

ALLEN'S CREEK WATERSHED MANAGEMENT PLAN

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Cover Photo: One of the few remaining open sections of the Allen's Creek on Murray-Washington Branch of the Allen's Creek in the spring of 2001 with significant amount of green algae in it.

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I. Introduction

Allen's Creek^[1] is a tributary of the Huron River that courses through, and is contained within, the City of Ann Arbor. Surface water flowing through the Ann Arbor urban environment accumulates and concentrates pollutants that then flow into the Huron River. The Huron River serves as a drinking water source, recreation resource, and aquatic habitat in Southeast Michigan. Moreover, this watercourse empties into Lake Erie, the shallowest of the Great Lakes.

Water runoff is a significant public health and economic concern in Ann Arbor. Poorly managed surface water runoff damages property, degrades ecosystems, and introduces risks for injury from erosion and contamination. Repetitive occurrences of surface and basement flooding, sometimes mixed with sewage, are clear symptoms of a stormwater management system stressed beyond its capacity. Moreover, the high level of impervious surfaces in our urban landscape reduces groundwater recharge as well as contributing to the degradation of water quality and risk of flooding. Poorly managed surface water runoff and decreased surface water quality threaten property values and tax revenues, with the potential to erode the economic vitality of the community and thereby contribute to urban decay.

Most of Allen's Creek is enclosed and inaccessible -- out of sight and out of mind except when storm events make it a public nuisance or hazard. Many residents are likely unaware of its existence. With most of the watercourse enclosed, Allen's Creek is often thought of as an "urban drain" for stormwater conveyance.

Although Allen's Creek has the potential to be a community amenity, issues of water quality, flooding, ecological health and structural integrity overshadow the creek's potential. With proper planning, government oversight, educational efforts and community investment, Allen's Creek will again become a resource to the city. By improving the health of the Allen's Creek Watershed now, the city is likely to reap long-term savings.

This watershed plan lays out a rationale and process for working with stakeholders, including residents, business operators, and policy-makers (see Appendix A), to evaluate conditions, identify concerns and options, and implement policies and programs to improve the Allen's Creek Watershed. It is intended to serve as a working document. This plan is expected to complement and draw from resources developed at the local, state and federal levels.

This plan will be submitted for incorporation into the regional Ann Arbor-Ypsilanti watershed plan produced by the Washtenaw County Drain Commissioner.

II. Issues of Concern

A. Water Quality

Surface water runoff collected in the Allen's Creek is delivered, untreated, to the Huron River, and the poor water quality of the Allen's Creek contributes to the unacceptably poor water quality of the Huron River. Because of poor water quality, human recreation activities are restricted, and fish, other indigenous aquatic life, and wildlife that depend on the Huron River are compromised.

The Allen's Creek carries an unacceptable load of pollutants, delivering the highest concentration of phosphorus to the Huron River of any creek or stream in the Middle Huron area (see additional information on this topic in



Allen's Creek - an upper section outlet

Section V.B.3 Phosphorous on page 9). In addition to phosphorous, the Allen's Creek transports to the Huron River other pollutants that include sediment, road deicing agents, metals, pesticides, motor oil and other automotive fluids, and organic nutrients from pet waste and leaf litter. Moreover, exposed sections of the Allen's Creek and Huron River are not safe for full human contact due to high levels of bacteria.

Anticipated implementation of EPA stormwater regulations will mandate cleanup of stormwater released into rivers. Federal and state regulations, as well as ethical considerations, mandate that the waterways meet health and safety standards, and compel attention to water quality as a critical concern of the Allen's Creek watershed.

Small creeksheds such as the Allen's Creek have the potential to improve the water quality of the larger watersheds. In a recent edition of the journal *Science*,^[2] the cover peer-review research article reports that small streams remove as much as half of the excess nitrogen from fertilizer runoff and auto emissions. In the nationwide study of 12 streams, it was found that the smaller the stream, with shallow depth and a high surface-to-volume ratio, the more quickly nitrogen was removed. Consequently, small streams significantly reduce levels of some water pollutants before the water is delivered to larger waterways. With changes in the management of the Allen's Creek, open channels could significantly reduce pollutant discharge to the Huron River and Lake Erie.



B. Flooding

Allen's Creek experiences recurrent flooding in its midstream and downstream sections. Development in the creekshed has resulted in extreme levels of impervious surfaces such as pavement and rooftops. Impervious surfaces prevent the natural absorption of rainwater and snowmelt into the soil, thereby increasing the amount and rate of water runoff, and carrying increased loads of pollutants into the waterways. Allowing the past development practices to persist will only worsen the problems related to excessive water runoff and the subsequent flooding, as well as degradation of water quality, unless the community implements mitigation efforts.

Additional concerns are emerging regarding exposures to potentially dangerous molds in homes and businesses that have been flooded once or flooded repeatedly. Exposure to molds is associated with development of allergies, asthma and skin rashes. Some strains of mold produce mycotoxins that tend to concentrate on the mold spores released into the air. Inhalation of these toxin-containing spores can seriously damage the lungs and central nervous system, and may cause death in immune-compromised individuals. The mold of most concern is the strain *Stachybotrys atra*, which has been associated with lung hemorrhage and death in infants living in flood-prone housing in a neighborhood in Cleveland, Ohio.^{[3], [4]} Cleansing and decontamination of mold in the home can be very difficult, or impossible in some cases, after the flooding.

C. Dangerous High Flows in Open Sections

The current high volumes and flows in open sections of the Allen's Creek present a clear and present danger to residents, their children, wildlife and pets. These high flows can be remedied with the suggested procedures outlined in this document.

D. Stream Ecology

Most of the Allen's Creek is buried in pipes or otherwise enclosed. The few open stretches of creek are

severely stressed, compromising their potential to sustain stream life. Stormwater deposition of excess phosphorous promotes growth of algae that can produce foul odors, degrade the aesthetic quality of the open channels and, by depleting the water of dissolved oxygen, kill aquatic organisms. In addition, high water volumes and erratic rates, particularly during storm events, effectively wash out most biota.

Consequently, aquatic organisms have little opportunity to become established in these open stretches of the creekshed. Deterioration of the streams contributes to ecological stresses faced by wildlife, diminishes enjoyment by people, and reduces the ability of the stream to filter and cleanse pollutants. Preservation and restoration of open creek areas with accompanying improved ecological health can promote water quality, reduce flooding by increasing water absorption and slowing water flows, provide a habitat for wildlife, and enhance recreational amenities for people.

E. Erosion and Sedimentation

The Allen's Creek Watershed flows through downtown Ann Arbor, the central campus of the University of Michigan, and south and west Ann Arbor neighborhoods largely in underground enclosures. Along the few stretches of the creek that remain exposed, channel banks suffer erosion that kills adjacent trees, uproots vegetation along the banks, widens and deepens stream channels, deteriorates ravines, threatens adjacent structures (e.g., buildings, bridges, sanitary sewers) and, by destabilizing the banks, may create unsafe situations for people. The erosion is due to high water flows, volumes and velocities that are direct results of excessive water runoff. Failure to protect stream banks in the past has resulted in expensive corrective construction projects. Channel widening, soil erosion and plant loss along the open channels undermines the water detention, absorption and cleansing potential of the open stretches of the creek. Reduction of water volumes and velocities, particularly during storm events, are needed to prevent further erosion in the remaining open stretches of the creekshed.

F. Natural Features

Short stretches of the few remaining open channels and many of the enclosed sections of Allen's Creek transverse areas with desirable natural features such as woodlands and ravines. The few sections remaining above ground routinely attract walkers, children and wildlife, and many of the enclosed sections underlie neighborhood parks and greenspaces. The natural features of these areas need protection. Moreover, with community involvement and investment, Allen's Creek could provide the residents of the city with much more than stormwater conveyance through the addition of natural areas of greenery, flowing water, and repose. With this, also, would come the commensurate economic benefit to the community.

G. Regulatory Protections

Because the Allen's Creek serves as a conveyance system of stormwater, much of it is under the jurisdiction of the Washtenaw County Drain Commissioner's Office. In addition, because it courses through much of the City of Ann Arbor, activities under the jurisdiction of the City of Ann Arbor significantly impact the conditions of the creekshed. With additional urban development, enactment and enforcement of regulatory policies on impervious surfaces, grading practices and site plan approval standards will afford further protections to this watershed.

H. Condition of the Enclosed Infrastructure

The majority of the Allen's Creek is enclosed in some form, and these structures require expensive and on-going maintenance. Using traditional engineering approaches to upgrade the system, by increasing water conveyance capacity, would be very expensive yet would not address water quality or streambed erosion. Moreover, additional expenditures to clean up the water before it is delivered to the Huron River are likely

because of the upcoming implementation by EPA of Phase II of the National Pollutant Discharge Limitation System (NPDES) stormwater regulations. Restoration costs are also significant. Furthermore, when repairs, replacements and upgrades to buried stormwater enclosures require tree removal, site clearing and excavation, natural features are lost in green spaces valued by the local neighborhoods and the city. Planning, implementation, oversight and enforcement of strategies and regulations that mitigate stormwater runoff can provide alternatives to expensive and often destructive repairs and upgrades to buried water conveyance systems. Utilization of ecological methods has the added benefit of providing green spaces and the attendant recreational amenities to the community.

I. Ground Water Recharge and Infiltration

The City of Ann Arbor relies on ground water for 20 percent of its overall drinking water supply. Surrounding areas, in many cases, rely on ground water for 100 percent of their drinking water.



A number of devices treat stormwater by using infiltration to remove pollutants and to recharge or replenish the ground water. Infiltration devices include porous pavements, wetland areas, rain gardens, infiltration basins, infiltration trenches and dry wells (sumps). Some infiltration devices effectively remove pollutants through binding onto soil particles, and by biological and chemical conversion in the soil. These systems, with long detention times, natural vegetation or grass bottoms, enhance pollutant removal by allowing increased time for settling. Moreover, the vegetation increases settling and adsorption of both sediment and pollutants. Although infiltration is a simple concept, infiltration devices must be carefully designed and maintained if they are to work properly.

Properly designed infiltration devices can closely reproduce the water balance that existed prior to development, providing ground water recharge, control of peak flows from stormwater, and protection of streambanks and surface soils from erosion due to high flows. A significant advantage of infiltration is that, in areas with a high

percentage of impervious surfaces, infiltration is one of the few means to provide significant groundwater recharge. Because much of the Allen's Creekshed resides within an urbanized area with high levels of impervious surfaces, infiltration offers distinct benefits for groundwater recharge and pollutant removal.

III. Objectives and Strategies

A. Major Objectives

- Improve the water quality of Allen's Creek, minimally to a level that meets all appropriate Designated Uses of the State of Michigan in accordance with the Clean Water Act of 1972.
- Reduce the water volumes, velocities, delivery rates and peak discharges into the Allen's Creek during rain events, to reduce pollutant runoff and the risk of flooding, soil erosion, streambed erosion and ecological destruction in the creekshed.
- Improve ground water recharge and infiltration.
- Restore and enhance Allen's Creek as a natural amenity by preserving and reviving the natural features of the creekshed, especially ravines, wetlands, woodlands, greenways and open stretches of the creek.

B. Strategies to Achieve these Objectives

- Engage major stakeholders.
- Quantify conditions of the Allen's Creek Watershed.
- Promote the review, development, compliance and enforcement of policies that protect the watershed.
- Promote stakeholder education and participation.
- Promote innovative programs to resolve issues of concern in the watershed.

IV. Background on Allen's Creek and its Watershed

A. Physical Description

Allen's Creek is a tributary of the Huron River. The Huron River Watershed encompasses approximately 908 square miles in parts of seven counties (Oakland, Livingston, Ingham, Jackson, Washtenaw, Wayne, and Monroe), running from the Huron Swamp in Oakland County and discharging into Western Lake Erie. The river is used for recreation, drinking water and power generation by the roughly one-half million residents of the watershed, and the watershed contains two-thirds of southeast Michigan's public recreational lands. More than 80% of residents in Southeast Michigan rely on surface water, including the Huron River, as a primary source of drinking water. Over 37 miles of the river and three tributaries have been designated Country Scenic Rivers by the Department of Natural Resources under the State's Natural Rivers Act, the only such designation for a river in central western Michigan.

Allen's Creek's catchment basin, or creekshed, encompasses 5.65 square miles, and is located entirely within the City of Ann Arbor boundaries. The length of the creek system is nearly 12 miles, and flows through the west and southwest sections of Ann Arbor, including much of the central and south campuses of the University of Michigan. The watershed ranges in elevation from 770 to 1020 feet, and receives approximately 30 inches of precipitation annually. Soils in the creekshed include impervious clay soils and pervious sandy soils (Figure 3 on page 49).

The main stem of Allen's Creek begins west of Pioneer High School, runs roughly parallel to Scio Church Road to South Main Street, then meanders through the University of Michigan Golf Course. After crossing under Stadium Boulevard east of Crisler Arena, the creek flows northward to the Huron River. Following the route of the Ann Arbor Railroad, the watercourse passes Fingerle Lumber, crosses South Main Street near the intersection with West Madison Street, flows along the western edge of downtown and the eastern edge of the Old West Side neighborhood, and crosses West Huron Street. The main stem then arches to the northeast between First Street and Chapin Street, crosses Felch Street just east of Spring Street, crosses Summitt at Wildt Street, and courses one block along Wildt Street before crossing North Main Street near Sunset Road, entering the Huron River just downstream of the Argo Pond Dam.

Three primary branches extend westward from the main stem: West Park-Miller Branch, Murray-Washington Branch, and Eberwhite Branch (Figure 1 on page 47).

The majority of the creek is enclosed in a stormwater pipe, although several open sections remain. These open sections of the Allen's Creek include stretches that run through Eberwhite Woods and run directly north of Liberty Street between Thaler Street and Virginia Park on the west side of Ann Arbor. The Allen's Creek is a legally established drain under the Michigan Drain Code (56 PA 40), maintained through the Office of the elected Washtenaw County Drain Commissioner and the Utilities Department of the City of Ann Arbor.

B. History of the Creekshed

Allen's Creek, named in 1824 after Ann Arbor co-founder John Allen, helped define the city's identity through the city's first century. John Allen and Elisha Rumsey set up their camp along the creek to have ready access to a water source, near what is now the corner of First and Huron Streets. As the century progressed, industries that required water located near the creek: a flour mill, tanneries, a foundry, and breweries. Along with the presence of these industries, the flat topography of the Allen's Creek valley led the Ann Arbor Railroad, in 1878, to locate its tracks parallel to the creek.

By century's end the city had become industrialized, and the water quality and biotic community of the creek had declined. With the development through the early twentieth century of what is now Ann Arbor's Old West Side neighborhood, more sources of pollution to the creek emerged, such as sewage from outhouses. A masonry arch enclosed the main stretch of the creek in 1926 and the lower segments of the main branches were enclosed shortly thereafter. Many masonry arches and bridges were simply buried and may have historical potential.

Development has added impervious surfaces, such as rooftops, driveways, roads and sidewalks. Eventually, increased levels of imperviousness contributed to major flooding (in 1947 and 1968), as well as to recurrent localized flooding experienced in recent years during moderate or large rainstorms (e.g., in 1998 and 2000). Increased runoff velocities eroded banks of open stream channels, which led to further enclosure projects, such as the Liberty-Glendale project in 1997-98.

V. Current Conditions

A. Impervious Surfaces

The amount of impervious surface in the creekshed negatively correlates with the health of the creek. Impervious surfaces are composed materials that prevent infiltration of water into the soil. These impervious surfaces include building rooftops, pavement surfaces (e.g., roadways, parking lots, driveways and sidewalks), and impaired pervious surfaces (compacted or otherwise altered natural surfaces whose pervious properties have been decreased through human action, e.g., baseball diamonds and typical lawns).

