Pebble Creek Watershed Implementation Plan

January 15, 2019

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Acronyms and Abbreviations

ARC	Alliance of Rouge Communities
AUID	assessment unit identifier
BEHI	bank erosion hazard index
BMP	Best Management Practice
cfs	cubic feet per second
CID	Corridor Improvement District
CN	curve number
CMI	Clean Michigan Initiative
CMP	Comprehensive Management Plan
DCIC	directly-connected impervious cover
FOTR	Friends of the Rouge
GIA	green infrastructure area
GIS	Geographic Information System
GLPF	Great Lakes Protection Fund
GLRI	Great Lakes Restoration Initiative
GLWQA	Great Lakes Water Quality Agreement
GSI	green stormwater infrastructure
HUC	Hydrologic Unit Code
I&E	Information and Education
L-THIA	Long-Term Hydrologic Impact Analysis
LSPC	Loading Simulation Program C++
MDEQ	Michigan Department of Environmental Quality
MS4	Municipal Separate Storm Sewer System
NLCD	National Land Cover Database
NPDES	National Pollutant Discharge Elimination System
NPS	nonpoint source
NRCS	Natural Resources Conservation Service
NWIS	National Water Information System
OCPR	Oakland County Parks & Recreation
OCWRC	Oakland County Water Resources Commission
OIALW	Other Indigenous Aquatic Life and Wildlife
QAPP	Quality Assurance Project Plan
P51	Procedure 51
PACE	Property Assessed Clean Energy
PBC	partial body contact
PPP	public – private partnership

R-B Index	Richards-Baker Flashiness Index
RCOC	Road Commission of Oakland County
ROW	right-of-way
RPO	Rouge Program Office
SEMCOG	Southeast Michigan Council of Governments
SWC	National Stormwater Calculator
SWMM	Storm Water Management Model
SWPPP	Storm Water Pollution Prevention Plan
TBC	total body contact
TSS	total suspended solids
TMDL	Total Maximum Daily Load
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WMP	Watershed Management Plan
WPCRF	Water Pollution Control Revolving Fund
WQS	Water Quality Standards

Executive Summary

The Pebble Creek Watershed Management Plan (WMP) builds on techniques applied in several southeast Michigan subwatersheds affected by stormwater runoff. This WMP uses a Best Management Practice (BMP) targeting methodology, which helps guide development of implementation strategies that will meet watershed planning goals and objectives. This approach places an emphasis on identifying BMPs, which can be implemented in critical areas and are eligible for Clean Water Act Section 319, Great Lakes Restoration Initiative (GLRI), or other grant funding opportunities.

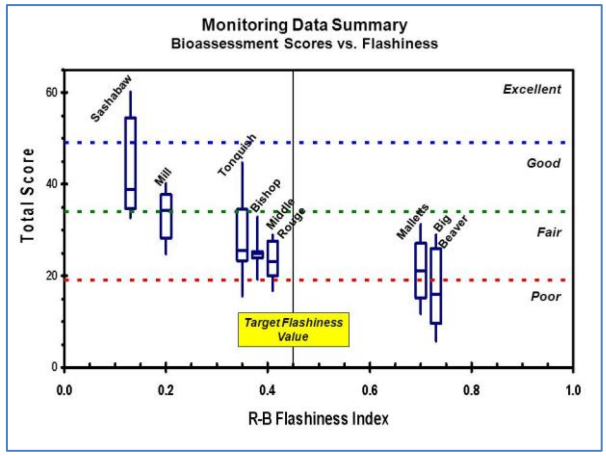
The technical approach used to develop this WMP draws on information gained and "lessons learned" from recent green infrastructure targeting efforts. These efforts were conducted using a stormwater management framework in conjunction with an outcome-based strategic planning process. Based on this approach, the Pebble Creek WMP identifies:

- ***targets*** to reduce urban stormwater volumes and pollutant loads needed to meet water quality standards and protect designated uses in urban watersheds;
- ***critical areas*** that contribute the greatest stormwater runoff volumes / pollutant loads and have a disproportionate effect on water quality; and
- ***BMP opportunities*** that, when implemented, will result in measurable improvements relative to mitigating the adverse effects of urban stormwater.

From a watershed implementation perspective, the Pebble Creek WMP also includes a concept referred to as green infrastructure area (GIA). Green infrastructure area defines the amount of directly-connected impervious cover (DCIC) that needs to be managed using urban stormwater BMPs to reduce flooding, threats to infrastructure, and loss of property, as well as achieve water quality standards (WQS) and protect biological communities. The emphasis on impervious cover is consistent with stormwater management methods used across the country. Urban BMPs that can be applied at specific locations typically focus on the amount and type of impervious area that can be directed to a stormwater facility (for either flow control or water quality treatment).

A key to successful implementation depends on identifying critical areas. Development of this WMP used a multi-scale analysis coupled with an assessment of impervious cover composition to highlight potential priority areas in the Pebble Creek Hydrologic Unit Code (HUC-12) that contribute the greatest stormwater volumes and pollutant loads. Identification of critical areas in the Pebble Creek HUC-12 watershed also included the use field inventory information. In addition, compilation and analysis of the field inventory data recognized the overarching need to align transportation planning with stormwater management activities. Not only do storm sewer networks typically follow the road right-of-way (ROW); other significant connected impervious surfaces (e.g., parking lots, driveways) are generally linked to the transportation system.

Outcome-based strategic planning for the Pebble Creek HUC-12 watershed hinges on sound, meaningful target development. Stream flashiness, expressed through the Richards-Baker (R-B) Index, connects aquatic biology and channel concerns with stormwater management activities. Because hydrology affects channel stability, stream habitat, aquatic biology, and the delivery of pollutant loads, these relationships provide a basis to examine urban BMP implementation strategies.



Biological and hydrologic conditions are linked to establish runoff volume reduction needs based on work conducted in southeast Michigan.

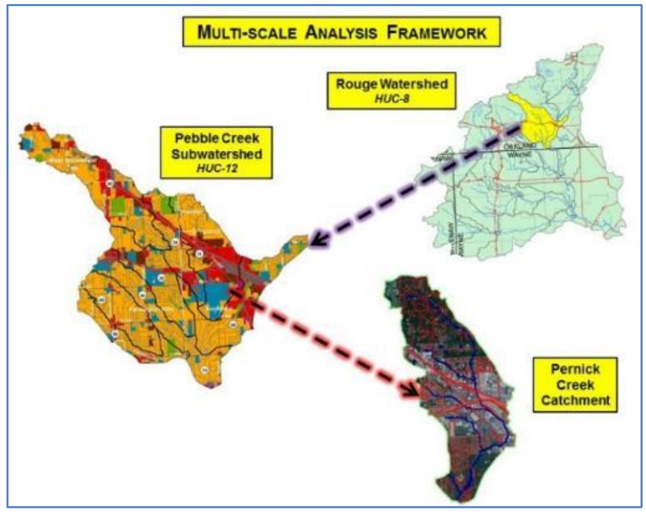
While the R-B Index provides a good indicator showing the relationship between hydrology and its effect on aquatic biology, stream flashiness is not particularly well suited for evaluating location specific stormwater BMPs in the Main Rouge and Pebble Creek watershed. This is because projects are typically implemented at smaller scales (i.e., site or catchment as opposed to the watershed scale). An approach routinely used in stormwater management emphasizes BMP designs based on mimicking pre-settlement hydrology; one that results in strategies focused on retaining the volume produced by a certain rain event (e.g., up to the two-year 24-hour storm). This approach emphasizes channel protection, which is influenced by stream flashiness that in turn affects aquatic habitat and biology.

