnel, in the long run, source control is the most cost-effective storm water management option. This is particularly clear for control of phosphorus (see next section below). In addition, the costs and benefits associated with frequent high efficiency sweeping should be spread among all the City watersheds and not just Millers Creek.

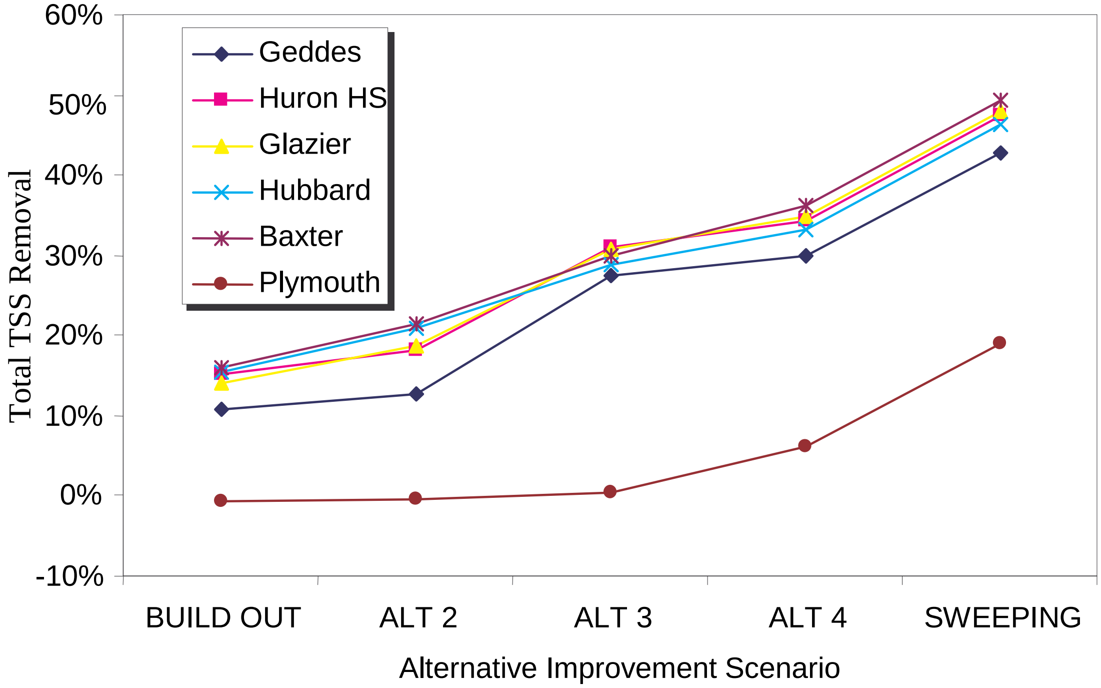

Figure 7.7 Calculated Total Suspended Solids Removals for 2-Year Design Recurrence Interval Storm Event

Total Phosphorus Reductions

Figure 7.8 shows the cumulative reductions for Alternatives 1-4 and the impact of passing and enforcing a no-phosphorus fertilizer ordinance in Ann Arbor, or at the state level. The impacts of a no-phosphorus fertilizer ordinance were based on draft results from a new, detailed, paired watershed study in Minnesota. The study compares water quality from one watershed with an imposed phosphorus fertilizer ban against a control watershed (with no ban). Over the summer of 2001, the watershed with the phosphorus ban recorded a 78% increase in phosphorus mass reduction over the control watershed (University of Minnesota, Duluth, Natural Resources Research Institute, et al., 2003. Lake Access Empact Metro Project. Lawn Fertilizer Project. http://www.lakeaccess.org/lakedata/lawnfertilizer/recentresults.htm).

Although the modeled reductions are less than the project goal of 50%, the Jackson, Michigan and Minnesota pilot studies suggest that street sweeping and phosphorus-free fertilizers can make up any shortfall necessary to achieve the target reductions.

The study utilized accepted water quality sampling and analysis protocol and analyzed mass results over multiple events. The paired watersheds appear to be identical in every way except for the phosphorus ban. These results emphasize the point that source control is ultimately the most efficient and most cost-effective tool to protect water quality. The level of phosphorus control after a ban in this area was assumed to be at the 50% level. In this case, merely implementing and enforcing a phosphorus ban would provide impacts that exceed all the calculated improvements from the modeled alternatives combined. Even assuming the mass loss achievements were half of the measured improvements in the Minnesota project, a phosphorus ban would still exceed the calculated improvements for the combined alternatives analysis.

However, as noted above, the alternatives analysis treated the benefits of infiltration very conservatively and did not assume removals via this route. In addition, dissolved phosphorus uptake was also not accounted for as a loss mechanism in this analysis, another very conservative assumption. Plant uptake is particularly high during the growing season, the critical period for the phosphorus TMDL, and would contribute to overall phosphorus losses following implementation.

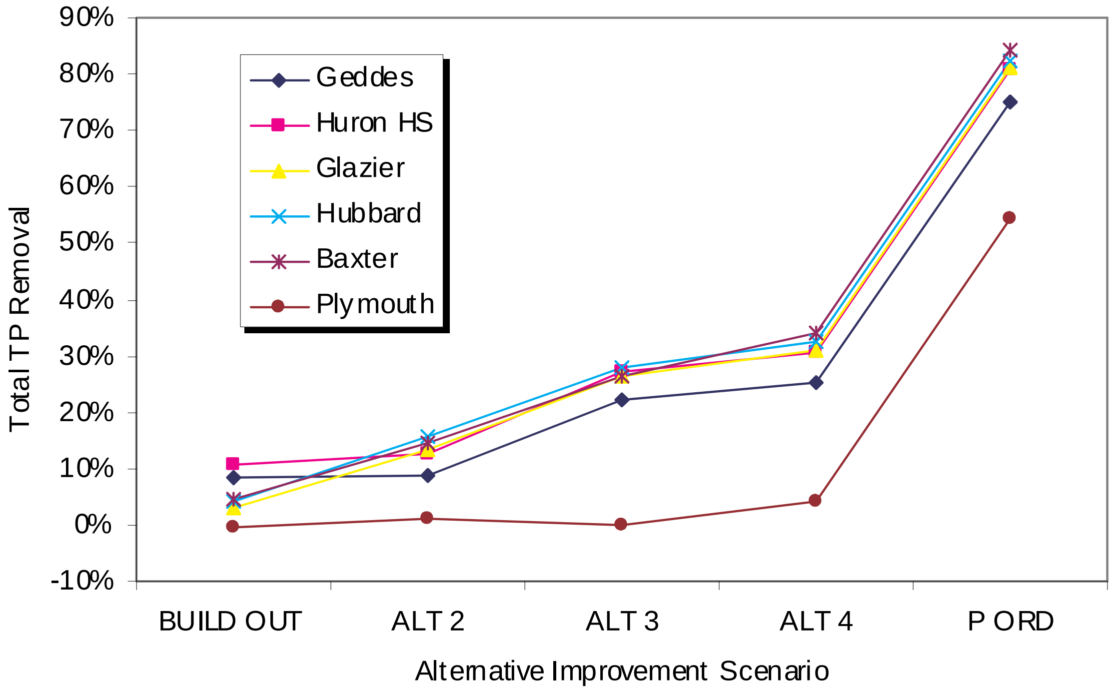

Figure 7.8 Calculated Total Phosphorus Removals for 2-Year Design Recurrence Interval Storm Event