Watershed planners suggest that creeks with more than 25% impervious cover in their catchment basin cannot support a healthy biotic community.^[5] Allen's Creekshed passed this threshold long ago. An analysis conducted by the Huron River Watershed Council indicates that 39.3% of the creekshed was covered by impervious surfaces in 1985. In 1990 the level was essentially unchanged at 39.4%, but the level jumped dramatically to 45.8% by 1995. Increased urbanization, with attendant additions of rooftops, driveways, roadways, parking lots, sidewalks and lawns, have fueled this trend. Current and future land use plans (see Figure 6 on page 52), suggest a continuation of this trend.^[6]

Increased volume and velocity of runoff, particularly during storm events, occurs with increase of impervious cover. For every acre of natural meadow converted to paved parking lot, the volume of water runoff is estimated to increase about 16-fold.^[7] Moreover, increased imperviousness can dramatically increase peak discharge, causing a sharp increase in the immediate water runoff during or following a rain event.

B. Water Quality

The eight Designated Uses for all waters of the State of Michigan are: agriculture, navigation, industrial water supply, public water supply at the point of intake, warm water fishery/cold water fishery, other indigenous aquatic life and wildlife, partial human body contact recreation, and total body contact recreation between May 1 and October 31. Due to excess nutrients and unacceptable levels of pathogens, Allen's Creek fails to meet the designated uses for warm/cold water fishery, other indigenous aquatic life and wildlife, and

total human body contact for recreation between May 1 and October 31. The Allen's Creek is not monitored on a regular basis, and few studies are available to determine the current status of the creek.

1. Non-Point Sources of Pollution

Water runoff from impervious surfaces concentrates pollutants by collecting urban runoff. The runoff is discharged to the Huron River without treatment, unlike what normally occurs with Ann Arbor's sanitary sewage. Because this water runoff collects pollutants from multiple, widespread sites, it is a major vehicle for delivering non-point sources of pollution to the river.

In the urbanized environment of the Allen's Creek Watershed, human activities generate the vast majority of pollutant deposition onto impervious cover. Vehicle use, landscaping practices (e.g., overuse of fertilizers, application of pesticides, raking leaves into street gutters), soil and stream bank erosion, erosion from construction sites, illicit connections to storm sewers, street and sidewalk de-icing practices, waste from domestic animals, improper outdoor storage of chemicals and littering are human activities that contribute non-point sources of pollution by depositing pollutants onto impervious surfaces.

Pathogens, also critical pollutants for the Huron River, can enter the Allen's Creek as non-point pollution. Untreated human sewage can mix with stormwater when sanitary sewers overflow (surcharge) in wet weather, often because of leaks and cracks in sewage pipes or because of local surface flooding. Additional non-point sources of microbial pollution are animal wastes of pets and wildlife that run off impervious surfaces into the stormwater system.

Another significant source of non-point pollution is the atmosphere. Pollutants in the atmosphere become deposited directly into surface waters or onto impervious surfaces from which they can be carried into the waterways by water runoff. Knowledge is generally lacking about the contribution of atmospheric pollutant deposition to the water quality of the Allen's Creek. Based on recent studies by the MDEQ and Dr. Gerald Keeler of the University of Michigan, mercury deposition from the atmosphere is a likely candidate for concern. Other studies clearly show that polychlorinated biphenyls (PCBs), dioxins, dibenzofurans and similar halogenated polycyclic compounds are dispersed and deposited by the atmosphere. Polybrominated biphenyls (PBBs) and PCBs are considered toxics of concern in the Michigan Great Lakes region.

According to a report released on May 7, 2001 by the Delta Institute in collaboration with EPA, International Joint Commission (IJC), and Lake Michigan Forum,^[8] toxic chemicals and metals — including seven chemicals included in the "dirty dozen" now subject to international phase out under a new United Nations treaty — continue to enter Lake Michigan in dangerous amounts and threaten the health of both humans and the ecosystem.

2. Point Sources of Pollution

Several industrial facilities have the potential to be point sources of pollution to the Allen's Creek. These facilities include the Ann Arbor News, GT Products and the University of Michigan Power Plant, which are regulated by the MDEQ. Other facilities include numerous gas stations, car dealerships and dry cleaning operations. Illicit discharges of pollution into Allen's Creek have been documented. In the early 1990s, for example, the Washtenaw County Drain Commissioner traced a major oil spill to an automobile dealership on Stadium Boulevard. Several facilities permitted under the National Pollutant Discharge Elimination System (NPDES) are located in Allen's creekshed. Information on permit parameters can be obtained from the state. A 1984 study from the Offices of the Washtenaw County Health Department and Drain Commissioner,^[9] lists businesses with storm drain connections, as well as businesses indirectly involved in the use of petroleum products.

3. Phosphorous

Excess loading of the river system with phosphorous is of particular concern, driving annual algae blooms in the creek and downstream in the Huron River's impoundments. Although phosphorus occurs naturally in the region, its presence in excessive amounts contributes to the formation of algae blooms. The algae blooms, in turn, limit recreation uses and threaten aquatic life and wildlife, which are protected by the federal Clean Water Act. Heavy algae blooms are observed each spring in the open channel of the Murray-Washington Branch of Allen's Creek that courses through the Liberty-Glendale neighborhood, fouling the air and water.

The Middle Huron Initiative, a voluntary strategy administered by the Huron River Watershed Council, identified the highest concentration of phosphorus in Allen's Creek compared with any other creek or stream in the Middle Huron region.^[10] Water quality monitoring by MDEQ in 1996 indicated that the Allen's Creek contributed 1,000 pounds of phosphorus annually to the Huron River system, or approximately 1/3 pounds/acre/year. Although highly concentrated in Allen's Creek, other sub-basins contribute greater quantities of non-point phosphorus (>5% of the total phosphorus load) to the Middle Huron.

In order to meet the limits of the Total Maximum Daily Load allocation (TMDL) and the designated uses established under the Clean Water Act, MDEQ has mandated a 50% reduction of the 1995 phosphorus loads in the middle Huron. Although point and non-point sources contribute to the high phosphorus levels associated with algae blooms, the practice of excessive application of lawn fertilizers has been identified as a principal source of phosphorus in residential stormwater runoff. Runoff from bare soils provides opportunities for phosphorous contamination of the creek, also.

4. Pathogens

In addition to a high concentration of phosphorus, Allen's Creek is included on the MDEQ list of waters not attaining water quality standards due to unacceptable levels of pathogens. Unacceptably high concentrations of *E. coli* were measured at the University of Michigan golf course (Washtenaw County Department of Environmental Health, 1995). Untreated runoff from the golf course containing waste from wild and domestic animals is the suspected source for the presence of microorganisms (MDEQ, 1999). However, localized basement flooding of sanitary waste mixed with stormwater has occurred in the Allen's Creek watershed in recent years: on Dartmoor Street in 1998 and 2000 and in the woodland directly west of Virginia Park in 2000. This indicates that sanitary sewage does mix with stormwater and suggests the possibility that human sewage may contribute to pathogen contamination in the Allen's Creek.

5. Other Pollutants

Data on pollutants other than phosphorous and bacteria are generally lacking. Although water quality studies of the Allen's Creek were conducted by the U.S. EPA in the 1980s under the National Urban Runoff Program (NURP) and the MDEQ as part of its development of the Total Maximum Daily Load (TMDL) allocation for the Middle Huron River in the middle 1990s, details on the results of these studies have not been successfully obtained. Dr. Michael Wiley from the University of Michigan measured markedly high conductivity in an open section of the Murray-Washington Branch of Allen's Creek (in the Liberty/Glendale Street area), suggesting heavy contamination of metals (personal communication to R. Loch-Caruso).

C. Water Volume and Dynamics

Minimal flow monitoring data exist for the system. The engineering firm of Black & Veatch conducted a flow-monitoring program in 1994 for the City of Ann Arbor Storm Water Master Plan. However, during the study period the storms were low intensity and low volume. Black & Veatch reported that the flow monitoring data were not used in the development and calibration of the computer stormwater model because the lack of data from high intensity and duration storms prevented adequate calibration of results in their model.

D. Flooding

Located on the 195 acres of the floodplain of the Allen's Creek are more than 650 parcels that include land uses ranging from single family residential to commercial and industrial operations. To date, stormwater management in the Allen's Creek Watershed has entailed conventional engineering flood control measures, that is, conveying stormwater via paved gutters and channels into stormwater pipes that deliver the water, untreated, to the Huron River. However, these conventional stormwater management techniques also exacerbate stormwater problems in the creekshed because they increase the rate and volume of water delivery, transferring and increasing stormwater impacts downstream. Increased urbanization of the Allen's Creek Watershed, with an estimated increase of impervious cover to 45.8% by 1995, is associated with increased occurrences of flooding. The system has the capacity to convey a storm in the range of the 1.5-year, 24-hour frequency storm.

A study by Black & Veatch^[11] documented that the Allen's Creekshed experiences the most severe flooding in the city. This study supported results of a survey on flooding of Ann Arbor residents conducted in 1994 by the Ann Arbor Water Utilities Department. Within the creekshed, 1,682 questionnaires were mailed and 517 responses were received. Major problems from flooding were reported by 136 respondents. A detailed summarization of these survey results is included in Appendix B.

Increased occurrences of flooding indicate that the conveyance system is unable to handle current runoff in the watershed. Basement flooding of homes occurs frequently in the Murray-Mulholland area during or after rains. In recent years and on numerous occasions, the water pressure has blown off stormwater manhole covers in the Murray-Mulholland area, so that manhole covers in this area are now welded shut. The Fingerle Lumber Company likewise experiences recurrent flooding, as do several buildings and Crisler Arena on the University of Michigan campus. Street flooding in recent years at Kingsley and First Streets was so extreme that a woman had to be rescued from her car trapped in several feet of water. Elder Street, an unpaved street off Eberwhite Boulevard, experiences frequent street flooding, also. Additionally, heavy rains in 1998 and 2000 produced basement flooding of homes on Dartmoor Street in the Eberwhite neighborhood that contained mixed sewage and stormwater. Mixed stormwater and sewage also flooded the basement of the Men's Shelter on Huron Street (near Chapin) in 2000.

In addition to inundating streets and basements, frequent stormwater flooding is destroying a several acre wooded area, a neighborhood commons park, immediately west of Virginia Park in the Liberty-Glendale area, just downstream of the section of Allen's Creek that was enclosed in 1997-98. Because this wooded area experiences flooding repetitively and frequently, the trees are dying at an accelerated rate. During a significant rain event in 2000 that measured 3.75 inches of rain overnight in a local rain gauge, staining of the vegetation in this woods, measurement by a neighbor and photographs after the rain event indicated that the floodwaters reached 6 feet. Although the manhole covers to the sanitary sewers are elevated in this woodland, flood debris on the top of the sanitary sewers indicated that stormwater covered the manhole nearest Virginia Park and entered the sanitary sewer system at this point. Evaluations by the Washtenaw County Drain Office and the Department of Environment and Infrastructure confirmed that sewage and stormwater likely mixed and contaminated this commons park area (personal communication to V. Caruso).

Minimal flow monitoring data exist for the system. The engineering firm of Black & Veatch conducted a flow-monitoring program in 1994 for the City of Ann Arbor Storm Water Master Plan. However, during the study period, the storms were low intensity and low volume. Black & Veatch reported that the flow monitoring data were not used in the development and calibration of the computer stormwater model because the lack of data from high intensity and duration storms prevented adequate calibration of results in their model.

E. Stream Ecology

No studies on the ecological health of the open sections of the Allen's Creek have been located.

F. Erosion

The Allen's Creek Watershed is experiencing increased erosion of land surfaces and stream banks. To counter severe erosion to the stream banks of one of the few open stretches of the creek, a recent project in 1997-98 enclosed a short stretch in the Liberty-Glendale area (at the cost of nearly \$500,000 to the city). Erosion continues in the remaining open stretches in this area, evidenced by gouging and widening of the channel and erosion of the stream banks. Also, erosion is exposing the cement bulkhead of the entrance to the enclosed section of the channel just west of Virginia Park. Similar indications of severe erosion exist just upstream of the Liberty-Glendale project in the open channel that runs through the property of the Westwood Apartments on Liberty Street. At this site, the eroding channel banks are toppling large and small trees across and into the stream. Soil erosion along sidewalks and the street are evident on West Liberty Street between Virginia Avenue and West Stadium Boulevard. Elder Street, off of Eberwhite Boulevard, experiences significant erosion from storm events. Erosion along the open channels of Eberwhite Woods is severe, as well, with evidence of gouging and widening of channels and erosion of stream banks.

In addition to deterioration of natural features and structures, erosion contributes to the degradation of the water quality of the Allen's Creek. Soil erosion is a significant source of phosphorous, and phosphorous is identified as a critical pollutant of concern (see previous section on Water Quality). Moreover, soil carried into the waterway increases sedimentation and, thereby destroys aquatic habitats.

G. Natural Features

Although the majority of the waterways in the Allen's Creek watershed are enclosed, some open stretches remain. Many of these streams are considered amenities valued by neighboring residents. A portion of the upper reaches of Allen's Creek main stem is open through the University of Michigan Golf Course at the corner of Stadium Boulevard and South Main Street. On the west side of Ann Arbor, open channels of tributaries of the Murray-Washington Branch course through the Westside Apartments on Liberty Street, through the private park greenspaces of the Glendale and Liberty Knoll Subdivisions between Glendale Circle and Liberty Street and across the southern boundary of West Park. In addition, open stretches of the Eberwhite Branch course through the Eberwhite Woods, the largest woodland/greenspace on Ann Arbor's west side.

All open stretches of the Allen's Creek on Ann Arbor's west side shows signs of extreme stress from high water volume, velocity, rate of delivery and peak discharge. Perhaps most evident is the erosion of the stream beds and banks, causing channel widening, ravine degradation and the death of trees along the banks. Closer examination shows the deterioration of the ecological health of the stream, with little evidence of establishment of biological communities. Although the open stretches of the Allen's Creek may not be able to support significant aquatic life, they nonetheless serve as important water sources for other wildlife such as birds and small mammals. Furthermore, they are valued by neighboring residents as a recreational amenity. These open channels provide opportunities for reducing water volumes, velocities and rates of delivery to the main drain system by providing pervious surfaces and opportunities for overflow. In addition, they improve water quality by increasing aeration and allowing absorption and filtration of excess nutrients and contaminants. Preserving and enhancing these open stretches of the Allen's Creek can protect natural features within the city while providing benefits for water quality and stormwater management.

Moreover, many sections of the Allen's Creek that are enclosed course through ravines and beneath wooded areas that are valued parks and greenspaces for neighborhoods. On Ann Arbor's westside, for example, a section of the Murray-Washington Branch lies beneath the Liberty-Knoll Commons private park and Virginia

Park. Sections of the West Miller Branch are buried in the ravine of the Wildwood Park and in wooded areas just north of West Huron Street. Replacing the current enclosed system with larger diameter pipes, to handle the high water volumes, velocities and peak discharges now experienced, would result in the loss of significant, valued natural features, including trees, ravines and woodlands. In fact there has already been natural feature destruction where sanitary sewers have been upgraded on the west side of Ann Arbor.

H. Regulatory Protections

Activities that impact the Allen's Creek Watershed are regulated by various agencies on the local, state and federal levels. Some of the more salient regulations are described here and are listed in Appendix C.

The Allen's Creek system is an established Chapter 20 County Drain, operated and maintained by the elected County Drain Commissioner and administered by the Statutory Drain Board. However, some sections are apparently under the jurisdiction of the City of Ann Arbor.

Allen's Creek is a tributary of the Huron River that courses through, and is contained within, the City of Ann Arbor. Since 1992, cities with populations exceeding 100,000 were required to develop and implement stormwater plans under Phase I of the National Pollutant Discharge Elimination System (NPDES) stormwater regulations. The EPA has promulgated a rule that requires smaller municipalities (with populations less than 100,000), to develop stormwater plans under the so-called "Phase II" rule. Moreover, under this Phase II rule, the EPA and states will develop strategies from which local governments will select those that best suit their needs and objectives.