With a focus on management practices that retain stormwater runoff volume, options examined in the Pebble Creek HUC-12 watershed looked at the resultant effect on stream flashiness. Desktop screening analysis links annual average volume reductions to R-B Index values. An advantage of desktop screening is that it also accounts for the relative effect of impervious cover on hydrology. Generally, the greatest increase in R-B Index values occurs at directly-connected impervious cover levels around 15 percent. This is consistent with other studies, which indicate that streams often show signs of degradation and are considered stressed when the DCIC exceeds these same levels.

Green infrastructure area is the amount of land needed to manage stormwater runoff from connected impervious surfaces.

Based on the relationship between bioassessment metrics and stream flashiness, volume reduction targets are identified by priority catchment groups and critical areas that meet channel protection needs. Implementation strategies identified in the Pebble Creek WMP place an emphasis on managing the effect of directly-connected impervious cover.

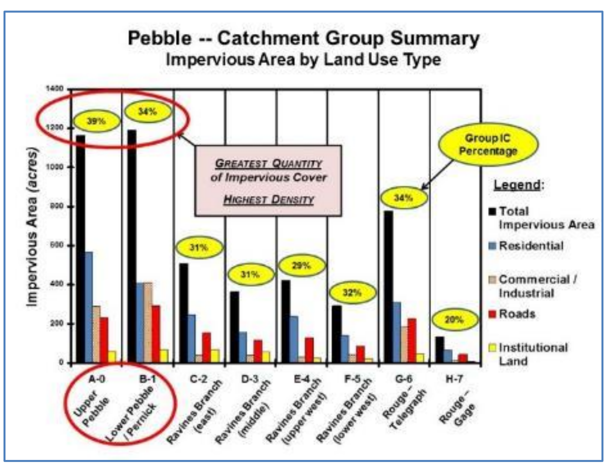
Identifying outcomes in the Main Rouge and the Pebble Creek HUC-12 watershed depends on an understanding of watershed conditions and stormwater management networks through drainage assessments. A key aspect in development of the Pebble Creek WMP is the multi-scale framework used to examine potential stormwater source areas and evaluate BMP implementation opportunities. The multi-scale analysis framework specifically moves to progressively smaller geographic areas based on priority concerns and opportunities to implement urban storm BMPs. Stormwater sources, including different land use contributions to runoff challenge, were characterized using impervious cover data.



Multi-scale analysis enables targeting of critical areas in the Pebble Creek HUC-12 watershed based on priority concerns and opportunities.

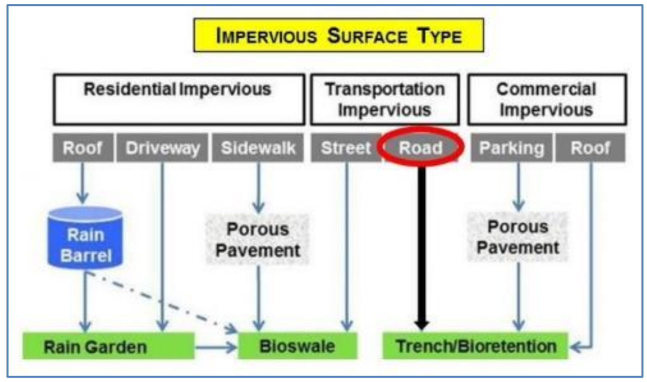
The Southeast Michigan Council of Governments (SEMCOG) compiled an inventory for Pebble Creek, which included impervious cover estimates based on evaluation of parcel-scale data including transportation corridors, parking lot locations, and building footprints. Critical areas in the Pebble Creek HUC-12 watershed were initially prioritized based on land use and impervious cover information. Impervious surface composition (type, amount, density) is characterized by land use category (residential, roads, etc.) to identify high priority catchments where: a) the total amount of impervious area is greater, and b) the percentage of impervious cover is higher. The data is also categorized by jurisdiction to describe the overall contribution by land use type and ownership. Coupled with the catchment delineations, this information allowed potential stormwater source locations to be examined and priority areas identified, which reflect the mix of different land uses present across the subwatershed.

While impervious cover composition provides a starting point to identify priority source locations, development of the Pebble Creek HUC-12 WMP highlighted the need for field inventory information to help refine the critical area analysis. The field inventory provided a focus on directly connected pathways, delivery mechanisms, and in-stream effects (particularly evidence of channel incision and bank erosion). This enabled targeting specific critical locations where BMP implementation will be most effective in achieving overall watershed management objectives. The field inventory information included detailed parking lot delineations (size and condition) developed by Michigan Department of Environmental Quality (MDEQ) staff. This was augmented with other field inventory data including roadway corridor data, storm sewer system inlet points, outfall locations, riparian indicators, channel metrics, existing treatment, planned improvements, and stream conditions at road crossings.



Land use / land cover information provided an estimate of how much different stormwater source areas potentially contribute to water quality concerns in the Pebble Creek HUC-12 watershed.

The drainage assessment in the Pebble Creek HUC-12 watershed highlights critical areas where BMP implementation will be most effective (i.e., critical areas that have a disproportionate effect on hydrology and water quality). In urban settings, critical areas are locations that have higher amounts and percentages of connected impervious cover. Coupled with rainfall data, impervious cover provides an estimate of potential stormwater runoff volume generated.

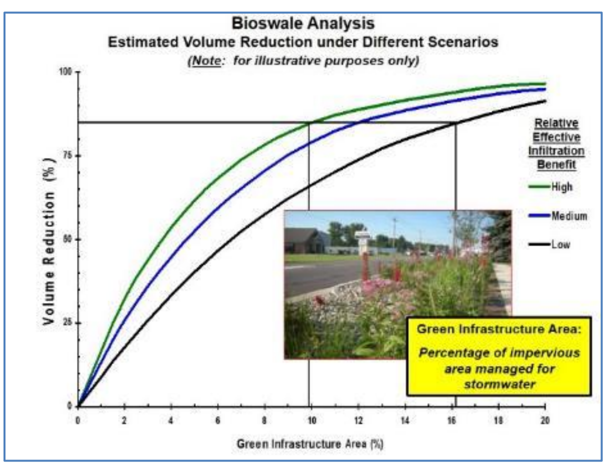


A key component of the options analysis for the Pebble Creek WMP is identifying the amount and type of impervious area that can be directed to a BMP.

Development of the Pebble Creek WMP considered an array of implementation strategies, both constructed runoff volume reduction practices and the use of natural areas. Major considerations include feasibility, constraints, potential effectiveness, and associated benefits. A key component of the options assessment for the Pebble Creek WMP is identifying the amount and type of impervious area that can be directed to a BMP.

Desktop analyses used in development of the Pebble Creek WMP provide estimates of the relative benefit derived from various management practices applied in critical areas. Specifically, desktop analyses can be used to evaluate relative BMP performance given the array of sizing options (e.g., bioretention media depth, amount of area retrofitted, etc.) and the range of design assumptions (e.g., native soil infiltration rates). Urban stormwater BMPs to achieve stream flashiness and volume reduction targets include bioretention, infiltration, vegetative conveyance, and porous pavement. Other aspects of the BMP options evaluation include physical suitability of the site, costs, access, maintenance needs, and design/build time.

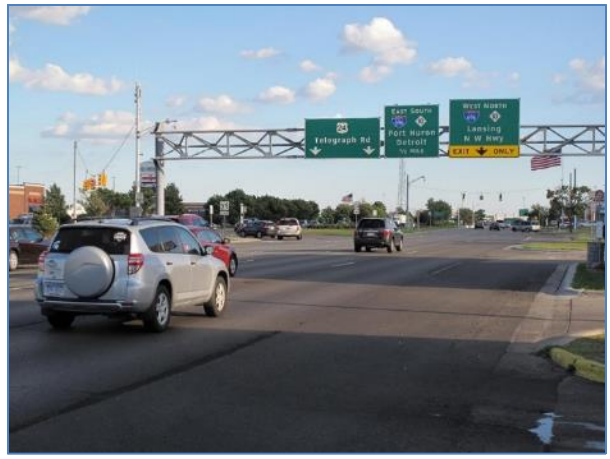
In addition to targeting stormwater volume reduction opportunities, another objective of the Pebble Creek WMP is to identify BMPs that can be implemented in critical areas and are eligible for grant funding (e.g., §319, GLRI). The Main Rouge and Pebble Creek, like many other urban watersheds, present some unique challenges with respect to determining whether or not proposed projects are grant eligible. This is because of the potential overlap with Section 402 National Pollutant Discharge Elimination System (NPDES) permits issued to Municipal Separate Storm Sewer System (MS4) jurisdictions. For example, projects and activities in the Pebble Creek HUC-12 watershed, which are required by MS4 permits, are not eligible for §319 grant funding.