The national floodplain regulations are minimum standards. The National Flood Insurance Program (NFIP) regulations, in fact, encourage states and local governments to adopt more stringent standards: "Any community may exceed the minimum criteria under this part by adopting more comprehensive flood plain management regulations." ^[12] Federal Executive Order No. 11988 prohibits the use of federal funds for construction in the floodway or 100-year floodplain.

Although the state floodplain regulations are stronger than those of many other states, the interpretation and enforcement by MDEQ of the floodway rules promulgated under Part 31 of PA 451 of 1994 may warrant discussion and review. A few states can provide models to Michigan for enhanced floodplain management. For example, Wisconsin's Floodplain Management Program, Chapter NR 116, prohibits residential and commercial occupation on or over a floodway.

Experiences in Allen's Creek suggest that the permitting process addresses the concern for increased stage that may cause harmful interference, requiring a hydraulic and hydrologic study, for example, but that it may not adequately address the concern for changes in direction of flow. Permitting a structure in the floodway built on piers, for example, avoids an increase in stage but does not address dangers associated with the temporary obstruction of flows in the floodway.

Depending on the specific circumstances of the site (for example, the narrowness of the floodway channel or the steepness of the floodway's gradient), a piered structure in the floodway, or one with fenced enclosures, may cause changes in the direction and levels of flow because of the accumulation of floating debris – tree branches, cars, dumpsters, recycle cans, patio furniture (including umbrellas, tables and chairs), paper, plastic, various objects – that can get caught on or between piers and obstruct the flow of floodwater. Such a structure could thus cause harmful interference.

Local regulations also suffer from some inadequacies. As is the case on the federal level, the city's floodplain regulations are minimal standards. They cover the basic compliance requirements for participation in the NFIP. There are also enforcement issues within the City of Ann Arbor. Recently, the city's Building Board

of Appeals (BBA) granted a variance from BOCA requirements to a developer to construct an office building, the first floor of which would be under the 100-year flood level, without wet-proof construction. As part of its NFIP participation agreement, the City of Ann Arbor agreed not to grant variances from BOCA floodproofing requirements. The MDEQ issued a letter of warning to the City of Ann Arbor Building Department, stating, "Continued use of the variance procedure to evade the building code and the NFIP requirements could result in the placing of the City on probation or suspension from the NFIP." The NFIP restriction against these types of variances has never been incorporated into the criteria by which the BBA evaluates variance requests. Such incorporation may allow the city to avoid the ultimate penalty of suspension from the NFIP.

Recent changes to the Ann Arbor City Ordinance Chapter 63, that specify on-site regulations for water runoff in alignment with the Rules of the County Drain Commissioner's Office, are an example of regulatory protections that benefit the creekshed.

I. Condition of the Enclosed Infrastructure

In its 1997 report, Black & Veatch estimated the cost of a full retrofit of the Allen's Creek stormwater system to be around \$41 million, out of a total cost for a citywide retrofit of almost \$98 million.^[13] Implementation of this construction would require tree removal and destruction of greenspaces valued by neighborhoods. Even with this significant investment, the critical issue of water quality would not be addressed, however. Consequently, additional costly expenditures would be likely, as the US EPA implements Phase II of the National Pollutant Discharge Elimination System (NPDES) stormwater regulations requiring the City of Ann Arbor to clean up the water before it is discharged into the Huron River. Maintenance and upgrades to the enclosed infrastructure will not abate stream deterioration, and restoration costs are also significant, as evidenced by the recent study of Malletts Creek (estimated at \$20 million).

J. List of Allen's Creek Watershed Maps

The following detailed maps of the Allen's Creek Watershed can be found in Appendix K, starting on page 47:

Allen's Creekshed with elevation, streets and floodplain. (GIS map)

Allen's Creek Creekshed with NPDES permittees (GIS map)

Allen's Creekshed with with future land use (per master plan) (GIS map)

Allen's Creekshed soils (GIS map)

Allen's Creekshed with sub-basins (GIS map)

Allen's Creekshed with natural features and open spaces (GIS map)

Allen's Creek Creekshed with 1995 land use (GIS map)

If gray scale maps appear in the current document, color maps are available and are in select final copies and in the hypertext file.

VI. Strategic Plan

Recognizing the enormity of the task, the variety of concerns and objectives of stakeholders, the requirements for financial investment and technical assistance, and critical limitations of time, the Strategic Plan outlines an approach to resolving critical concerns in the Allen's Creek Watershed. This is a working plan, designed for immediate action as well as on-going strategic planning.

A. Engage Major Stakeholders

1. Rationale

Implementation of improvements to the Allen's Creek Watershed will be greatly facilitated by communication and cooperation among the major stakeholders. Because the watershed is located within the City of Ann Arbor, individuals and organizations that operate within the city are all potential stakeholders. Stakeholders in the Allen's Creek Watershed generally belong in one of five categories: residents, businesses, government organizations, nonprofit organizations and other public organizations.

2. Potential Stakeholders

An alphabetical listing of potential stakeholders can be found in Appendix A on page 30.

Residents of Ann Arbor. All residents of Ann Arbor, whether homeowners or renters, are potential stakeholders because their homes lie within the watershed area. Even if the residences are not adjacent to Allen's Creek waterways or drain systems, homeowners pay taxes to the city, rely on stormwater management and contribute water runoff to the system. Moreover, various human activities throughout the watershed, such as vehicle and land use, can impact the watershed. Resident stakeholders of particular interest are individuals whose homes experience flooding, lie within the floodplain or floodway, lie near open channels of the creek, or are located along wooded areas or ravines through which enclosed sections of the creek traverse. Some, but not all, neighborhoods in Ann Arbor have organized neighborhood groups, and these groups can serve as a mechanism for communicating with resident stakeholders. Some of these identified groups are: Old West Side Association, Old West Side Garden Club, West Park Neighborhood Association, Murray-Mulholland Residents Association, Glendale-Liberty Neighborhood Group, North Central Neighborhood Association, Dover- Parkside Neighborhood Association and Parkside Commons Condominium Association.

Businesses that operate within the City of Ann Arbor. Businesses are potential stakeholders that lie within the watershed area, pay taxes to the city, rely on stormwater management for their operation, and engage in activities that can impact the health of a watershed. Business stakeholders of particular relevance include owners and operators of businesses that experience flooding, lie within the floodplain or floodway, or lie adjacent to enclosed sections of the creek. In addition, businesses in the building trade are important potential stakeholders because development and soil disturbance can significantly impact the watershed. Because the Ann Arbor Railroad and Conrail course through critical areas of the Allen's Creek Watershed, they are particularly relevant potential stakeholders. Some of the stakeholder businesses are organized into associations that can serve as a mechanism for communication. These organizations include the West Stadium Business and Professional Association, Downtown Development Authority and the Chamber of Commerce.

Local, regional, state and federal government organizations. Organizations at all levels of the government are potential stakeholders because they oversee policies and regulations that impact the watershed. Because the Allen's Creek Watershed lies entirely within the City of Ann Arbor, the city government of Ann Arbor is a significant stakeholder. City government offices and organizations of particular interest include the Mayors Office, City Council, Water Utilities Department, Parks and Recreation Department, Planning Commission, Parks Advisory Commission, Building Department, Historic District Commission, and Transportation Department. Regional government organizations of particular interest include Washtenaw County, Urban Area Transportation Study (UTAS) and Southeast Michigan Council of Governments (SEMCOG). Most of the Allen's Creek system is under the jurisdiction of the Washtenaw County Drain Commissioner's Office, making this government organization a significant stakeholder. Various state government organizations that are potential stakeholders include the Department of Environmental Quality, Department of Natural Resources, Department of Transportation, and Bureau of Construction Codes. At the federal level, the U.S. Environmental Protection Agency and the Federal Emergency Management Agency are significant potential

stakeholders.

Other public organizations. Several other public organizations are important potential stakeholders in the watershed. The University of Michigan is an important stakeholder, as an educational institution, employer, and the largest single landowner in Ann Arbor. The Huron River Watershed Council, its Middle Huron Initiative, and various watershed groups in southeast Michigan are potential stakeholders that share the common interest of protection of the Huron River watershed. In addition, the Ann Arbor Transportation Authority is a potential stakeholder because of the significant impact of vehicle use and pavement on the watershed. The Ann Arbor Public School system is a potential stakeholder because it is a significant landowner, including sites through which opened and enclosed sections of the Allen's Creek flow. Additionally, science teachers may wish to incorporate study of the watershed in the curriculum.

Non-profit organizations. Various nonprofit organizations have interests in the well being of the Allen's Creek. These include the Huron Valley Group Sierra Club, Potawatomi Land Trust, Ecology Center, Huron Land Use Alliance, and the League of Women Voters.

Allen's Creek Watershed Group. The Allen's Creek Watershed Group is an open, self-selected group of citizens, business owners and operators, government liaison representatives and other public organization representatives, with no attempt to balance representation among the potential stakeholders, that has been meeting regularly to initiate actions to protect the Allen's Creek Watershed. The Allen's Creek Watershed Group has designed the present plan as an initial working plan for the management of the watershed, aiming to provide a rationale and strategy for working with stakeholders to evaluate conditions, identify options, and implement policies and programs to improve the Allen's Creek watershed.

Clearly, there are many potential stakeholders. Moreover, the potential stakeholders are likely to have widely divergent concerns, resources and priorities. This presents significant challenges for designing and implementing specific actions for management of the watershed.

3. Open Meeting with Potential Stakeholders

An open meeting with potential stakeholders will be held for the purpose of communicating the rationale for designing a watershed management plan, a description of the current understanding of the conditions of the watershed, and the identified concerns of the stakeholders. Although concerns identified by the Allen's Creek Watershed Group will be presented, an important aspect of this meeting will be to identify concerns of a broader representation of stakeholders in the watershed. Another important objective of this meeting will be to identify and involve stakeholders with the technical expertise and resources that will be required to develop and implement a more detailed watershed management. This plan must meet the requirements for the Clean Michigan Initiative administered by the Michigan Department of Environmental Quality and the MEDQ requirements of an approval plan.

4. Formation of Steering Committee

A specific outcome of the open meeting with potential stakeholders will be the identification of a lead organization and the formation of a steering committee, the Allen's Creek Watershed Management Plan Committee. The purpose of the steering committee will be to oversee the implementation of the watershed management plan. Members of the stakeholder group will be invited at the open meeting to serve on the steering committee. Membership of the steering committee will include representatives from each of the major stakeholder categories identified above and, ideally, representatives from each of the significant stakeholder organizations. The lead organization will, ideally, have the staff and resources necessary to organize and oversee implementation of the plan.

5. Continuing Communication with Stakeholders

Although the steering committee will include members of various stakeholder groups, broader communication will enhance the likelihood of success of the watershed management plan. To improve communication, the steering committee meetings will be announced in the newspaper and will be open to the public. Also, the steering committee will submit press releases of newsworthy items to local news groups. Members of the steering committee will be available to speak to various groups of stakeholders. As an important link, a WebSite will be maintained that includes the most current version of the watershed management plan, agendas and minutes of steering committee meetings, data on the conditions of the watershed, and a mechanism for the public to communicate with the steering committee.

6. Identification and Prioritization of Critical Concerns of Stakeholders

Inherently, the identification and prioritization of critical concerns in the Allen's Creek Watershed will be an ongoing process as concerns, data on the watershed, and information on potential interventions are collected and analyzed. The steering committee will be responsible for identifying and prioritizing critical concerns in the ongoing development and implementation of the Allen's Creek Watershed Management Plan.

B. Quantify Conditions of the Allen's Creek Watershed

It is important to establish baseline data and to conduct regular monitoring on a continuing basis of the conditions of the Allen's Creek. These data will provide the community with the detailed knowledge of the watershed that will improve decision making and afford a mechanism for tracking progress after policy or program implementation.

1. Water Quality Monitoring

Based on past studies by the U.S. EPA and the MDEQ (described earlier), phosphorous and pathogens should be monitored. Additional study should determine whether other pollutants should be monitored. Because Dr. Michael Wiley (University of Michigan) found extremely high conductivity levels in an open channel of the Murray-Washington Branch, metal contamination should be considered.

Data collection should take place at the outlet of Allen's Creek to the Huron River and at several points along the system. Potential monitoring stations within the creekshed include points where the main branches intersect with the main stem and where major tributaries intersect with main branches. At an even closer level of detail, monitoring and data collection could take place within the 46 drainage sub-areas modeled by Black & Veatch in the 1997 City of Ann Arbor Storm Water Master Plan.^[14]

2. Water Volume and Velocity Monitoring

Past efforts to monitor water volumes and flow dynamics (as well as quality) in Allen's Creek were thwarted because surging within the pipes was so forceful that monitoring equipment was damaged, destroyed or washed away. Nonetheless, some measure of these phenomena is highly desirable to facilitate understanding, evaluate options and appraise the effectiveness of actions. A review of available instrumentation should identify whether new options may allow measurement of water dynamics even under surge conditions. Alternatively, quantification of the occurrence of surges themselves could be used as baseline data by which to measure progress of implemented programs, for example, through the use of tell-tales in drain manholes.

3. Hydrology, Hydraulics and Stormwater Monitoring

Accurate hydrologic, hydraulic and stormwater modeling of Allen's Creekshed is necessary in order to determine the magnitude of the problem and whether proposed programs would be effective in improving water flow and quality. The modeling of the Allen's Creek watershed undertaken by Black & Veatch in 1997 was insufficient.^[15] Flow monitoring data were not used in the development and calibration of the stormwater model because the data collected were insufficient.

4. Impervious Cover Monitoring

A study by the Huron River Watershed Council analyzed the extent of impervious surface in the Allen's Creek Watershed. In 1995, the last year included in this analysis, the watershed had 45.8% impervious cover. Because impervious cover has a very significant impact on water quality and water dynamics in the watershed, monitoring changes in impervious surface will provide important information for development and evaluation of watershed policies and programs. It is recommended that impervious surface in the watershed be analyzed on a five-year basis. The goal of reducing impervious surface must be incorporated in any new city ordinances that affect this watershed.

5. Erosion Monitoring

Both soil and stream channel erosion should be monitored. Initial baseline information will need to be obtained because there is currently no database on this, only anecdotal information. A walking tour of the watershed is recommended to collect baseline data on erosion (as well as other concerns). Locations of particular concern can then be noted and monitored on an ongoing basis. Because there are only a few stretches of open channel in the Allen's Creek Watershed, local existing groups will be recruited to monitor nearby channels using a consistent evaluation scheme (to be developed). For example, the Eberwhite Woods Committee and Elementary School could assist with the channels in Eberwhite Woods, and the Glendale-Liberty Neighborhood Group could monitor the channel in that neighborhood.

6. Biological Monitoring

In addition to erosion, open channels of the Allen's Creek should be monitored for their ecological health. Local groups will be recruited to conduct regular surveys of sentinel aquatic species through the Adopt-a-Stream Program of the Huron River Watershed Council. The occurrence of algae blooms will be noted as an index of excess nutrient contamination.

7. Flooding Monitoring

The City of Ann Arbor Water Utilities Department monitors flooding events. Information on past flooding occurrences will be requested from the Water Utilities Department for the last 15 years, summarized over five-year periods, to obtain baseline information. After initiation of implementation of the watershed management plan, flooding information within the Allen's Creek Watershed will be summarized on an annual basis and made available to the steering committee to facilitate program and policy development and evaluation. This summarization should include details on the type flooding that occurred (e.g., street, basement, mixed stormwater and sewage), and a ranking scheme indicating the severity of flooding.

8. Floodplain Recalculation

In addition, a review and reanalysis of the floodway and floodplain is warranted, given the extensive increase of impervious surfaces that has occurred since the last analysis. The floodplain in the Glendale-Liberty area along the Murray-Washington Branch of the Allen's Creek was recalculated for a stormwater project in 1997^[16]. This calculation put the floodplain at an elevation 1.2 feet higher than the recorded floodplain. Several homes built up to the edge of the floodplain, as calculated at the time of the neighborhood development, now lie within the newly calculated 100-year floodplain. With the significant increase of impervious cover in the watershed, it is likely that the current floodplain is out-of-date in other areas of the watershed.

C. Promote the Review, Development, Compliance and Enforcement of Policies that Protect the Watershed

1. Identify and Inventory Existing Relevant Policies and Regulations

Protection of the watershed depends on public policies and regulations. Public policies and regulations that

are relevant to the protection of the watershed will be identified and inventoried. This inventory should be easily accessible to stakeholders, for example on a WebSite (with hyperlinks, if relevant) and by pamphlets. City, county, regional, state and federal policies and regulations will be included in this inventory. Appropriate government offices (stakeholders) will be recruited to assist in this process. The Codes and Ordinances Worksheet developed by the Center for Watershed Protection is one example of a starting point for information and regulations.

2. Inform Stakeholders of Existing Regulations and Policies

Many stakeholders may be unaware of existing regulations and policies that serve to protect the watershed. In this regard, compliance with existing regulations and policies may be enhanced by improved communication among stakeholders, in particular between government agencies, residents and business operators. By improving understanding of how human activities impact the watershed, how the conditions of the watershed impact human society, and public knowledge of existing regulations that protect the watershed, the general public can become a partner with government organizations to promote compliance and enforcement of existing regulations. Inherently, advancement in this area would depend on education strategies outlined in a later section. Additionally, mechanisms should be established to facilitate access of the public to knowledgeable government sources, such as contact information or hyperlinks on a WebSite.

3. Promote Improvements to Public Policies

Public policies and regulations will be reviewed for completeness and adequacy for protection of the watershed. Immediate actions are recommended, as identified below, and additional options for consideration are included in Appendix D on page 34.

Strengthen the city's stormwater runoff regulations. The City of Ann Arbor has recently (June, 2000) improved regulation of stormwater runoff by implementing changes to Chapter 63, the city ordinance that specifies site development. These changes align the city's policies with those of the Rules of the Washtenaw County Drain Commissioner's Office. These changes were encouraged and are strongly supported by this group.

However, there are areas in the city where street and basement flooding occur every few years. It is recommended that construction projects upstream from these critical areas be required to restrict surface water runoff to higher standards. Specifically, in these critical zones it is recommended that (1) new developments achieve zero stormwater runoff for a 100-year event, (2) construction that replaces or modifies existing structures does not increase surface water runoff and reduces surface water runoff, if possible. In addition, it is recommended that the city develop policies to encourage the use of stormwater as a design amenity.

Strengthen the city's floodplain regulations. As part of a comprehensive watershed management plan, the City of Ann Arbor should address deficiencies in floodplain management regulations. Unless addressed, the presence of impervious surfaces in the floodplain prevents water absorption and detention, increasing the volume and rate of delivery of water to the waterways and thereby exacerbating flooding conditions. Moreover, delivery of pollutants into the waterways is extreme under flooding conditions. Because of deposition of pollutants by human activity onto impervious surfaces in the floodplain and floodway, pollutants are washed into the waterways under flooding conditions, thereby degrading water quality. In addition to issues related to impervious surfaces, structures in the floodplain and floodway contribute to the problem by adding debris to the flood waters and obstructing flow. Threats of economic losses and liability are sufficient to warrant action on this matter.

A basis for addressing the deficiencies in floodplain management regulations has been provided by the Ann Arbor City Council in its April 5, 1999 "Resolution Regarding Enhanced Management of Ann Arbor's

Floodplains and Floodways." Prohibition of the construction of new buildings in the floodway or, at least, in areas of the floodway that present special hazards (e.g., a narrow channel or steep gradient) is recommended. Construction of potential or temporary obstructions such as berms, piers, "tight" fences and retaining walls should be prohibited, to protect against potential damming and diversion of flood waters. City policies should be promoted and developed to encourage acquisition and/or retrofit modification of existing structures in the floodplain, to allow the floodplain to function as a water detention, absorption and infiltration area. In addition, revisions to the Building Code are recommended that would require that the lowest finished floor of new construction be at a specified height (one or more feet) above the 100-year floodplain elevation, i.e., something greater than what is now required. The recommended changes have the benefits of improving water quality, and secondarily, of limiting potential liability for the city.

Strengthen the state's floodplain regulations. As part of its revision of the state floodplain regulations, the MDEQ should be encouraged to adopt the Wisconsin standard and prohibit any encroachment in or above the floodway or, minimally, in those portions of the floodway where the channel is narrow and/or the gradient is steep. Additionally, the MDEQ should be encouraged to consider potential debris accumulation and temporary obstruction to flow in its floodplain regulations.

National Floodplain Insurance Program (NFIP) Community Rating System (CRS). Enroll the City of Ann Arbor in the National Floodplain Insurance Program (NFIP) Community Rating System (CRS) and implement the criteria in the CRS to maximize the city's score. This action would improve water quality by allowing the floodplain to function more normally and would provide an added benefit to residents in the form of lower flood insurance premiums.

Support New EPA Stormwater Regulations. Support and quickly adopt the US EPA implementation of improved water quality and water quantity performance standards for municipal stormwater and watersheds.

Revise City policies related to creekshed water quality. Develop city utilities and engineering regulations that incorporate standards and practices sensitive to preservation of natural features of the watershed. Schedule and design leaf collection procedures to reduce runoff into the creek. Remove sand from roadways early in the spring to reduce its runoff. Utilize existing parcels of the Parks Department to reduce runoff and promote water cleansing and ground water recharge.

4. Promote Enforcement of Existing Regulations

If there is evidence of poor compliance with current regulations, the procedures of those government offices charged with the responsibility of overseeing those regulations should be reviewed. The outcome of such a review should include recommendations for changes in procedures and/or policies that aim to improve compliance. Penalties or fines, in particular, should be reviewed to determine if they are realistic to promote compliance and enforcement.

D. Promote Stakeholder Education and Participation

Efforts will be undertaken to raise the awareness of residents and commercial operators of the presence, conditions and governing regulations of the watershed. Education of the public about water quality issues will be undertaken to increase community support for the planning process and for allocating resources to implement actions.

Proposed public education activities include, but are not limited to:

- Distribution of the Allen's Creek Watershed Plan to significant and interested Stakeholders.
- Formation of a city-wide Allen's Creek Task Force to work with Stakeholders in the creekshed.
- Development of an Allen's Creek WebSite that includes the current Watershed Management Plan,

- meeting notices, maps and other relevant information.
- Linking monitoring stations to an Allen's Creek WebSite. For example, the City of Palo Alto, California, has established a "Creek Level Monitor" web site that is accessible from the city's home page^[17] that updates flow information at key points along the city's three major creeks every 90 seconds.
- Submitting letters to the editor or "Other Voices" to the local newspaper.
- Contributing expertise on stormwater issues at public meetings and to various city committees, commissions and task forces, illustrating the interconnectedness of stormwater with most human activities.
- Conducting watershed walks along specific branches of the creek, discussing ravine, wetland and woodland protection, stormwater surging at manhole covers, localized flooding, etc.; these walks could be a part of organized environmental awareness events such as Huron River Day.
- Production of brochures describing the Allen's Creek Watershed and key issues.
- Conducting informational and educational mailings, such as the tip cards produced by the City of Ann Arbor Water Utilities Department and the Huron River Watershed Council, that provide homeowners and businesses information on strategies to mitigate impacts on the water quality of Allen's Creek.
- Making presentations and leading discussions at community events and gathering places, such as neighborhood schools and neighborhood organizations
- Publishing informational articles in neighborhood group publications, such as "The Old West Side News."
- Development of programs to promote voluntary fertilizer reduction through changes in lawn care practices and by encouraging soil testing before applying fertilizer (this program is developed in greater detail in Appendix D on page 34).

E. Promote Innovative Programs

1. Stormwater Detention and Retention Facilities

The feasibility of stormwater detention and retention facilities should be evaluated for the Allen's Creek system. By reducing the rate of delivery of surface water runoff into the waterways, risks of flooding and delivery of pollutants will be reduced. Ideally, stormwater detention and retention facilities would be located in the headwaters of the main stem or three major branches (see Appendix E on page 36 for specific potential sites). Stormwater detention structures such as rain-barrels, cisterns, and rain gardens are the primary options for providing on-site stormwater management on small sites in a heavily developed watershed such as the Allen's Creek. Large-scale landscape projects or underground detention tanks are options for larger sites.

Landscape approaches. Aboveground landscape approaches offer multiple benefits, including aeration, filtration and absorption of water, potential replenishment of groundwater, and slowed rate of delivery of water to the main water courses. These attributes improve water quality while reducing risks of local flooding. Landscape approaches include development of wet meadows, wetlands, ponds and water gardens. Large-scale, aboveground landscaped stormwater detention facilities can be modeled after the Buhr Park project in the Malletts Creek Watershed. Buhr Park has been retrofitted with a wet meadow and will soon have additional stormwater landscaping integrated into its grounds. The University of Michigan recently performed a study on the use of rain gardens in the Mallet's Creek Watershed in Ann Arbor. This study concluded that up to 15% of stormwater in the Mallet's Creek watershed could be managed through implementation of ecological landscaping retrofits such as rain gardens and that up to 50% of the watershed residents were receptive to the idea. The City of Ann Arbor could contract a feasibility study on the costs and benefits of retrofitting the entire Allen's Creek watershed with rain garden detention.

Rain barrels. Rain barrels can be an effective means of detaining residential stormwater runoff in urban environments while conserving water for uses such as garden watering. Rain barrels also provide a means for creating personal connections



*Recycled Juice
Barrel*

between residents and stormwater. Rain barrels generally capture the first 1/4 to 1/2 inch of rain of roof systems. The 1/4 to 1/2 inch rain events are on average the most common rain events and contribute the most non-point polluted waters flowing into our fresh water systems. Slowing these flows may reduce a significant amount of pollution delivered to the stormwater system.

The city of Dearborn, Michigan just recently (2000) instituted a rain barrel program.

Recycled juice plastic barrels and government sponsored ready-to-use barrels offer residents inexpensive alternatives to the ready-made store bought, more expensive, options. In addition, with rising city water, sewer and stormwater fees rain barrels will gain more acceptance. There is an option to reduce or eliminate altogether stormwater fees to those who implement rain barrel, rain garden or other stormwater management programs on their sites.



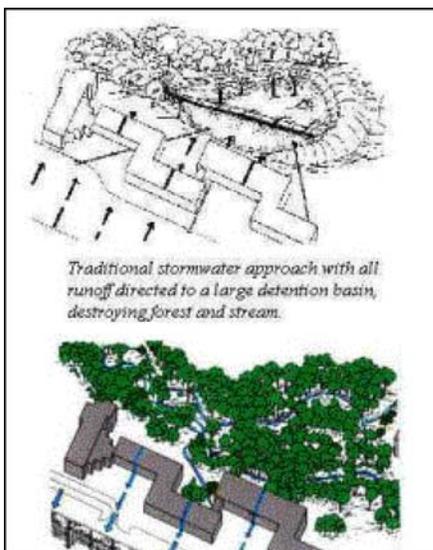
*Side Yard Rain
Garden*

Rain Gardens. The creation of rain gardens in public spaces with signage explanations will provide educational benefits as well as stormwater detention. A program will encourage private and commercial landowners to use rain gardens wherever possible.

Retrofit existing parking lots and streets. A program to retrofit strategic existing parking lots and streets with water retention/detention systems to limit stormwater runoff is recommended, particularly in the headwater areas of Allen's Creek. Specific sites recommended for consideration are West Stadium Boulevard and the old Farmer Jack's-Secretary of States parking lot just north of the Stadium Post Office.

Underground detention tanks. Underground detention tanks may be most suitable for some sites, although they will require excavation for their installation, regular maintenance, inevitable replacement and greater cost. For these reasons, they are not recommended unless other alternatives are infeasible. Such detention tanks can be coupled with systems that provide a measure of water cleansing. An example of this approach is the stormwater detention tank being installed by the University of Michigan near Palmer Drive. Underground detention tanks were also approved in plans for Ashley Mews, and are proposed for the new Homeless Shelter (2001).

2. Alternatives to Impervious Surfaces.



Because of the significant impact of impervious surfaces on stormwater delivery of pollutants to the waterways and local flooding, alternatives to impervious surfaces should be encouraged. Because the Allen's Creek Watershed is an urban watershed, rooftops and pavement contribute the largest impervious surface areas. Innovative strategies to minimize surface water runoff from these structures include utilization of **green roof systems** and **porous pavement** (described in greater detail in Appendix F and Appendix G). Example at right is from Cahill Associates (CA), where water is directed into porous pavement infiltration parking areas away from forest and stream. ^[18]

Moreover, buildings could be encouraged to minimize surface water runoff by incorporating rainwater in the building design and utilizing the water as an amenity. An indication of the

pavement, preserving stream and forest.

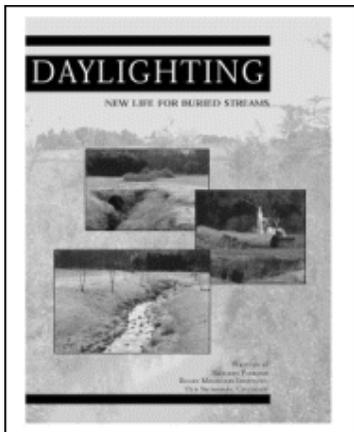
possibilities for stormwater detention in multi-story buildings in Ann Arbor can be seen in the design of Sloane Plaza on Huron Street, just west of State Street. This building features a detention mechanism whereby stormwater passes down through overly narrow pipes and therefore backs up into a detention area at ground level.

3. Incorporating Daylighted Water Courses in Urban Design

The opening of enclosed stream channels, or daylighting, is a viable option for many municipalities, including Ann Arbor. The benefits to water quality of daylighting stream channels along the Allen's Creek include water aeration, purification by vegetation, and nutrient uptake by vegetation to reduce delivery of pollutants and sediment to the Huron River. In addition, contaminant spills are more readily identifiable in a stream than in an enclosed storm drain. Daylighted stream channels would provide opportunities for reducing water velocities, erosion and flooding, also.

Many municipalities have daylighted stormwater drains to restore open stream channels. Berkeley CA, DeKalb County GA, Barrington IL, Saint Paul MN, McLean VA, Boulder CO, and Pontiac, Kalamazoo and Traverse City in Michigan are just a few examples of municipalities that have undertaken and succeeded with such projects. Similarly, the restoration of the buried Ashbridge Marsh has been incorporated as an element of the regeneration of the Don River as it flows through Toronto.

In the EPA-funded report "Daylighting: New Life For Buried Streams" ^[19] (more fully referenced in Appendix H), Richard Pinkham describes potential environmental and economic benefits for incorporating daylighting of streams into urban design. This report provides detailed descriptions of 18 projects, partial description of five other projects, and discussion of 23 additional projects in various stages of implementation.



Regarding environmental benefits, Pinkham writes:

"[daylighting] can relieve choke points and flooding problems caused by under-capacity culverts; increase hydraulic capacity over that provided by a culvert, by recreating a floodplain; reduce runoff velocities—thus helping prevent erosion—as a result of natural channel meandering and the roughness of the stream bottom and banks; replace deteriorating culverts with an open drainage system that can be more easily monitored and repaired; cost less, or only marginally more, than replacing a culvert."

Regarding economic benefits, Pinkham writes:

"Daylighting projects can revitalize surrounding neighborhoods by providing new amenities. The investment in the stream can motivate investments in nearby properties and businesses, which may see an increase in walk-ins as people come to enjoy the re-opened stream."

An example of economic benefit is provided in Kalamazoo Michigan, a city very similar in size, region and makeup to Ann Arbor. In Kalamazoo, tremendous benefits were realized from daylighting the Arcadia Creek in a once decrepit section of the downtown area. Daylighting this stream created a 500 year flood protection to the downtown area, so that downtown land owners no longer require flood insurance. Tax revenues in this downtown area jumped from \$60,000 to \$400,000 annually within five years. Additionally, new business activities in the area generate \$12 million annually in new sales and payroll.