Desktop analyses used in developing the Pebble Creek WMP examined the effect of key design parameters and the relative level of implementation needed to achieve targets.

The challenges facing stormwater management in the Pebble Creek HUC-12 watershed is indicative of those in other urbanized areas of Michigan; a typical mix of residential development, commercial areas with large parking lots, and roadways managed by multiple jurisdictions. The resultant increase in impervious cover has led to flashy stream flows, flooding problems, bank erosion, and siltation; all affecting aquatic habitat and biological conditions.

The initial assessment for Pebble Creek focused on green infrastructure opportunities associated with the state transportation system. An important "lesson learned" from that effort recognized the overarching need to align transportation planning with stormwater management activities. Not only do storm sewer networks typically follow the road ROW; other significant connected impervious surfaces (e.g., parking lots, driveways) are generally linked to the transportation system at all jurisdictional levels. In addition, development of the Pebble Creek WMP included consultation with key stakeholders to examine other BMP opportunities, their feasibility / effectiveness, potential funding mechanisms, and other important planning considerations (e.g., site design, costs, maintenance).



The Pebble Creek WMP recognizes the need to align transportation planning with stormwater management activities.

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1. Introduction

The Pebble Creek watershed (HUC-12 04090004-0404), located in Oakland County, includes the segment of the mainstem Rouge River from its confluence with Franklin Branch to Eight-Mile Road and its tributaries (Figure 1, Figure 2). This watershed drains nearly 23 square miles of the Main 1-2 Storm Water Management Area (SWMA), flowing through the Cities of Southfield and Farmington Hills, as well as West Bloomfield Township.

In addition to the mainstem Rouge and Pebble Creek, this subwatershed contains several other tributaries, notably Pernick Creek and the Ravines Branch. The middle reach of Pebble Creek, north of the confluence with Pernick Creek is characterized as a deep ravine. Pernick Creek is significantly influenced by urban development that affects its hydrology and water quality. The segment of the Main Rouge in this watershed also experiences typical urban watershed problems including high flow variability, loss of habitat, bank scouring, and severe streambank erosion (City of Southfield, 2012).

The Environmental Protection Agency (EPA) has approved Total Maximum Daily Loads (TMDLs) for biota and *E. coli* bacteria across the entire Rouge River watershed, with the Main Rou*ge* identified as an impaired stream. The biota target is the re-establishment of fish and macroinvertebrate communities that result in a consistent Acceptable or Excellent rating from the Michigan Department of Environmental Quality (DEQ) Procedure 51 Biological Community Assessment Protocol (ARC 2012).

This Watershed Management Plan (WMP) was created to complement the array of water quality management activities being conducted in this area within Oakland County. The County and the communities within the watershed recognize that this WMP is part of a broader regional effort involving state, municipal, business, and federal leaders to improve the quality of water resources in southeast Michigan. The shared goals between Southfield, Farmington Hills, West Bloomfield, Oakland County, DEQ, the Michigan Department of Transportation (MDOT), and the Southeast Michigan Council of Governments (SEMCOG) brought their offices together to develop this plan.

This WMP is intended to support local efforts to move toward an integrated approach in managing limited resources (technical/financial) while maximizing environmental benefits. Water quality management activities conducted by the local jurisdictions include stormwater reduction projects developed as part of their Municipal Separate Storm Sewer System (MS4) efforts. In addition, the integrated approach promoted by this WMP also incorporates infrastructure projects identified through each jurisdiction's Capital Improvement Program (CIP) planning process and asset management programs. Finally, this integrated approach recognizes the overarching need to align transportation planning with watershed management activities. Not only do storm sewer networks typically follow the road right-of-way (ROW); other significant connected impervious surfaces (e.g., parking lots, driveways) are generally linked to the transportation system.