Daylighting sections of Allen's Creek could provide opportunities for the artistic incorporation of drainage systems into the urban fabric. One idea could be to utilize groundwater discharge that would otherwise flow directly into the drain system as a source for fountains, ponds, and other amenities to beautify the city.

An emerging paradigm for artistically incorporating the surface flow of rainwater into urban design is well summarized in the following quote from James Patchett:

“Depending on what progress is made in implementing best management practices - for example, if substantial progress were made in reducing imperviousness and increasing infiltration, to the point where the rate and flow of stormwater runoff became significantly reduced - then the possibility of daylighting selected stretches of the enclosed portions of the creek might be considered.”

More details on daylighting are described in Appendix H.

4. Institute a City-Wide Office to Oversee Parking Lot Space Conversion, Residential Rain Barrel and Rain Garden Implementation

It is recommended that an office in the City of Ann Arbor oversee programs for conversion of parking lot spaces, utilization of residential rain barrels, and implementation of rain gardens as alternative stormwater management practices. The city office will oversee the design and permit process for these alternative stormwater management practices, and will assist in identifying and acquiring funds for such projects. This alternate assignment of tax dollars to improve water quality and reduce volumes of runoff will, in the long term, be beneficial and cost effective compared with traditional stormwater management systems. Additionally, the devastating effects on existing natural features associated with traditional “upgrades” of these systems will be virtually eliminated.

5. Stormwater Cleansing Systems

A number of firms have developed technological methods for improving water quality in urbanized watersheds. One such product, the StormCeptor, intercepts stormwater and provides a certain measure of purification before the water reaches the storm sewer system. Oil and grit separators are another mechanism for cleansing stormwater.

6. Preserve Existing City and County Owned Properties in the City’s Floodway and Floodplain

The city and county are urged to retain ownership of parcels of land in the existing floodway and floodplain, so that these parcels can be incorporated in a watershed-based stormwater management plan. Land in the existing floodway and floodplain is strategically located for stormwater management, possibly through incorporation of these and, where feasible, adjacent parcels in future greenway and greenway connection systems. Retention of city and county owned properties will also prevent development in the existing floodway and floodplain of potentially hazardous or flood-prone structures in these respective areas. The preservation of historic neighborhoods will be considered in any such program. Moreover, additional control of stormwater will benefit these neighborhoods by reducing risks for flooding.

F. Restore and Preserve Natural Features

Protection and restoration of natural features in the Allen's Creekshed can improve stormwater management and water quality, in addition to maintaining and enhancing neighborhood character. Two natural features that are particularly relevant in Allen's Creekshed are ravines and wetlands.

1. Ravines

The ravines of Allen's Creekshed help define its special character. In particular, much of Ann Arbor's west side is distinguished by the ravines that formed as part of the Allen's Creek Watershed. Increased disturbance by construction activities in recent years has caused soil erosion and damaged the aesthetic integrity of the ravine system. Soil erosion is a significant source of pollution to the waterways, contributing sediment,

phosphorous and other pollutants to stormwater runoff. Suggestions for the maintenance and enhancement of the ravine system include:

- Initiate programs under the Great Lakes Commission's Soil Erosion and Sedimentation Control grant program to undertake the maintenance and restoration of the Allen's Creek ravines
- Request new city standards and practices for installation of utilities in ravines and creek areas, to replace the usual 30' to 50' swaths cleared for trenches
- Establish designated conservation easements on creek ravines, based on the precedent set along the ravine near Edmund Place at West Huron Street

2. Wetlands

Wetlands offer many benefits to watersheds. Wet meadows and ponds slow the delivery of water to the main watercourses, allow percolation of water into the soils and vegetation, and improve aeration. By these means, they reduce the delivery of pollutants to waterways and also provide filtration of pollutants in the runoff. Consequently, wetland preservation and restoration is recommended in the Allen's Creek Watershed. An initial step is to undertake a functional assessment of the wetlands of the Allen's Creek watershed, including criteria for preservation, enhancement and restoration potential. Appendix I on page 45 presents identified potential sites for wetland restoration. In addition, it is recommended that the city implement property tax credits for individuals and others who undertake the restoration of urban wetlands.

3. Daylighting of Streams

Daylighting stream channels presents an option for restoring the Allen's Creek as a natural feature in the City of Ann Arbor, providing naturalized areas for human recreation and wildlife in the urban environment. Open stream channels provide numerous environmental and economic benefits, including improved water quality, reduced water velocities, and reduced risks from flooding (see Section IV.E.3 and Appendix H for further discussion). Enclosed sections of the Allen's Creek should be surveyed for potential sites for creek bed daylighting and restoration.

4. Greenway Development

Opportunities exist to create a greenway system through the Allen's Creekshed. Residents and community members within the Allen's Creek watershed may be receptive to the use of parklands within Ann Arbor for stormwater detention purposes if the process also enhances the recreation amenity of the parks. This greenway should be integrated into other city plans. For example, an Allen's Creek greenway could start from the planned greenway along the Huron River and run through downtown Ann Arbor all the way up to the University of Michigan athletic campus. Furthermore, the greenway could potentially branch out along Allen's Creek up through Ann Arbor's west side, linking existing parks (and perhaps creating new park spaces) along the creek system. Details regarding a potential plan for such a greenway are provided in Appendix J on page 46.

VII. Conclusion

Whether below or above ground, Allen's Creek is a principal watercourse in the City of Ann Arbor with significant impacts on the city, its residents and businesses, and the Huron River. By weaving stormwater management into the fabric of urban development as described in the strategic plan, it should be possible to improve water quality, reduce risks and consequences from flooding, and preserve and restore natural features for less cost and greater benefit than expected from traditional structural and water treatment solutions.

This watershed plan challenges current popular ways of thinking about surface water runoff. The traditional means of managing stormwater, by enclosing it for conveyance to a receiving river system, resulted in greater

quantities of pollutants delivered more efficiently to the river, while threats of flooding, erosion, destruction of streams, and deterioration of natural features went unabated or worsened. It is hoped that the ideas set forth in this management plan provide a blueprint for creative and successful resolution of the critical issues facing the Allen's Creek Watershed.

Appendix A. Potential Stakeholders

Allen's Creek Watershed Group
Ann Arbor Public Schools
Ann Arbor Railroad
Ann Arbor Transportation Authority
Army Corp of Engineers
Building Department, City of Ann Arbor
Chamber of Commerce
City Council, City of Ann Arbor
Conrail
DDA Citizen's Advisory Council, City of Ann Arbor
Dover-Parkside Neighborhood Association
Downtown Development Authority, City of Ann Arbor
Fairglen Commons Neighborhood Association
Federal Emergency Management Agency
Flooded residents and businesses
Eberwhite Woods Committee, Ann Arbor Public Schools
Environmental Commission, City of Ann Arbor
Huron River Watershed Council
Liberty Glendale Neighborhood Group
Mayor's Office, City of Ann Arbor
Michigan Department of Environmental Quality
Michigan Department of Natural Resources
Michigan Department of Transportation
Michigan State Bureau of Construction Codes
Murray-Mulholland Residents Association
National Park Service
Neighborhood groups
North Central Neighborhood Association
Old West Side Association
Old West Side Garden Club
Parks & Recreation Department, City of Ann Arbor
Parkside Commons Condominium Association
Planning Commission, City of Ann Arbor
Planning Department, City of Ann Arbor
Residents along the creek and ravines
Residents and businesses within the floodplain and floodway
Transportation Department, City of Ann Arbor
U.S. Environmental Protection Agency
University of Michigan
Upstream businesses such as the West Stadium Business and Professional Association
Washtenaw County Drain Commissioner
Water Utilities Department, City of Ann Arbor
West Park Neighborhood Association

Appendix B. 1994 Creekshed Survey Results ^[20]

1. Has any of the following occurred in your area: basement flooding/ street flooding/ backyard flooding/ trash and debris in ditches/ erosion?

Major Problems	Minor Problems	No Problems	Don't Know
136	301	1,523	284

2. Has rainfall or storm water entered your home or business in the past?

No	Floor Drains	Bathtub, Toilet, or Sink	Windows/ Window Wells	Floors or Walls	Other
318	51	6	32	95	36

3. Has flooding occurred around your home or property?

No	Yard Flooding	Damage to Lawn/ Trees	Damages to Fences/ Buildings	Erosion of Ditches	Other
350	75	15	11	13	29

4. Has flooding occurred in a street near your home?

No	Yes
414	103

5. How many times has flooding occurred at your location during the past 5 years?

Never	Once	Two Times	Three Times	Four Times	Five or More
307	25	24	20	14	68

The city can provide copies of the survey and results through the City of Ann Arbor Water Utilities Office

Appendix C. Partial Summary of Relevant Government Regulations

A. Federal Regulations

1. National Flood Insurance Act of 1968 modified by Acts in 1973 and 1994

This is the basis for the National Flood Insurance Program (NFIP). It enables property owners in participating communities to purchase federally backed insurance protection against losses from flooding. The participating community must adopt and enforce a floodplain management ordinance / resolution to reduce future flood risk to new construction in floodplains identified on Flood Insurance Rate Maps. Under the NFIP Community Rating System, property owners with flood insurance pay lower premiums if the city receives a high score by implementing stringent floodplain management measures.

2. BOCA National Building Code

The National Building Code contains requirements for flood-resistant construction in Section 3107.0, which is referenced in the city's Floodplain Management Resolution, and a section on an appeals process and variance standards in section 121.0.

B. State of Michigan Regulations

1. Water Resources Protection Act, Part 31 of PA 451 of 1994 and Administrative Rules R 323.1311-1316

Floodplain Regulatory Authority found in these regulations applies to all types of construction (residential and non-residential). These regulations prohibit residential occupation of the floodway and other encroachments in the floodway if they may cause "harmful interference" (that is, an increased stage or change in direction of flow of a river or stream that causes or is likely to cause damage to property, a threat to life, a threat of personal injury, or pollution, impairment, or destruction of water or other natural resources).

2. Subdivision Control Act – PA 288 of 1967

This act requires that, during the platting process, no buildable lot may be created in a floodplain on land below the 100-year floodplain level

Ann Arbor Floodplain Management Resolution adopted November 1991 (originally adopted June 1974). This resolution is modeled on FEMA documents, and represents the minimum standards necessary to participate in the National Flood Insurance Program. It adopts the Flood Insurance Rate Maps dated January 2, 1992 and commits the city to enforcing the Flood Resistant Construction sections of the BOCA Code.

C. City of Ann Arbor Regulations

1. Chapter 57: Subdivision and Land Use Control, Section 5:127(1)(c)

This ordinance requires projects to be planned and constructed so as to prevent net loss of flood storage capacity due to floodplain mitigation. It provides protection priorities for floodplain activity by categorizing floodplains into high, mid-level, and low priorities, based on existing disturbances in the floodplain. The ordinance also includes Guidelines for the Protection and Mitigation of Natural Features in the section on Land Development Regulations.

2. Chapter 63:

Recent changes (2000) to the Ann Arbor City Ordinance Chapter 63 specify on-site regulations for water runoff in alignment with the County Drain Commissioner's Office Rules and in some cases goes beyond them.

D. Regional Regulations

In a recently published report^[21], the U.S. Environmental Protection Agency has given a March 2003 deadline to area cities and townships for watershed cleanup.

The area includes Lansing, East Lansing and seven townships.

The nine municipalities have joined forces with the Tri-County Regional Planning Commission to form the Regional Stormwater Committee.

"During certain times of the year you are not allowed to touch the water in the Red Cedar (River)," committee chairman, Roger Buell, told the Lansing State Journal. "We intend to improve the quality of the water so it can be swimmable and fishable."

The committee must meet six requirements set by the EPA, including public education, controlling illicit discharge of septic tanks and monitoring construction site runoff.

Buell said the committee will develop a watershed management strategy. After determining a cost and getting EPA approval, the committee will seek state and federal grants to fund the project, said Jon Coleman, Tri-County Regional Planning Commission executive director.

The Red Cedar and Grand rivers are on Michigan's Impaired Water Bodies list. The list shows what bodies of water aren't meeting standards.

Appendix D. Education Program to Reduce Fertilizer Use

Allen's Creek delivers the highest concentration of phosphorus to the Huron River of any tributary stream in the middle Huron area. One of the principle reasons for the high level of phosphorus in residential stormwater is excessive application of lawn fertilizers.

The most effective solution to the problem of fertilizer-based phosphorus inputs would be limiting lawn fertilization. As advocated by the Huron River Watershed Council's Information and Education campaign, clippings from grass that is mowed high can be an excellent source of natural nutrients for a lawn. Also, lawn conversions from turf to native plant species eliminate the need for fertilizer altogether. The Allen's Creek Watershed Plan advocates the continuation of educational campaigns to familiarize residents with options for fertilizer use reduction. If voluntary effort should fall short, the community could discuss the feasibility of other approaches to reduce fertilizer use.

If the community supports continued fertilizer use, controlling excessive use by promoting lower cost alternatives to phosphorous can be explored. The key is to provide a less expensive and more environmentally sound lawn fertilizer and to inform the public about how applying less fertilizer can get the same or better results.

The Huron River Watershed Council is working with Michigan State University Cooperative Extension to encourage county residents to test their soil before applying fertilizer. This initiative aims to help people apply the appropriate type and amount of fertilizer to their lawns, and thereby reduce fertilizer runoff to the Huron River. To promote this effort, a publicity campaign run during the months of March and April of 1999 encouraged residents to take samples of soil to local fertilizer stores. Each soil test cost \$15. The results were sent within two weeks. Participating stores stocked the fertilizers recommended by the soil experts. This program could ultimately reduce the costs of unnecessary fertilizer purchases and improve the quality of the Huron River. Increasing local publicity, establishing the program as an annual event, distributing information tip cards to residents each spring and issuing tip cards to all new residents in the area could enhance the program. In the future this program could be linked with community activities – for example, youth organizations and school clubs could collect soil samples.

Specific options for an education plan to reduce fertilizer use include:

- City of Ann Arbor sponsorship of an annual spring campaign to encourage residents to have their soil tested
- Identification and reduction of impediments to having soil tested (e.g., because the cost of sample testing was suggested as a barrier to soil testing, it would be useful to conduct a follow-up analysis with people who used the program this year to see how much money they saved by using the soil-testing program and how this changed their attitudes; next year's ads could then feature information on residents who used the program and have a good lawn with less cost)
- Encourage businesses and institutions to lead the way by getting their soil tested as one element of the Community Partners for Clean Streams program, and establish a public recognition program for their participation
- Establish awards for businesses using the least fertilizer
- Work with lawn care companies in the area to market creek-friendly fertilization packages (involving county extension agents in this effort)
- Create awards for the most environmentally responsible lawn care company
- Create awards for the most creek-friendly front yard

- Advertise and promote the availability of slow-release fertilizers both in stores and elsewhere
- Use “Issues of the Environment” and other local radio shows to promote soil testing
- Promote soil testing in the Ann Arbor News, the Observer, Agenda, and other community publications
- Provide a pamphlet on Allen’s Creek and creek-friendly homeowner stewardship with the initial tax bill sent to new residents

Appendix E. Potential Sites for Stormwater Detention

A preliminary examination of sites suggests the following locations might be candidates for stormwater detention / retention facilities:

City offices may obtain easements for retention sites on private properties with approval of council and if the purchase price is not prohibitive.

Main Stem

- Ann Arbor Railroad side yard north of Hoover
- Pioneer High School parking lot

Eberwhite Branch

- Parking lot in the center of the block bounded by Liberty, Third, and Murray Streets at the end of Krouse St. off Third.

Murray-Mulholland Branch

- 2060 W. Liberty Street
- Virginia Park
- Slausen School grounds

West Park/Miller Branch

- West Park
- Fox Village Center parking lot
- Veterans Park

Appendix F. Green Roof Systems

One example of an effective alternative to impervious roofs is the green roof system, of which James Patchett, the founder of the Conservation Design Forum in Elmhurst, Illinois writes:

“...to enclose stormwater in a pipe, and convey it away from the site as quickly and efficiently as the law allows, is to fail at every level. Water should be collected, experienced for its beauty and function, cleansed, recycled, and absorbed on-site unless conditions dictate that it should be dispensed elsewhere. [Such] projects are characterized by surface water drainage systems artistically incorporated into the site in a variety of ways that communicate the beauty and function of water at every sensory level. Building and landscape functions are completely integrated through the use of green roof systems, coupled with internal and external collection, cleansing and recycling systems that, in turn, provide water for irrigation, gray water, and climate control. This combination of measures is designed to significantly reduce or outright eliminate the off-site discharge of stormwater runoff.^[22]

Research has indicated that even very simple green roof systems, composed of a 3 to 4 inch soil layer over a permeable sub-grade, and planted with a basic mixture of sedums, often in combination with a few grasses and wildflowers, can effectively absorb and evapo-transpire 70 to 80 percent of the total precipitation that falls on the roof. Imagine the runoff reduction levels that could be achieved, particularly in urban areas that contain literally hundreds of acres of rooftop. A 70 to 80 percent absorption rate in the Chicago area, for instance, would result in the reduction of a minimum of 700,000 to 800,000 gallons of surface water runoff per acre of green rooftop per year. This is water that could be captured, easily cleansed, and reutilized on-site.^[23]

In another contribution to the evolving technique of green roof systems, the architect William McDonough, who delivered the first Sustainable Development lecture at the University of Michigan during the latter's 1999 series, described a polymer he and his business partner had developed for a roof shingle that would absorb water during a rainfall and expand like a sponge. Patchett and McDonough have teamed up on development and redevelopment projects that emphasize minimal/zero stormwater runoff, including the Coffee Creek Center project in Chesterton, Indiana and a green roof retrofit of Chicago's City Hall.

It is reasonable to anticipate the construction of multi-story buildings that would either have zero stormwater runoff or use stormwater as a design amenity. For example, rainfall on the rooftop and sides of a multi-story building could be captured in a tank in the basement, and then pumped during dry periods up to street level through decorative fountains along the building's facade. The water would then either recycle back into the tank, or pass from the fountains into the storm drain system.

Appendix G. Porous Pavement for Parking Lots, Bike Lanes, Bikeways, Sidewalks and Roadways

Porous pavement allows stormwater runoff to infiltrate the pavement layer and enter the underlying soil. This provides for a high degree of soluble and fine particulate pollutant removal, groundwater recharge, and low flow augmentation and stream bank erosion control. Porous pavement is feasible on sites with gentle slopes, permeable soils and relatively deep water table and bedrock levels.

Alternatives to conventional asphalt that utilize a variety of porous media, often supported by a soil matrix, structural matrix, concrete grid, or modular pavement, allow water to percolate through to a sub-base for gradual infiltration.

Porous pavement can reduce long term paving costs, greatly help recharge ground water, help clean roadway polluted stormwater and reduce stormwater management constructions and long-term roadway and stormwater systems maintenance costs. The development of natural microbiological action in the pavement, shortly after installation, has been shown to provide significant natural detoxification of roadway pollution before entering the soil matrix.

Additionally uses of porous pavement have been used to significantly reduce urban road noise. Some projects are underway to install this product specifically for this purpose.

The City of Ann Arbor and the University of Michigan could begin incorporating the use of porous pavement in an effort to cut the substantial cost of road, parking lot, sidewalk, bike lane and bikeway construction projects and the commensurate reduction of considerable stormwater pollution and related stormwater management systems expenses. When calculations take into account all the obvious costs, including the true environmental cost, porous pavement systems have the potential to deliver substantial savings over time.

Wisconsin DNR Nonpoint Source Program Redesign Initiative - Draft Report September 1999. "The use of porous pavement is recommended."

The United States Air Force (USAF) construction specifications state in part: "The USAF has implemented a variety of energy saving and pollution prevention strategies in the planning, design and construction of many facilities. By addressing these issues simultaneously the USAF will gain the synergy of realizing each of these goals contributing to the whole."

It goes on to state: "Consider pervious paving systems as an alternative to impervious systems; e. g., porous asphalt or concrete (constructed with "open-graded" aggregate lacking fine particles) instead of traditional asphalt. Reserve impervious pavement use for special situations such as swelling soils, highly plastic soils, or steep slopes."

US Federal Highway Administration.- Transportation Research Board; Nevada Department of Transportation; American Association of State Highway and Transportation Officials; World Road Association--PIARC CONFERENCE PROCEEDINGS 16, 1997: "In 1986, porous asphalt (drain asphalt or open-graded asphalt) was introduced in the Netherlands. By 1997, approximately 40% of all highways in the Netherlands had been paved with this open asphalt."

New Hampshire Department of Environmental Services, Nonpoint Source Program March 1998 reports: "Concern over the impacts of increased runoff from urbanizing areas has increased the availability of

porous asphalt pavement. Porous pavement is similar to conventional asphalt in durability, but has a lower percentage of fine particles, allowing water to soak through."

The Southface-Journal of Sustainable Building • Volume 1, 1999 describes Bruce Ferguson's, a professor at the University of Georgia's School of Environmental Design, report relating to the structural properties of porous pavements and their possible applications:

"Because porous pavements allow rainwater to seep into the ground through pavement, the amount of stormwater runoff is reduced and water quality is improved. Porous pavements can be made of concrete, asphalt, open-celled stones, and gravel, that are mixed in a manner that creates an open cell structure allowing water and air to pass through.

"Unlike traditional concrete or asphalt, porous pavements typically provide a void content of 15-25%, offering improved filtration and an enormous amount of surface area to catch oils and chemical pollutants. The bacteria living in these spaces break down pollutants preventing much of the polluted runoff that normally occurs with traditional pavements. Parking lots, in particular, hold a tremendous potential for this material because of the amount of oil and other hydrocarbon liquids that seep from parked cars.

"Concerns about clogging up porous pavements can be "designed out", according to Ferguson, by reducing erosion and sediment runoff through strategic design and water retaining ground cover.

"Although the rate of water filtration of porous pavements usually drops from an initial high of 160 inches of water per hour to a constant rate of **16 inches of water per hour**, this is still far above most conceivable rain events and highly effective in controlling stormwater drainage.

"There is also a broader urban application for this building material. The strength and durability of porous pavement appears to be equal to traditional materials. There are several examples of parking lots built more than twenty years ago with porous pavement that are still structurally sound and in use. Porous pavement is also less susceptible to freeze-thaw cracking. The material's ability to retain stormwater while improving water quality makes this material a very exciting example of green or sustainable building practice.

"Ferguson also advocates a new mind set when designing stormwater management systems. Rather than designing a system for huge storm events that may occur only once a century, water management planners should consider the smaller, more frequent rain intervals. Atlanta, for example, receives significantly more than half its annual rainfall from precipitation events of less than an inch. "The ecosystem lives and dies on daily events", Ferguson says. A stormwater system incorporating porous pavement will be much more effective in reducing runoff and increasing the amount of filtered groundwater."

Washington Aggregates and Concrete Association (WACA) in it's 1999 'Building with Concrete and WACA Awards' This award to a porous pavement installation company states in part: "According to the concrete industry, the potential benefits for the use of "no fines" concrete fits well with the direction public works departments and developers are considering to meet the new standards for stormwater management. The immediate benefits of using "no fines" concrete result in no water leaving the site, eliminates the need for stormwater collection and detention systems, and increases the pervious to impervious ratio of a property. The multiple layer pavement and drainage system will naturally provide water retention and will essentially mimic the drainage and filtration action of naturally unpaved surfaces.

"No fines" or "Portland cement pervious pavement" is acknowledged and suggested as a best management practice in the Puget Sound Stormwater Management Manual.

EPA Office of Wetlands, Oceans & Watersheds Technical Note 21, Thomas Cahill, Cahill Associates:

“Contrary to prevailing wisdom, porous pavement/underground recharge bed BMP applications can be developed successfully. The quandary is illustrated vividly by porous pavement, a technique proposed over twenty years ago. After numerous unsuccessful installations, use of porous pavement is routinely rejected by most engineers, designers, and stormwater program developers.

Contrary to prevailing wisdom, however, porous pavement/underground recharge bed BMP applications can be developed successfully. Cahill Associates (CA), a suburban Philadelphia environmental engineering firm, has been designing and constructing porous pavement/recharge bed installations in Middle Atlantic State locations for over 12 years. Their porous pavement installations serve a range of building parking needs and customers include office centers, fast food restaurants, libraries, and condominiums. Areas covered range from 3,000 to 147,000 square feet. Experience has shown that most porous pavement failures occur because of a lack of erosion/sediment control during construction. In many instances, contractors, unfamiliar with what they were doing and why they were doing it, allowed substantial quantities of sediment to erode onto the pavement surface after installation.”

The Natural Resources Defense Council 1999 Report: "Stormwater Strategies-Community Responses to Runoff", This 11 chapter bound publication and internet published report states in part: "Porous asphalt and concrete differ from regular asphalt and concrete because fine materials are not added to fill in the gaps between the coarser aggregate in the pavement material, so that myriad small holes allow water to infiltrate. Porous asphalt and concrete are recommended for appropriate locations to recharge groundwater, reduce stormwater management costs and improve stormwater quality."

Timothy Randhir, Assistant Professor, Department of Natural Resources Conservation, Holdsworth Natural Resources Center University of Massachusetts, Amherst, also reports: "Open-graded (10% volume of voids in asphalt concrete) asphalt concrete was found to exhibit superior physical characteristics compared to conventional paving methods. Porous pavements allow for detention storage, increase aquifer recharge, improve water quality by reducing shock loading, alleviate flash flooding, and preserve natural drainage patterns."

Porous pavement in a cold climate thesis 1999-04-20 Sweden ISSN 1402-1757 / ISRN LTU-LIC--99/21--SE / NR 1999:21

State in part: “In-situ measurements of ground temperature, frost heave, groundwater levels, and runoff was performed. The draining function of the porous asphalt at different ambient air temperatures in the range -10 °C to +20°C was investigated in the laboratory. It was found that porous pavements have a potential to reduce meltwater runoff, avoid excessive water on the road surface during the snowmelt period, and accomplish groundwater recharge by local disposal of stormwater. The porous pavement was more resistant to freezing and frost heave than a comparable impermeable pavement. The full-scale porous pavement construction was not damaged by irregular frost heave. Thawing of porous pavement was a rapid process, which was explained by meltwater infiltration during the beginning of the snowmelt period.”

Appendix H. Exploring the Option of Surface Water Flows - Daylighting

Well over 95% of Allen's Creek have been enclosed in storm drains. As the community continues to implement ameliorative watershed management policies, the possibility will arise of bringing significant stretches of Allen's Creek back into the daylight.

In the upper stretches of the watershed, this could include removing the storm drain pipes altogether and restoring the natural creek channel. This process might occur in areas such as West Park or the ravine running east from Veteran's Park, for example.

Regarding the main branch of the storm drain, say from W. William St. down to the Huron River, restoring the original creek channel would pose more of a challenge. Current very high flow rates and volumes during flooding events would likely create a significant hazard and would need to be mitigated. Also, part of the main branch of the storm drain runs directly under buildings, which would need to be removed; this would be both costly and politically controversial.

In some areas there is an alternative: the creation of a parallel, "designed" open channel running through the lower Allen's Creek valley. The storm drain would remain in place to handle storm and flood events, while the open channel above ground would contain a continuously running stream of high-quality surface runoff water.

This concept draws inspiration from the work of James Patchett and Herbert Dreiseitl. As described by Patchett in "**Water Conservation**," Volume III, No. 1, Spring 1999, the journal of the American Society of Landscape Architects, surface water flows of stormwater can be designed both as aesthetic amenity and as a reminder to people in the community of the existence of a watershed and its ecology. The concepts they have advanced are suitable for an urban watershed such as Allen's Creek.

In "Daylighting: New Life For Buried Streams" Written by Richard Pinkham Rocky Mount Mountain Institute^[24], a US EPA funded report, documents in detail 18 projects that have day-lighted over 14,000 feet of waterways in the continental United States. Another five completed projects in the United States are listed and it describes or lists another 23 projects that are in various stages of consideration.

As Richard Pinkham of the RMI describes it "[t]he term *daylighting* describes projects that deliberately expose some or all of the flow of a previously covered river, creek, or stormwater drainage. Daylighting projects liberate waterways that were buried in culverts or pipes, covered by decks, or otherwise removed from view. Daylighting re-establishes a waterway in its old channel where feasible, or in a new channel threaded between the buildings, streets, parking lots, and playing fields now present on the land. Some daylighting projects recreate wetlands, ponds, or estuaries."

In just one example sited, the city of Kalamazoo daylighted a five-block section of Arcadia Creek in downtown as part of a multi-year, multi-million-dollar redevelopment project completed in 1995. From 1989 to 1992, the Downtown Development Authority and its consultants completed engineering studies, did design work, secured development agreements, and funded the project. Construction took place from 1989 to 1995.

The combined stream, channel, stormwater pond, and double culvert provide Kalamazoo with protection from a **500-year flood**. Authorities have now redrawn local floodplain maps. Downtown properties **no longer pay flood insurance**.

The flood-protection benefit and amenity value of the creek combine with the overall redevelopment effort to boost the attractiveness of Kalamazoo's downtown for private investment. Ken Nacci, director of the Downtown Development Authority, puts it succinctly: "What we have is much better than what we had." Public-sector investments of \$18 million for the entire redevelopment project have leveraged more than **\$200 million** in private development, including a new museum, a bank headquarters, and other institutions and businesses. Property tax revenues to the city from the redevelopment zone have increased from \$60,000 to **\$400,000** annually. Activities at the new festival site by the stormwater pond generate an estimated **\$12 million annually** in sales and payroll for local businesses. Nacci also notes: "... and we still have some available properties" that could be added to further increase the tax roles.

The Downtown Development Authority issued bonds based on tax-increment financing; these bonds are now being repaid by property-tax revenues from the redevelopment zone.

In the recently published book "The Language of Landscape"^[25], Anne Whiston Spirn, Professor at MIT, Boston Massachusetts, describes similar work in both Philadelphia, Pennsylvania and Boston, Massachusetts, where she helped design the plans that created a conversion of slums and abandoned areas in floodways and floodplains into green spaces and open creek areas with great success. Neighborhoods in these areas have also changed dramatically for the good in a few short years after completion of the projects.

She argues that these areas do not become slums because of the people who live in them but because of their inherent un-livability in the floodways and floodplains. Additional redevelopment of dilapidated structures and abandoned sites in the areas were rejected with her guidance and foresight.

Sprin writes about the Philadelphia project, "Rain now runs off rooftops, streets, and sidewalks into ponds in the parks, ponds that contain the water and slow its passage to the sewer, the treatment plant, and the river.

Mill Creek parks are now models of community development, environmental education, and water management, the first sewer, urban floodplain to be mapped in the United States, the first use of inner-city vacant land for stormwater detention to prevent combined sewer overflows, the pilot for many other projects in Philadelphia that saved millions of dollars."

Ann Arbor has great opportunities in these areas as well, similar to Boston, Philadelphia, Kalamazoo and other cities that worked hard to make the most of their natural resources and bring natural landscapes back to downtowns. It is clear these city's citizens and the environment have reaped much as a result.

Appendix I. Optional Site for Wetland Restoration

Wetland preservation and restoration should be undertaken in Allen's Creek. An example of a potential wetland site for restoration is the parcel owned by the Ann Arbor Art Center on Felch Street. This site appears to have been at one time a floodplain wetland adjacent to Allen's Creek. However, industrial use as an oil station with a cement and concrete oil storage platform built into the wetland led to the wetland's degradation. The deteriorating platform remains. This wetland could be restored for water quality and quantity benefits, perhaps as part of the Allen's Creek greenway. Another potential site is the wetland in West Park, southeast of the band shell, which appears much larger in an aerial photograph taken in 1948.