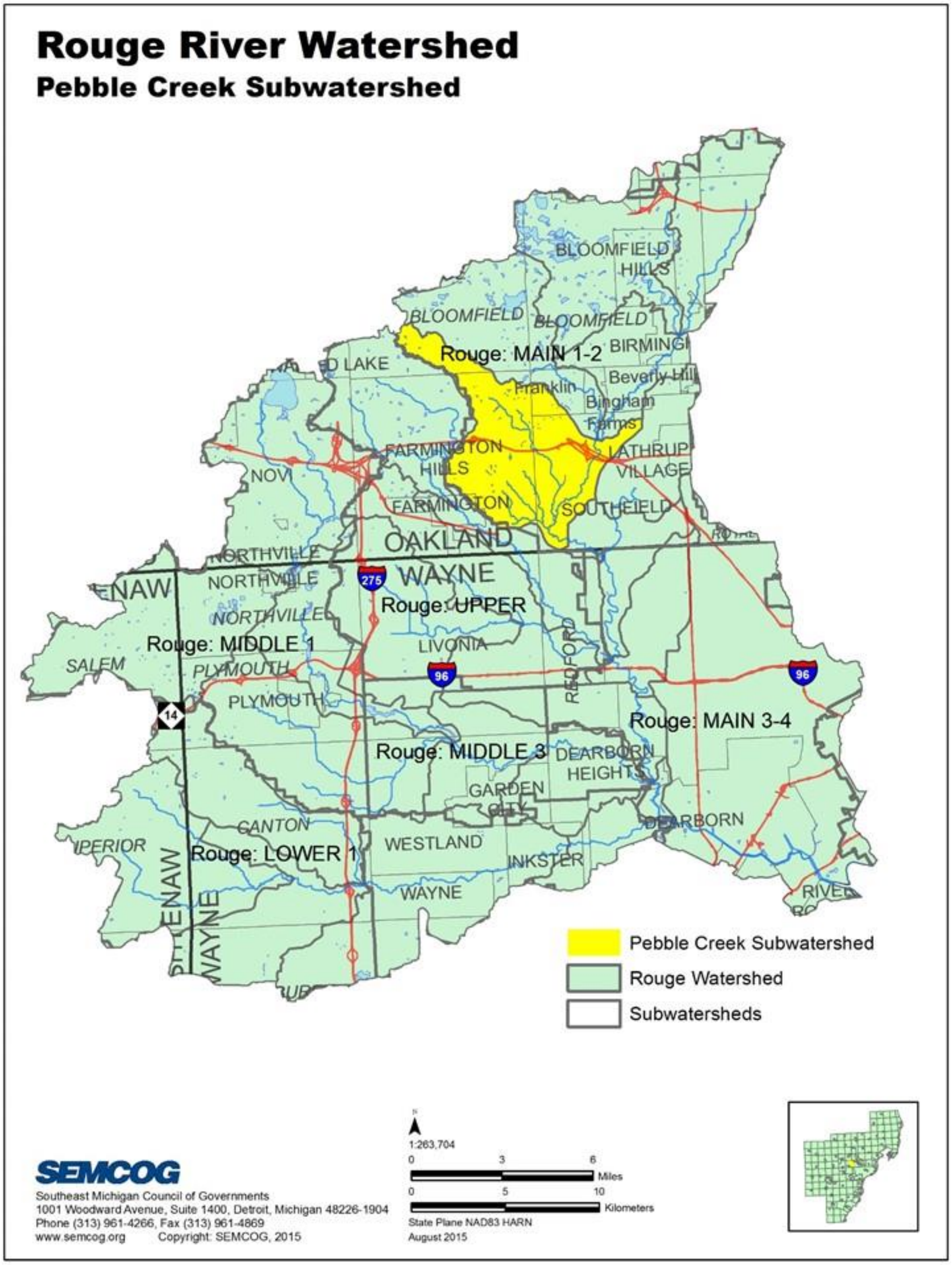


Figure 1. Location of Pebble Creek subwatershed within River Rouge watershed

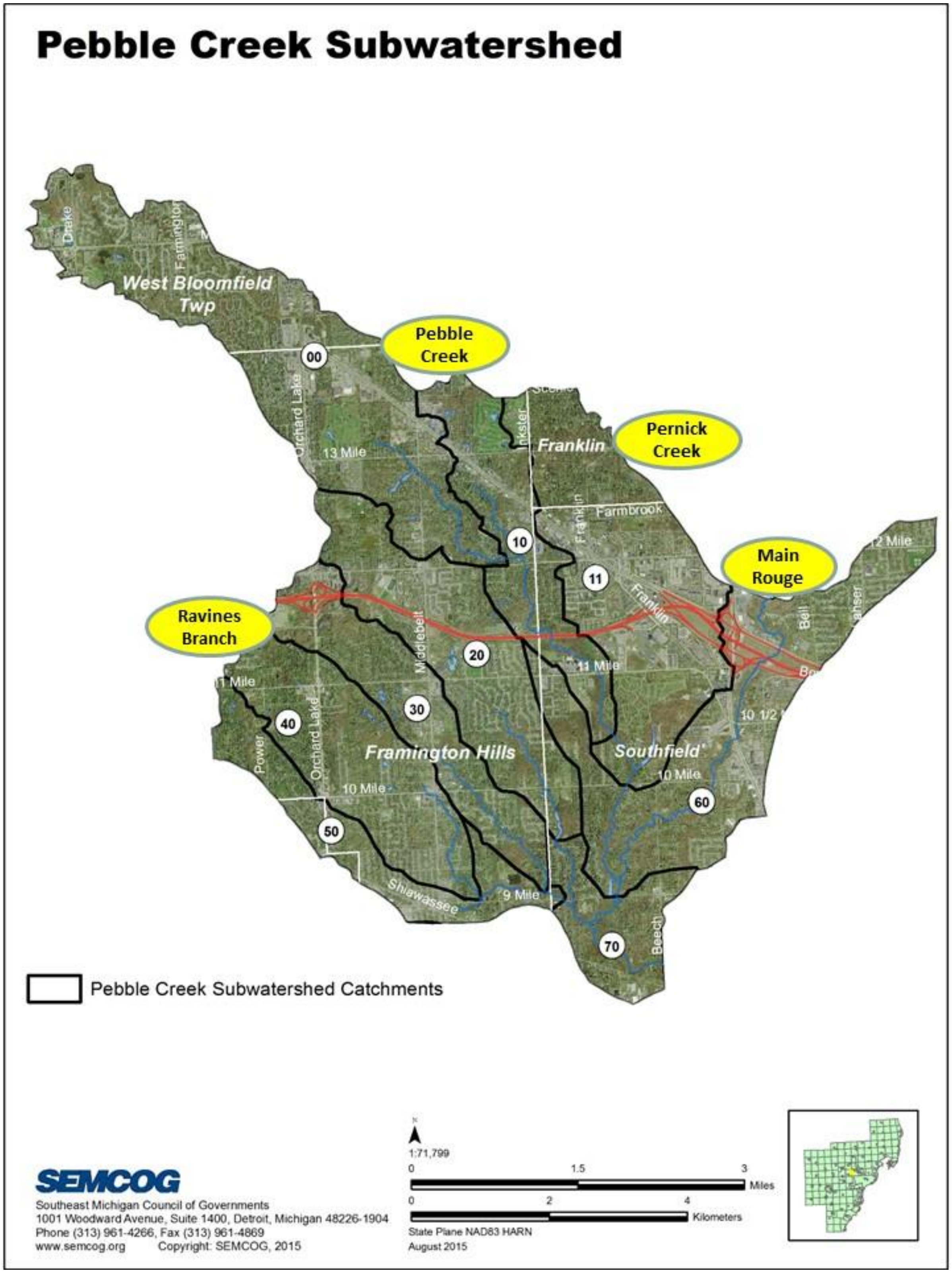


Figure 2. Aerial imagery -- Pebble Creek subwatershed

2. Problem Statement

Numerous watersheds blanket the State of Michigan. Water quality within these watersheds is directly connected to activities on the land. Land use and land cover play significant roles that directly affect the quality of rivers and streams within local watersheds. Historic landscapes provide various functions and values that benefit water resources. Wetlands, woodlands, grasslands, prairies, and riparian corridors all play integral parts in the overall water cycle. They each help in their unique way to filter and reduce stormwater runoff entering local streams. As development has progressed across the region, the quantity of impervious cover and associated urban areas have increased. At the same time, historic landscape features have decreased.

Many urban areas within Michigan and the Great Lakes region experience excessive stormwater runoff that leads to flooding and water quality problems.

2.1 Background

Many urban areas within Michigan contain a number of water bodies that are impaired due to excessive stormwater runoff. Very large volumes of stormwater are discharged during and after storms disrupting natural hydrologic patterns. In addition to much higher flows during wet weather, there are lower flows in streams in dry weather, as the impervious surfaces result in reduced recharge of shallow groundwater aquifers. Compounding problems associated with the volumes of runoff and hydrology, runoff from urban and suburban areas has substantial concentrations of pollutants. The combination of the effects of the runoff volumes and pollutant loads cause nonattainment of designated uses.

Implementation of appropriate urban BMPs, including low impact development / green infrastructure practices which infiltrate, evapotranspirate, and / or harvest and reuse runoff, need to be planned and implemented in areas to help restore and protect uses. Siting and sizing of appropriate BMPs can reduce pollutant loadings to meet restoration targets and help restore the natural hydrology. Implementing the appropriate BMPs is critical to achieving water quality standards and protecting designated uses, which is the primary focus of goals and objectives for the Pebble Creek HUC-12 WMP.

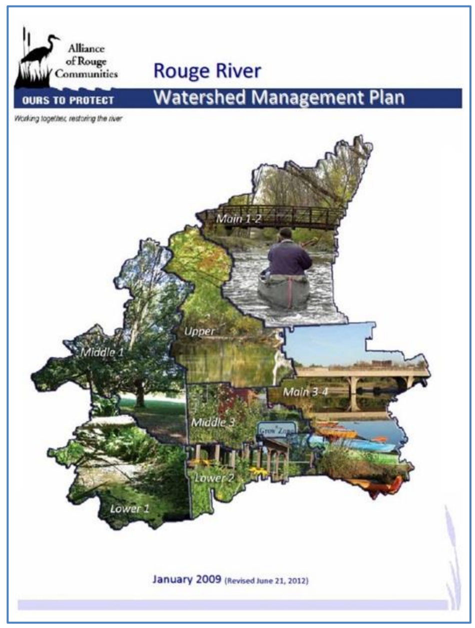
Successfully managing stormwater runoff is a major component of water infrastructure challenges.

Watershed management plans serve as guides for communities, counties and watershed groups to protect and improve water quality and related natural resources. These plans consider all designated uses, pollutant sources, and impacts within a drainage area. Common elements of the watershed management plans include goals, objectives and actions to address water quality and water quantity challenges. This includes identifying protection and restoration opportunities. The basis of these planning efforts is the underlying theme for defining stormwater runoff reduction targets.

Successfully managing stormwater runoff is a significant component of the water system infrastructure challenges facing Michigan. The demographic and economic changes that have taken place over the last decade, combined with aging distribution, treatment, and other systems and the decline in revenue to maintain them, have led to major challenges to local governments. Roads continue to deteriorate, while the vast majority of water and sewer systems are well past their useful life.

A multitude of approaches have been applied for decades. Traditional methods, such as expanded conveyance to solve localized flooding issues or increased detention to reduce peak flows, have not been enough. More recently, green infrastructure has been used in managing stormwater to control flooding from small storms and improve water quality in a way that offers a wide range of other environmental, economic, public health, and social benefits. However, a system of practices must be strategically placed to see documented reductions. Most communities in Michigan recognize that this involves a comprehensive, integrated approach. However, this recognition alone does not solve the significant technical and financial challenges facing local governments as they work to address the adverse effects of excessive stormwater runoff.

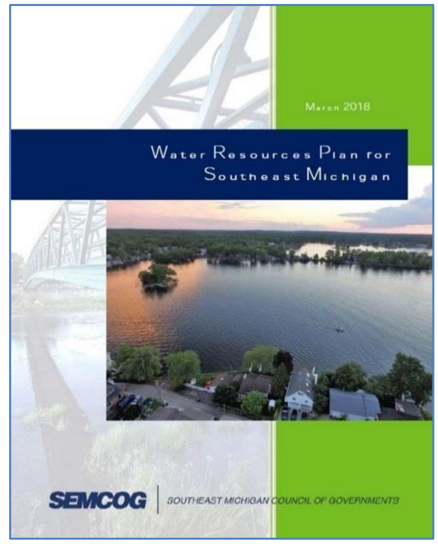
River Rouge Watershed Management Plan



The Rouge River Watershed Management Plan (WMP) was developed to serve as a guide for communities, counties and watershed groups to protect and improve water quality and related natural resources. This plan represented a year-long effort by the Alliance of Rouge Communities (ARC) to update and consolidate seven subwatershed management plans completed in 2001 into one sustainable Rouge River WMP. This WMP described overall characteristics and conditions in the Rouge River watershed, as well as the progress that has been made in improving water quality due to millions of dollars of restoration efforts across the watershed. The WMP also highlights the challenges that still remain; particularly with managing flow variability, including both flow rates and storm water runoff volume, along with bacterial loading in wet weather conditions (ARC, 2012).

The overall purpose of this WMP was to build on past successes and to continue to implement a cost-effective approach to improving water quality in the Rouge River as well as meet the requirements of the NPDES Phase II permit that each ARC community must comply with. This Rouge River WMP included a variety of identified projects and management strategies at the HUC-8 scale to that will continue to improve Rouge River water quality, aesthetics and recreational opportunities. This plan has increased the focus on managing storm water flow and volume. The impacts to the Rouge River watershed due to increased impervious surfaces, such as rooftops, parking lots and roadways, has caused an increase in the total volume of storm water runoff, the frequency of runoff reaching the streams, the peak flow rate of runoff and the quality of runoff. While, historically, storm water ordinances addressed storm water flow rates and runoff, this watershed plan has refined that focus to additionally emphasize the reduction of storm water volume using various “green infrastructure” techniques. Setting a long-term target of reducing storm water volume by approximately 300 million cubic feet across the watershed will significantly reduce the amount of storm water runoff entering the river system.

Water Resources Plan for Southeast Michigan



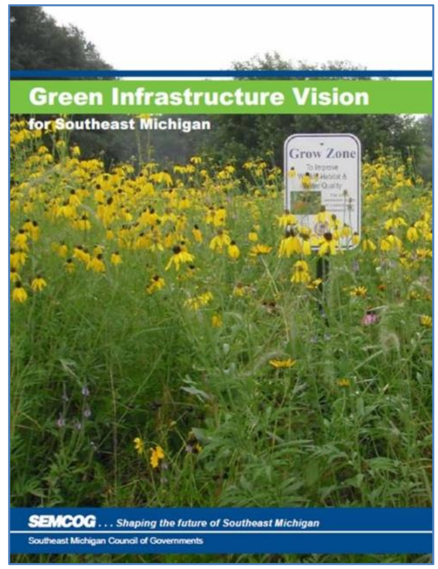
The *Water Resources Plan for Southeast Michigan* builds upon two prior plans – the 1978 and 1999 *Water Quality Management Plans for Southeast Michigan*. While building upon these previous plans and ongoing regional initiatives, its focus is on integrated water resources management, including advancing the blue economy, natural resource protection and enhancement, and water infrastructure systems. The integrated water resources management approach sets the framework for 28 regional policies that address the core challenges in the region, while supporting ongoing achievements in protecting and restoring Southeast Michigan's water assets. The emphasis on integrated water resource planning is to restore and improve water resources as well as identify efficiencies and optimize investments to protect public health in the region.

This plan also recognizes that the region's water resources and quality of life are supported by infrastructure; specifically drinking water, wastewater, stormwater, and transportation. The *21st Century Infrastructure Commission Report* found that there is a $4 billion gap in annual infrastructure funding for the state, while also emphasizing the need for a renewed effort to replace aging and failing infrastructure systems using new technologies, sustainable funding, and an integrated approach. Addressing the needs of these infrastructure systems, along with public and private utilities, in an integrated, strategic, cost-effective, holistic manner will protect public health, the environment, and the region's future economic growth. Through asset management programs, local, regional, and state agencies can work collaboratively to achieve the greatest value for investment while protecting environmental and public health.

The end goal of an integrated water resources approach is strategic decision-making that achieves multiple outcomes instead of a traditional silo-based approach; a goal that is also central to the Pebble Creek Watershed Implementation Plan. Components of this integrated approach include increasing partnerships and collaboration, optimizing investments, enhancing public education, addressing climate resiliency, and improving water resource monitoring.

Partnerships and collaboration are vital to implementing the policies outlined in the *Water Resources Plan for Southeast Michigan*, supported by increased investments in water infrastructure, natural resources, and the blue economy. Public awareness of water resource benefits and challenges will support these increased investments and collaboration across agencies and jurisdictions. Finally, the *Water Resources Plan for Southeast Michigan* indicates that improving water resource monitoring programs will guide investments and collaboration needed to work towards state water quality standards.

Green Infrastructure Vision

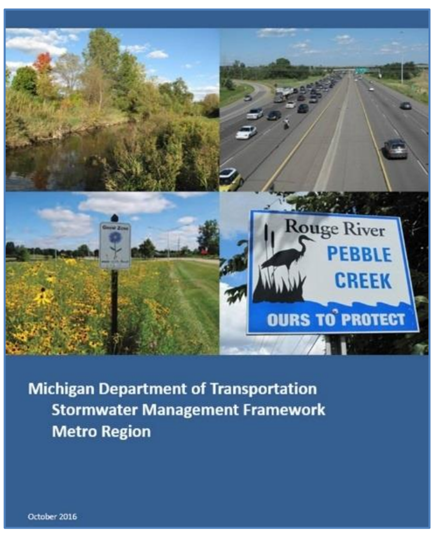


In 2014, SEMCOG completed the *Green Infrastructure Vision for Southeast Michigan*. The GI vision provides the following guidance to support local, regional and state planning efforts:

- Defines and identifies existing green infrastructure across southeast Michigan;
- Envisions future opportunities for growing the green infrastructure network; and
- Establishes regional policies to achieve the long-term Green Infrastructure Vision.

Reducing the quantity of stormwater runoff is a common priority in southeast Michigan watersheds. Within both the natural and built environments of green infrastructure, the connection to water quality is significant. Wetlands, woodlands, and prairies naturally capture, filter, and infiltrate rain water, while constructed practices replicate these types of natural systems. These systems work together to improve water quality in local lakes, streams, and rivers in southeast Michigan and, subsequently, the Great Lakes. Results from the stakeholder visioning sessions and public survey supported the connection between green infrastructure and the region's water by identifying "protecting water quality" as the top-rated green infrastructure benefit.