Appendix J. Greenway Development Options

An Allen's Creek greenway could start from the planned greenway along the Huron River and run through downtown Ann Arbor up to the University of Michigan athletic campus. Further, the greenway could potentially branch out along Allen's Creek up through Ann Arbor's west side, linking existing (and possibly new) parks along the creek route.

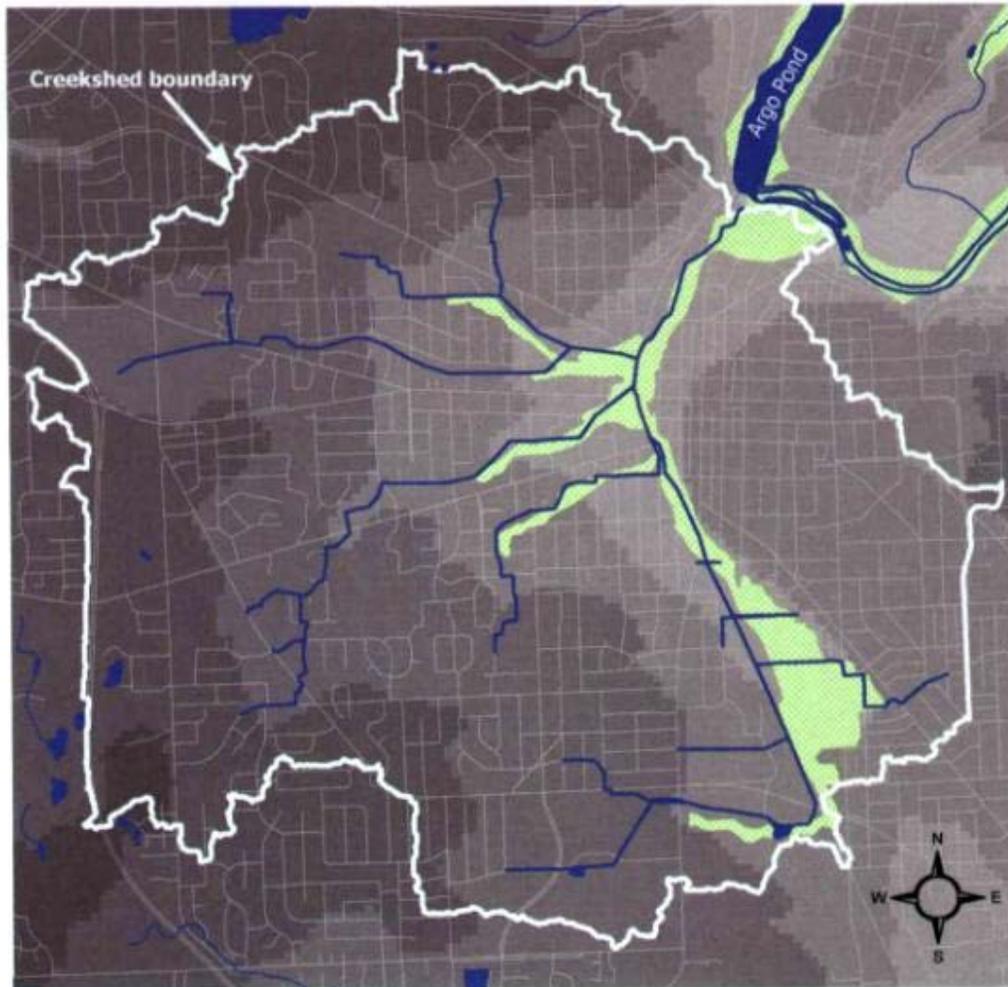
For example, a connected greenway along the West Park Branch could run from the main stem of Allen's Creek at the Ann Arbor Railroad, through West Park, up along ravines to Wildwood Park and then to Veteran's Park. Because the City of Ann Arbor is considering a detention pond for the triangular lot behind the Kmart in the Maple Village Shopping Center, this detention facility could be designed as a park as well and be linked to Veterans Park via the greenway path. Finally, the greenway could be extended to Evergreen Park on the far west side of the city.

Several issues emerge regarding the question of greenway development. For example, it would not be possible to link the parks along the upper branches with an uninterrupted green pathway. Part of the path would have to be along street and sidewalks. However, the path could be marked as part of the Allen's Creek greenway system, with decorative guideposts signifying that spot's location on a map of the watershed.

In the lower Allen's Creek watershed along the main stem of the creek from the University of Michigan golf course to the Huron River, a different set of considerations emerges. Here, much of the floodway is developed and includes significant historic residential neighborhoods. A greenway through these neighborhoods would be planned to provide homeowners in these neighborhoods with an adjacent amenity.

Appendix K. Allen's Creek Watershed Maps

Figure 1. Allen's Creekshed with elevation, streets, and floodplain



elevation (feet)
770 - 787
787 - 841
841 - 895
895 - 948
948 - 1002
1002 - 1025

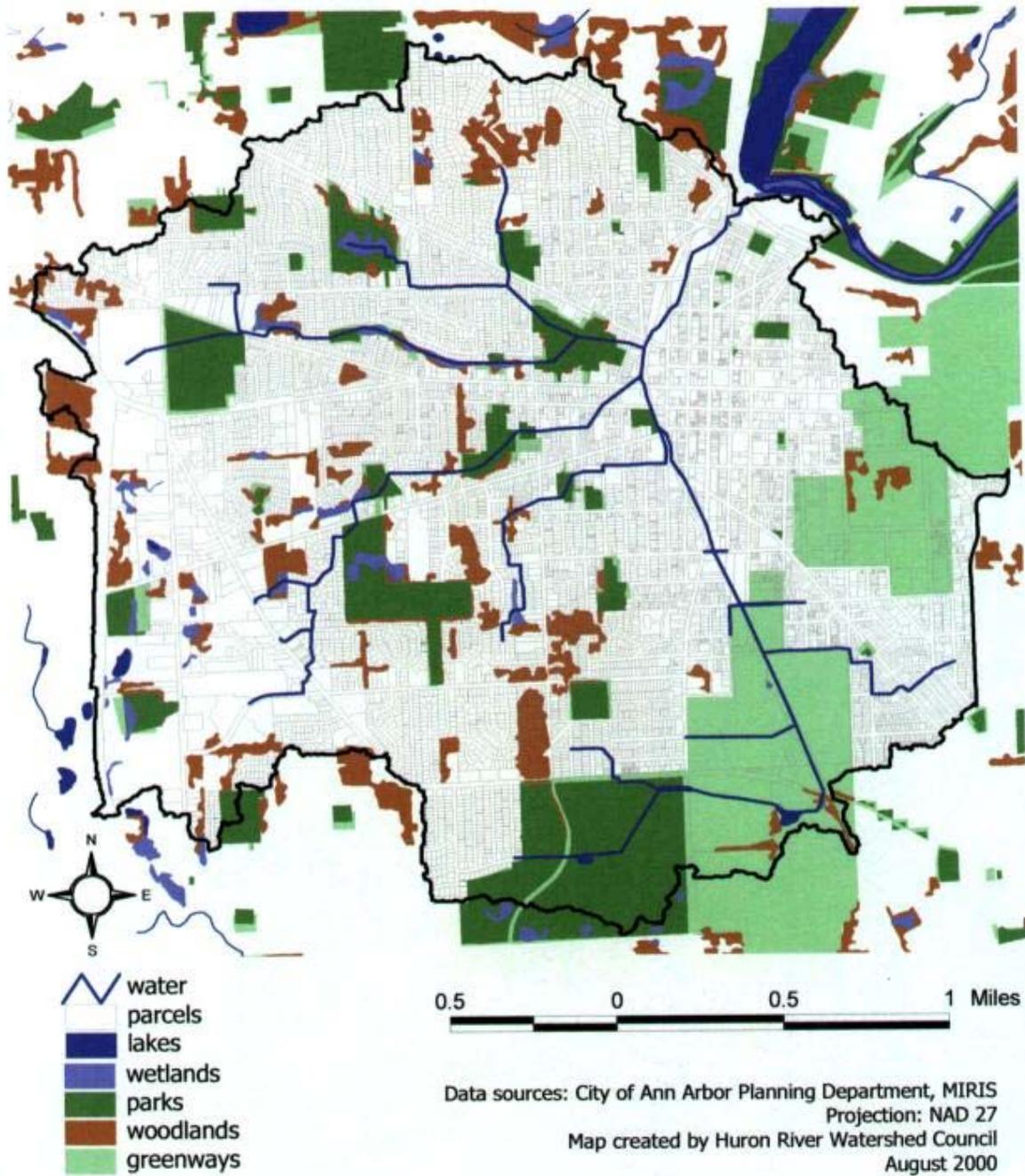
-  water
-  floodplain
-  streets



Data sources: City of Ann Arbor Planning Department, MIRIS
Projection: NAD 27
Map created by Huron River Watershed Council
August 2000

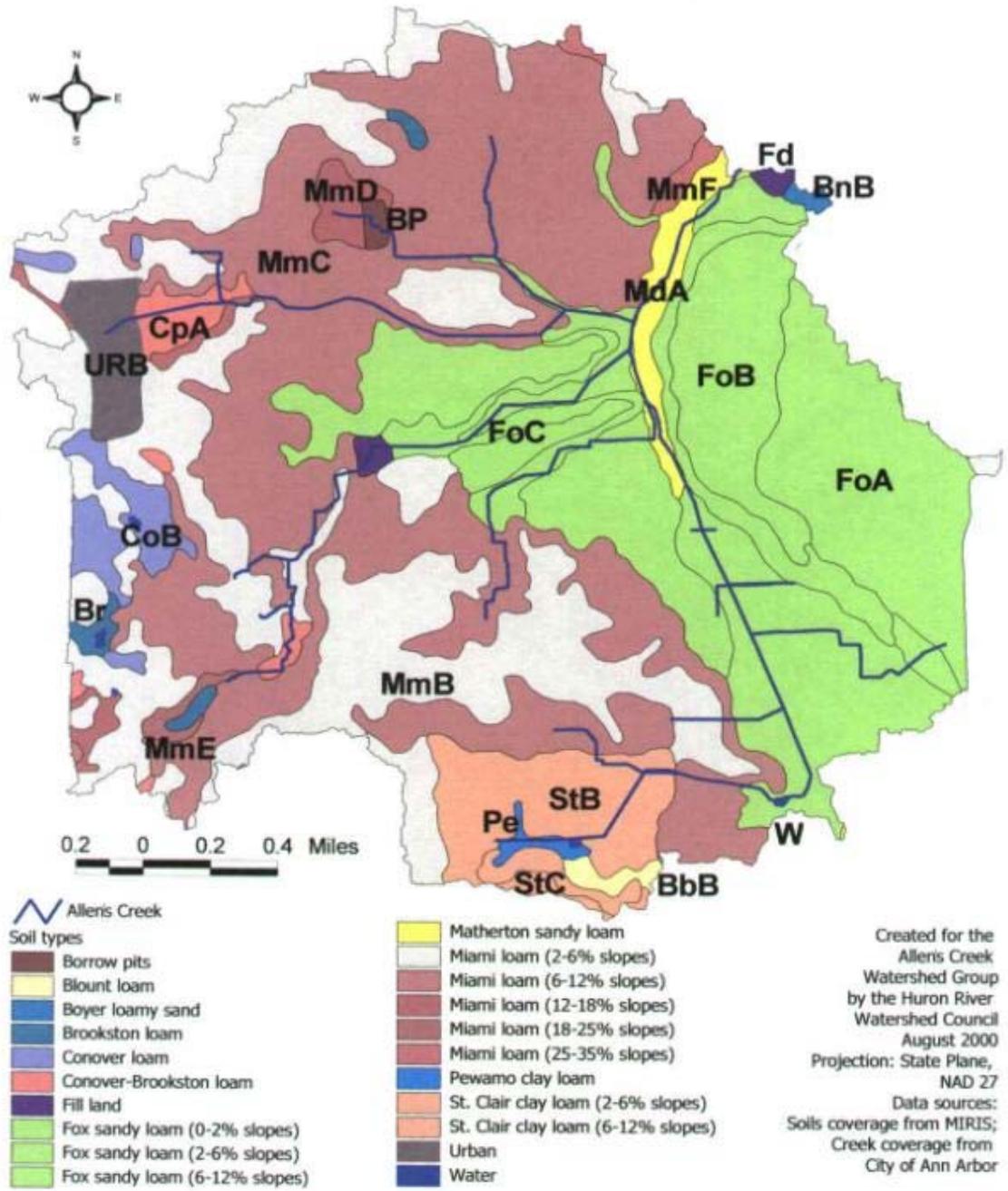
1.

Figure 2. Allen's Creekshed with natural features and open spaces



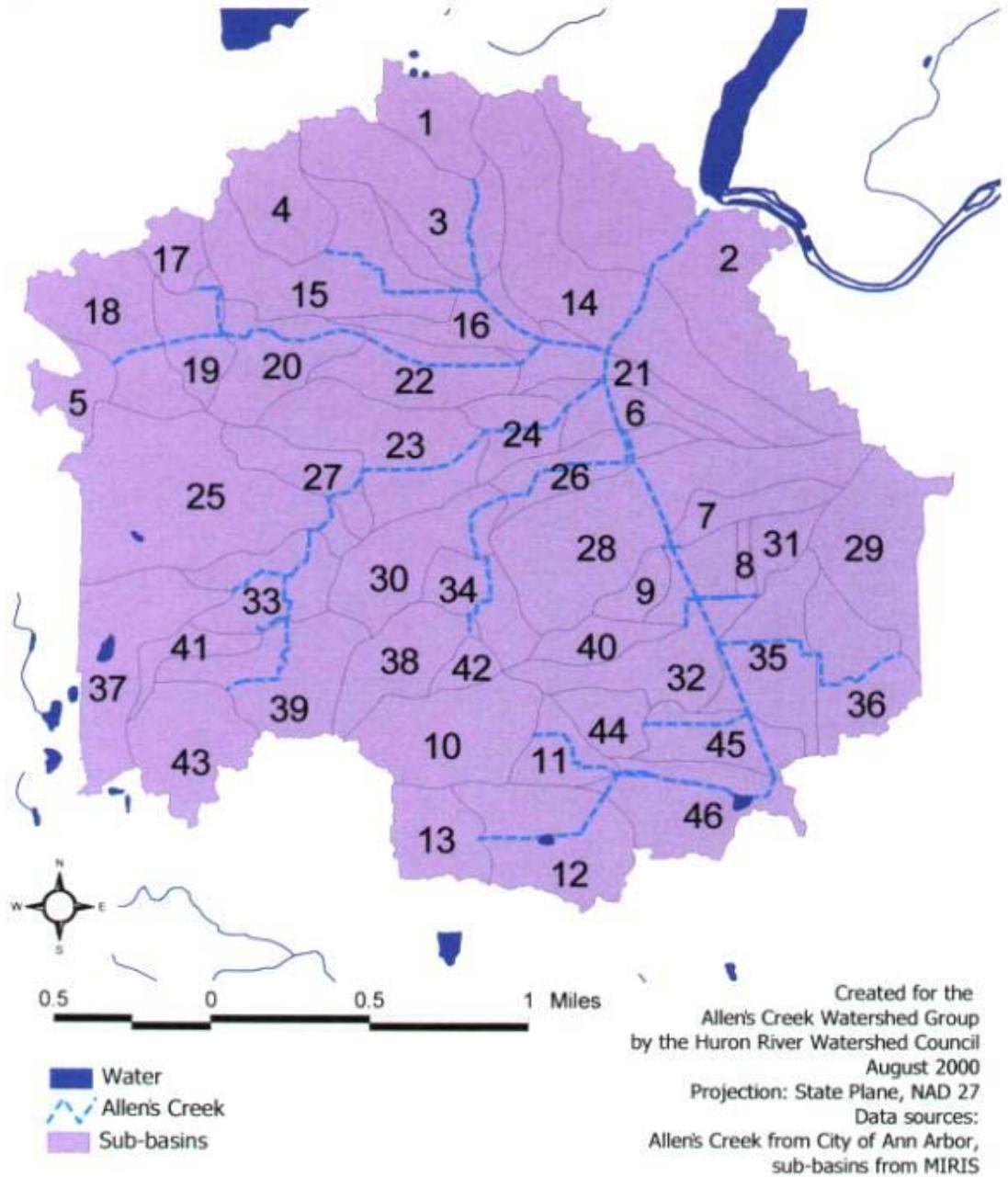
2.