Michigan Department of Transportation Stormwater Management Framework



The Michigan Department of Transportation (MDOT) Stormwater Management Framework aligns watershed planning and transportation planning to work towards early consideration of stormwater management (SEMCOG 2016). The technical basis of this project outlines an approach to define how much stormwater management should be considered that will achieve MDOT program objectives while also working towards state of Michigan water quality goals.

This project arose out of the next steps contained within the Green Infrastructure Vision for Southeast Michigan (GI Vision). The GI Vision establishes a framework for priorities that will lead to alignment with other programs including transportation and infrastructure, recreational projects such as non-motorized and water trails, transportation safety and economic development. Aligning regional projects and programs supports strategic investment with limited monetary resources.

From a watershed planning perspective, the GI Vision outlines focus areas for green infrastructure implementation, including roadways, parking lots, institutional properties and riparian corridors. The MDOT framework recognizes that local watershed plans outline goals, objectives and actions to restore water resources. Aligning the GI Vision with local watershed plans in partnership with transportation planning will provide the basis for estimating the role of green infrastructure in working towards water quality standards.

2.2 Technical Approach

The technical approach for development of the Pebble Creek HUC-12 WMP on information gained and "lessons learned" from several green infrastructure targeting efforts. These efforts were conducted using a stormwater management framework in conjunction with an outcome-based strategic planning process. Building on this framework, the technical approach identifies:

- ***targets*** to reduce urban stormwater volumes and pollutant loads needed to meet water quality standards and protect designated uses in urban watersheds;
- ***critical areas*** that contribute the greatest stormwater runoff volumes / pollutant loads and have a disproportionate effect on water quality; and
- ***BMP opportunities*** that, when implemented, will result in measurable improvements relative to mitigating the adverse effects of urban stormwater.

From a watershed implementation perspective, the Pebble Creek WMP includes a concept referred to as green infrastructure area (GIA). Green infrastructure area defines the amount of directly-connected impervious cover that needs to be managed using urban stormwater BMPs to reduce flooding, threats to infrastructure, and loss of property, as well as achieve water quality standards (WQS) and protect biological communities. The emphasis on impervious cover is consistent with stormwater management methods used across the country. Urban BMPs that can be applied at specific locations typically focus on the amount and type of impervious area that can be directed to a stormwater facility (for either flow control or water quality treatment).

A data-driven approach was used; one that improves the cost-effectiveness of stormwater management in Pebble Creek, the Main Rouge, and in other southeast Michigan urban watersheds.

2.3 Pebble Creek HUC-12 Watershed Impairments

The Pebble Creek watershed appears on Michigan's list of impaired waters (Goodwin, et. al., 2017*)* as not meeting the Other Indigenous Aquatic Life and Wildlife (OIALW) designated use because of biological impairments in two assessment unit identifier (AUID) stream segments. Two Pebble Creek watershed AUIDs are also not meeting total and partial body contact recreational designated use due to bacteria (Appendix A).

The macroinvertebrate community structure data indicate that siltation due to excess total suspended solids (TSS) loads is one cause of the biological impairments (Goodwin, 2007). The poor macroinvertebrate community is also attributed to a lack of suitable habitat for colonization (due to past channel alterations). In addition, high storm water flows that runoff from impervious surface sources can be a major factor that affects aquatic communities, thus influencing bioassessment scores. Stable flow regimes support the establishment of healthy macroinvertebrate populations. Flashy flows (e.g., due to excessive urban runoff) disrupt aquatic community structure and increase the transport of TSS loads that cause downstream siltation problems.

2.4 Applicable Water Quality Standards

The authority to designate uses and adopt WQS is granted through Part 31 (Water Resources Protection) of Michigan's Natural Resources and Environmental Protection Act (1994 PA 451, as amended [Act 451]). Pursuant to this statute, MDEQ promulgated its WQS as Michigan Administrative Code R 323.1041 – 323.1117, Part 4 Rules. Designated uses to be protected in surface waters of the state are defined under R323.1100.

Designated Uses

At a minimum, all surface waters of the state are designated and protected for all of the following designated uses: agriculture, navigation, industrial water supply, warmwater fishery, other indigenous aquatic life and wildlife, partial body contact recreation, total body contact recreation (May 1 to October 31), and fish consumption.

Numeric Criteria and Targets

Outcome-based strategic planning hinges on sound, meaningful target development. Stream flashiness, expressed through the Richards-Baker (R-B) Index, connects aquatic biology and channel concerns with stormwater management activities. Because hydrology affects channel stability, stream habitat, aquatic biology, and the delivery of pollutant loads, these relationships provide a basis to examine urban BMP implementation strategies.

Stream flashiness provides a metric that connects aquatic biology and channel stability concerns to stormwater management strategies.

The R-B Index provides a good indicator showing the relationship between hydrology and its effect on aquatic biology. However, stream flashiness is not well suited for evaluating location specific stormwater BMPs in the Pebble Creek HUC-12 watershed. This is because projects are typically implemented at the site-scale as opposed to watershed scale. An approach routinely used in stormwater management emphasizes BMP designs based on mimicking pre-settlement hydrology; one that results in strategies focused on retaining the volume produced by a certain rain event (e.g., up to the two-year 24-hour storm). This approach emphasizes channel protection, which is influenced by stream flashiness that in turn affects aquatic habitat and biology.

With a focus on management practices that retain stormwater runoff volume, options examined in the Pebble Creek HUC-12 watershed looked at the resultant effect on stream flashiness (Appendix A). Based on the relationship between bioassessment metrics and stream flashiness, volume reduction targets are identified by priority catchment groups and critical areas that meet channel protection needs (Appendix B). Implementation strategies identified in the Pebble Creek WMP place an emphasis on managing the effect of directly-connected impervious cover.

3. Potential Sources

Identifying outcomes for watershed planning depends on an understanding of conditions relative to sources of stormwater runoff. Numerous studies have shown that as the level of impervious cover increases, water quality problems associated with stormwater also increase. Due to the decreased ability of areas infiltrate water, rain falling on impervious surfaces produces higher volumes of stormwater runoff. Runoff from impervious areas also pick up contaminants that accumulate on these surface types (e.g., roads, parking lots) resulting in increased pollutant loads delivered to receiving waters. In addition, higher stormwater runoff volumes lead to increased stream flashiness and place more shear stress on natural streams. These conditions result in channel incision, bank erosion, siltation, and general aquatic habitat degradation.

3.1 Land Use and Impervious Cover Composition

Source areas were initially identified based on land use and impervious cover information. To identify potential sources by area and category (e.g., land use, impervious cover type), the Pebble Creek HUC-12 watershed was divided into catchments using delineations provided by MDEQ. SEMCOG has evaluated land cover information from 2010 aerial imagery. The SEMCOG impervious cover estimates are based on evaluation of parcel-scale data including transportation corridors, parking lot locations, and building footprints. SEMCOG's building data layer represents the digital footprint of each building in southeast Michigan, as of April 2015 (Appendix A).

The SEMCOG land use/land cover data provides detailed information on impervious surface composition, which is used to prioritize stormwater sources and provide an estimate of the relative stormwater runoff contribution. An impervious surface composition summary for the Pebble Creek HUC-12 watershed is presented in Figure 3. This chart conveys two types of information useful for evaluating stormwater sources in the drainage assessment; the quantity of impervious area for each land use category and the density of impervious cover in each catchment group. The quantity aspect identifies the catchment groups that contain higher amounts of total impervious area. The value in the oval for each subwatershed represents the percent impervious cover (or density aspect).

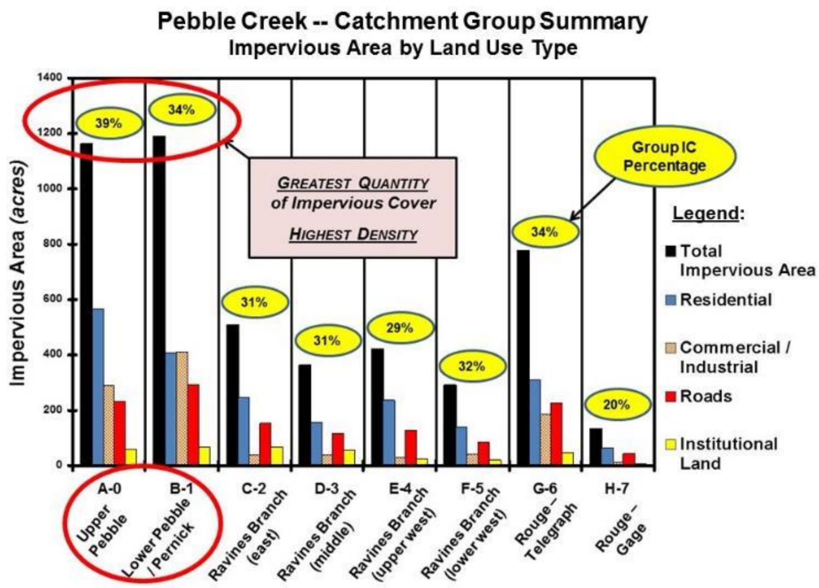


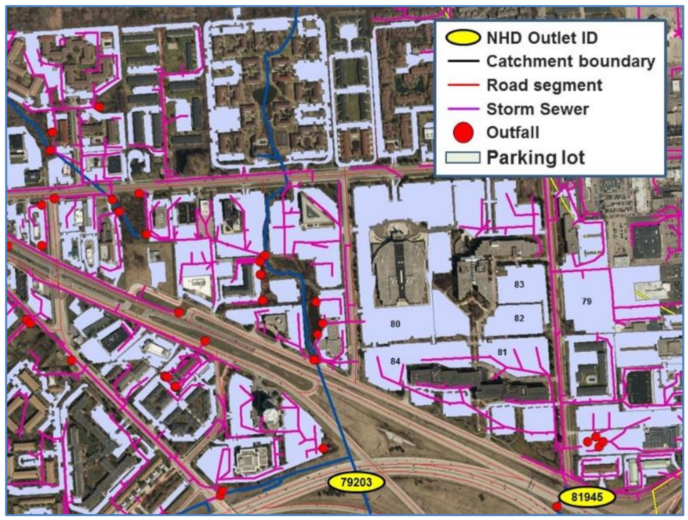
Figure 3. Impervious surface composition -- Pebble Creek

3.2 Surveys and Inventories

Land use and impervious surface composition pointed to four high priority catchments in the Pebble Creek watershed (Appendix A). An important aspect of moving from priority catchments to critical areas is the field inventory. Watershed observations enable critical areas to be identified and prioritized for BMP implementation. Asset management is also a major consideration for targeting specific project needs in critical areas. In addition to degraded water quality, biology, and stream habitat, problems that result from excessive stormwater runoff include flooding, threats to infrastructure, and loss of property due to bank erosion. Other assets that factor into the process include existing treatment.

The process of compiling field inventory information for the Pebble Creek HUC-12 watershed included an evaluation of available GIS data layers and air photos coupled with windshield surveys. Key NHD outlet locations were used as a starting point to identify potential critical areas within priority catchments. These outlet locations were based on a combination of reported channel condition problems and field observations. Stormwater asset information was incorporated into the field inventory analysis with a focus on outfalls larger than 30 inches in diameter that discharge to critical area NHD outlets.

The GIS transportation network data from SEMCOG enabled identification of high traffic volume roadway corridors tributary to NHD outlet locations that could be significantly affected by stormwater runoff from these potential source areas. Parking lots delineated by MDEQ were also a vital component of the field inventory analysis. Summary tables were developed describing NHD outlets, key stormwater assets, primary road corridors, and parking lots.



Compiling field inventory information for the Pebble Creek HUC-12 watershed included an evaluation of GIS data layers and air photos coupled with windshield surveys in priority catchments.

3.3 Critical Area Analysis

An important aspect of addressing water quality problems and concerns is to ensure that management plans recognize two key parts for successful implementation: stewardship and critical areas. In this urbanized watershed, stewardship is reflected through the commitment by the local communities in taking a proactive role to solve water quality problems through a focused and coordinated approach. Stewardship also involves a coordinated approach to working with other key partners (e.g., businesses, advocacy groups) in adopting proven BMPs in a comprehensive manner through conservation systems.

Critical areas represent those locations where management measures are needed to achieve watershed plan goals and objectives. The Pebble Creek WMP is designed to take a broad look at the full array of issues and concerns that affect flooding, threats to infrastructure/private property, and water quality in the watershed. In this way, projects are identified, prioritized, and scheduled for implementation in an integrated fashion, improving the overall cost-effectiveness of relevant programs that lead to documented positive results.

Identifying outcomes for watershed planning depends on an understanding of watershed conditions and stormwater management networks through drainage assessments. The technical approach uses a multi-scale analysis framework, specifically one that moves to progressively smaller geographic areas based on priority concerns and opportunities to implement urban storm BMPs.

Asset management was an important part of critical area identification to ensure that flooding, threats to infrastructure, and property loss were considered.

The drainage assessment highlights critical areas where BMP implementation will be most effective (i.e., critical areas that have a disproportionate effect on hydrology and water quality). In urban settings, these are locations that have higher amounts and percentages of connected impervious cover. Critical areas are also located in close proximity to local streams (e.g., road crossings, major stormwater outfalls).

Critical areas are initially prioritized based on land use and impervious cover information. Impervious surface composition (type, amount, density) is characterized by land use category (residential, roads, etc.) to identify high priority catchments where: a) the total amount of impervious area is greater, and b) the percentage of impervious cover is higher. The data is also categorized by jurisdiction to describe the overall contribution by land use type and ownership. Coupled with rainfall data, impervious cover provides an estimate of potential stormwater runoff volume generated.

Critical areas include high traffic volume road corridors adjacent to commercial development; areas that pose technical / financial challenges.

While impervious cover composition provides a starting point to identify priority source locations, the pilot efforts highlight the need for field inventory information that refines the critical area analysis. The field inventory provides a focus on directly-connected pathways, delivery mechanisms, and in-stream effects (particularly evidence of channel incision and bank erosion). This enables targeting specific critical locations where BMP implementation will be most effective in achieving overall watershed management objectives.

The impervious surface composition analysis highlighted priority locations and potential runoff volumes that can be directed towards urban stormwater BMPs in Pebble Creek. Watershed observations coupled with an initial field inventory enabled the planning system to continue prioritizing critical areas for BMP implementation. Asset management was a major consideration in identifying data gaps and assembling field information to ensure that flooding, threats to infrastructure, and loss of property were considered. Other assets that factor into the process include existing treatment.

Critical areas in high priority catchment groups are shown in Figure 4, listed in Table 1, and summarized in Appendix C.