Figure 3. Allen's Creekshed soils

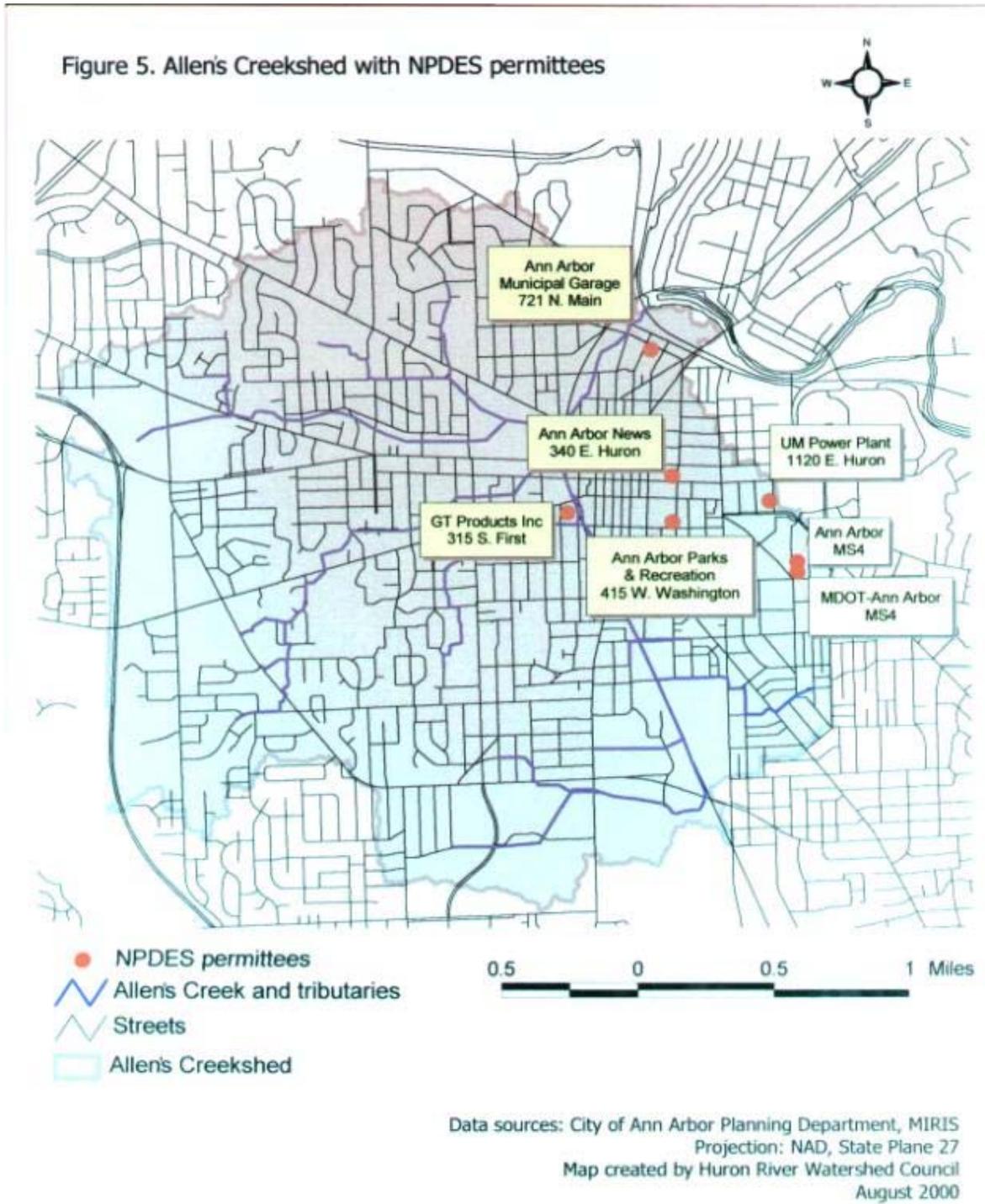


3.

Figure 4. Allen's Creekshed with sub-basins

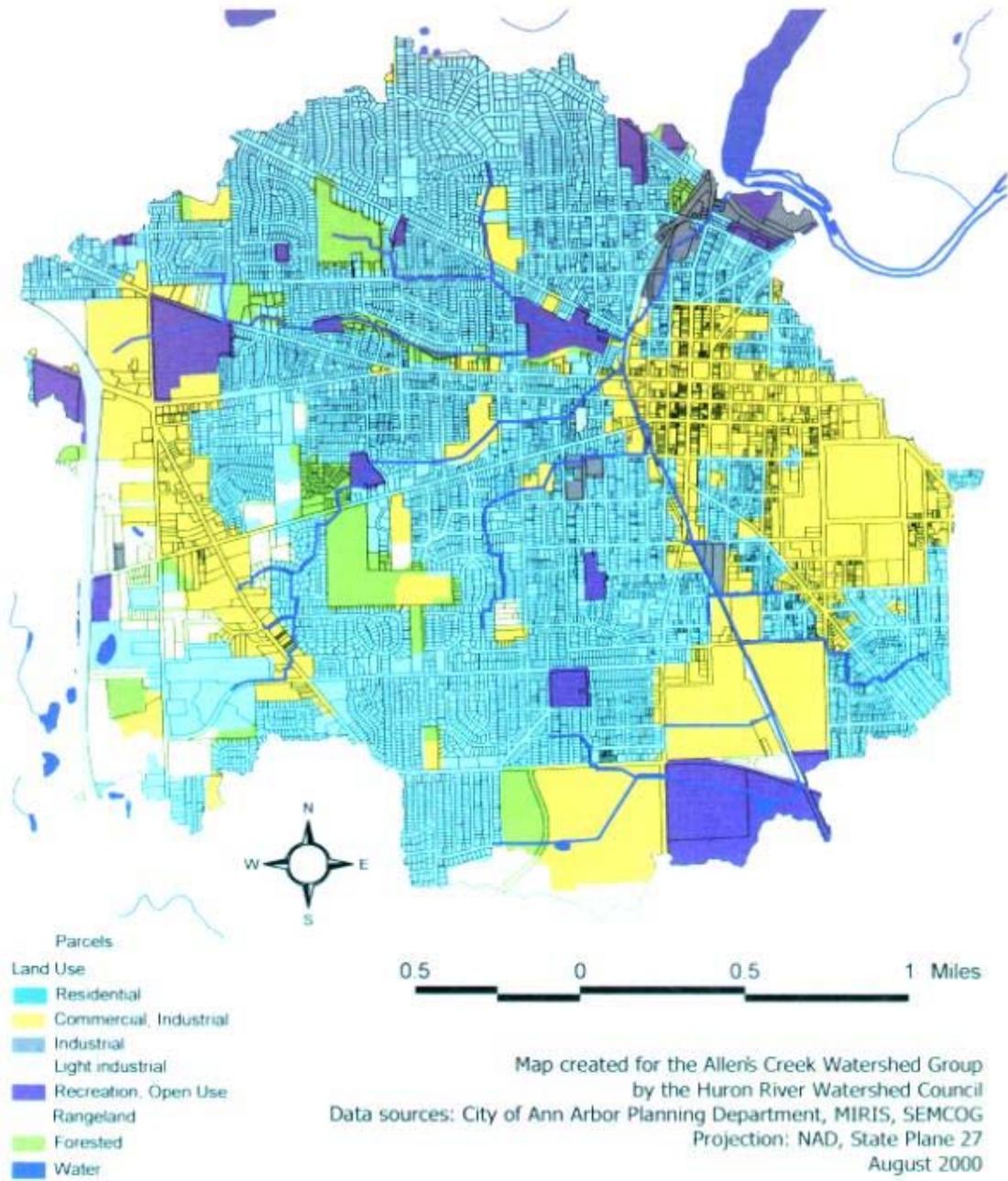


4.



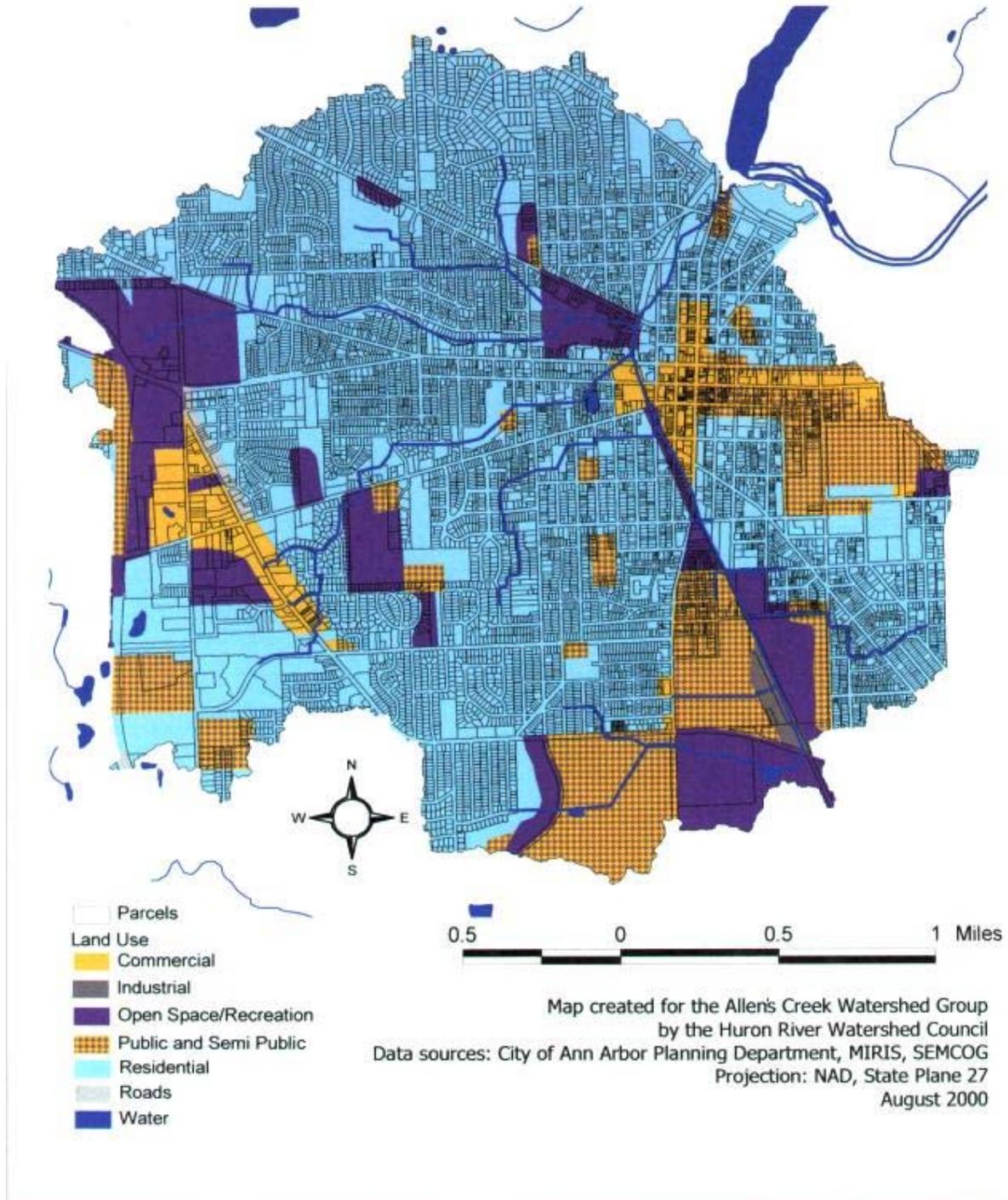
5.

Figure 6. Allens Creekshed with 1995 land use



6.

Figure 7. Allens Creekshed with future land use (per master plan)



[1] Also referred to as Allens Creek, Allen's Drain or Allens Drain.

[2] "Control of Nitrogen Export from Watersheds by Headwater Streams," Bruce J. Peterson, Ecosystems Center, Marine Biological Laboratory, Woods Hole, MA. *Science*, Vol. 292, No. 5514, 6 Apr 2001, pp. 86-90.

[3] United States Center of Disease Control. Update: Pulmonary hemorrhage/hemosiderosis among infants -- Cleveland, Ohio, 1993-1996. *MMWR*. Vol. 46, No. 2, pp. 33-35, 1997; see also <http://www.cdc.gov/epo/mmwr/preview/mmwrhtml/00045680.htm>.

[4] United States Environmental Protection Agency - Children's Health Initiative: Toxic Mold; Referenced January 2001 at

<http://www.epa.gov/appcdwww/crb/iemb/child.htm>.

[5] "The Importance of Imperviousness," T. R. Schueler, *Watershed Protection Techniques* Vol. 1, No. 3, Fall 1994, pp. 100-111; "Impervious Surface Coverage: The Emergence of a Key Environmental Indicator," C. I. Arnold and C. J. Gibbons, *J. Am. Planning Assn.* Vol. 62, No. 2, Spring 1996, pp. 243-258.

[6] Huron River Watershed Council, 2000.

[7] "The Causes of Urban Stormwater Pollution," in *Stormwater Strategies-Community Responses to Runoff*, The Natural Resources Defense Council, Chap. 2, 1999 (see also <http://www.nrdc.org>)

[8] "Reducing Toxic Air Pollution in Lake Michigan," Delta Institute, 2001, www.delta-institute.org referenced May, 2001.

[9] "Allen Creek Drain Water Quality Survey and Status Report," the Offices of the Washtenaw County Health Department and Drain Commissioner

[10] "The Middle Huron Initiative - Phosphorous Reduction Strategy for the Middle Huron Watershed," A. Brenner and P. Rentschler, Huron River Watershed Council, 1996.

[11] "City of Ann Arbor, Michigan Storm Water Master Plan," Black & Veatch, Nov. 1997.

[12] 44 CFR Sec. 60.1(d)

[13] "City of Ann Arbor, Michigan Storm Water Master Plan," Black & Veatch, Nov. 1997.

[14] "City of Ann Arbor, Michigan Storm Water Master Plan," Black & Veatch, Nov. 1997.

[15] "City of Ann Arbor, Michigan Storm Water Master Plan," Black & Veatch, Nov. 1997.

[16] Midwestern Consulting, Ann Arbor MI, Design Report to the City of Ann Arbor - Liberty Glendale Storm Drainage Improvement Project, MCI Job # 96218 - December 2, 1996

[17] <http://www.city.palo-alto.ca.us/earlywarning/creeklevels.html>

[18] Cahill Associate's Dupont Project is one of over two dozen installations of porous pavement and innovative stormwater management systems; <http://www.thcahill.com/english/projects/porousproj/dupont.htm> (2000)

[19] "Daylighting: New Life For Buried Streams," by Richard Pinkham Rocky Mount Mountain Institute, Old Snowmass Colorado 2000

[20] "City of Ann Arbor, Michigan Storm Water Master Plan," Black & Veatch, Nov. 1997.

[21] Detroit Free Press, December 4, 2000

[22] Patchett, *op cit.*, p. 1.

[23] Patchett, James, "Letter from the Chair," *Water Conservation*, Volume III, Number 1, Spring 1999, p. 3.

[24] "Daylighting: New Life For Buried Streams," by Richard Pinkham Rocky Mount Mountain Institute (www.rmi.org), Old Snowmass Colorado, 2000, <http://www.rmi.org/images/other/W-Daylighting.pdf>

[25] "The Language of Landscape", Anne Whiston Spirn, Yale University Press, 1998; <http://www.yale.edu/yup>