Figure 4. Overview of Pebble Creek HUC-12 watershed critical area locations

Table 1. Field inventory summary for Pebble Creek HUC-12 watershed critical areas

Critical Area		**NHD Outlet**	**Key Asset(s)**	**Major Road Corridor(s)**	**Parking Lots**		**Notes**
ID	**Size** *(acres)*				**Total Number**	**Size** *(acres)*	
00.a	200	78845	3835 *(culvert)*	Orchard Lake Road	12	38.3	Orchard Place
00.b	50	78845	3835 *(culvert)*	Orchard Lake Road	9	11.3	OLR - Harmon Oaks area
00.c	215	83755	4311 *(culvert)*	Orchard Lake Road	17	48.0	Jacobs Drain
00.d	180	83924	442916 *(66" pipe)*	Northwestern Highway	13	30.3	East Pebble Drain
00.e	10	83651	2330 *(culvert)*	13-Mile Road	1	3.1	Glen Oaks Golf Course
00.f	110	83651	2349 *(culvert)*	Northwestern Highway	17	33.9	NWH – Middlebelt area
10.a	120	81549	4355 *(culvert)*	Northwestern Highway	8	13.0	Coy Drain
10.b	65	83679	SC7113 *(42" pipe)*	11-Mile Road	6	22.8	Hollander Drain
11.a	320	79209	SC3882 *(60" pipe)*	Franklin, 12-Mile, NW Hwy	29	61.9	Peterson Drain
11.b	150	81656	SC8972 *(42" pipe)*	Franklin, 12-Mile, NW Hwy	31	48.9	West Branch Pernick
11.c	345	84998	SC6346 *(60" pipe)*	12-Mile Road	25	91.4	Lockdale Drain
60.a	260	82052	SC15974 *(60" pipe)*	12-Mile, Lahser	7	20.5	Jilbert Drain
60.b	80	83512	SC5382 *(48" pipe)*	Telegraph Road	3	16.1	Tel-Twelve Mall storm main
60.c	95	83526	SC669 *(78" pipe)*	Civic Center Drive	8	38.3	Dearborn Drain
60.d	165	83534	SC3945/SC6878 *(2X - 36" pipe)*	Telegraph Road	22	41.0	Telegraph twin storm mains
60.e	105	83534	SC2572 *(36" pipe)*	Telegraph Road	15	31.1	Denso storm main

4. Watershed Management Objectives

4.1 Plan Requirements

In 2008, the U.S. Environmental Protection Agency (USEPA) released the "Handbook for Developing Watershed Plans to Restore and Protect Our Waters". This handbook describes nine key elements required for approval as a TMDL Watershed Plan that will address concerns on threatened or impaired waters *(Table 2)*. These nine key elements are designed to ensure that planned improvements within TMDL watersheds are sufficient to restore water quality.

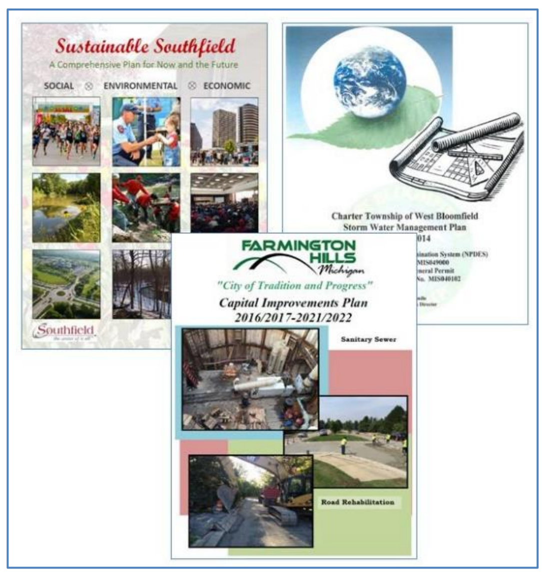
4.2 Specific Goals and Objectives

The goal of this Watershed Implementation Plan is to restore and protect the Pebble Creek HUC-12 watershed through a strong, documentable data-driven approach to identify, prioritize, and implement projects in ways that improve the cost-effectiveness of stormwater management programs. This WMP is intended to improve and protect receiving waters from urban stormwater discharges, and to reduce flooding through implementation of appropriate BMPs placed at critical locations in the watershed.

Another major goal of the Pebble Creek HUC-12 WMP is the use of an integrated water resources approach based on strategic decision-making that achieves multiple outcomes; one consistent with policies outlined in the *Water Resources Plan for Southeast Michigan* (as opposed to traditional silo-based methods). Again, components of this integrated approach include increasing partnerships and collaboration, optimizing investments, enhancing public education, and improving water resource monitoring.

Partnerships and collaboration are particularly vital to implementing the Pebble Creek HUC-12 WMP. Information presented in Southfield's most recent Comprehensive Management Plan (CMP) provides an excellent example (City of Southfield, 2016). This plan not only considers the value behind protecting natural resources, but also recognizes the importance of physical settings that encourage healthy lifestyles and attitudes. Southfield's CMP promotes good site design, naturalized approaches to landscaping, and the use of well-designed BMPs to reduce pollution.

Again, consistent with policies promoted in the *Water Resources Plan for Southeast Michigan* the Pebble Creek WMP recognizes that public awareness of water resource benefits and challenges will support increased investments and collaboration across agencies and jurisdictions. This includes improving water resource monitoring programs that guide investments and collaboration needed to work towards state WQS.



A major goal of this WMP is use of an integrated approach to increase partnerships and collaboration so that limited resource investments are optimized.

Table 2. USEPA's nine minimum elements of a watershed plan

Plan Element	Description
A	**Identify causes and sources of pollution** *that need to be controlled to achieve goals identified in the plan.*
B	**Estimate pollutant loading into the watershed and the expected load reductions** *expected as a result of implementing management measures that will help reduce pollutant loads.*
C	**Describe management measures that will achieve load reductions and targeted critical areas.**
D	**Estimate amounts of technical and financial assistance and the relevant authorities needed to implement the plan** *including long-term operation & maintenance of management measures, information / education activities, monitoring & evaluation activities.*
E	**Develop an information/education component** *that identifies the education & outreach activities or actions that will be used to implement the plan.*
F	**Develop a project schedule** *for implementing the management measures outlined in the plan*
G	**Describe the interim, measurable milestones** *to measure and track progress in implementing the management measures.*
H	**Identify benchmarks to measure progress** *towards attaining WQS through monitoring.*
I	**Develop a monitoring component** *that determines whether progress is being made toward attaining or maintaining the applicable WQS addressed in the plan.*

5. Watershed Implementation Plan

The ultimate measure of success will be documented changes in water quality, showing improvement over time. The top priority for this plan is to identify and reduce sources of excess stormwater runoff in the Pebble Creek HUC-12 watershed.

5.1 Management Measures

Management measures needed to address each cause and source impairment in the Pebble Creek watershed focus on an integrated approach, which considers the range of factors associated with urban stormwater. This integrated approach follows Michigan's guidance that describes the preferred steps for urban stormwater management (MDEQ, 2017). These implementation actions, ranked in order of importance, are the foundation of the strategy that will bring the Pebble Creek HUC-12 watershed back into attainment with water quality standards. These include: prevention/minimization/infiltration, treatment, mitigation, conveyance, and storage.

The priority measures described below and summarized in Table 3 consider important aspects of stormwater management needed to achieve Michigan's bioassessment criteria for the Pebble Creek watershed (e.g., reduce volume, decrease peak flow rate, improve water quality). In addition, the use and restoration of natural features (e.g., riparian areas such as the Rouge Green Corridor, wetlands, original topography, open spaces) are an integral part of the Pebble Creek WMP.

1. Reduce the rate and amount of stormwater runoff from priority parking lots. Parking lots offer the greatest opportunities for stormwater volume and rate reduction in the Pebble Creek watershed. A total of 516 parking lots have been digitized, which comprise approximately 1,059 acres of paved surfaces in the watershed (or over seven percent). More than half of the inventoried parking lots are in the 16 critical areas within four priority catchments. An array of BMPs (e.g., green infrastructure) can be implemented within parking lots, which reduce stormwater runoff volume and decrease peak flow rates. Available practices can be applied either individually or as a treatment train (MDEQ 2017).

Opportunities exist on commercial and/or industrial parking lots adjacent to roads that could provide overall stormwater reduction benefits.

2. Install integrated stormwater management systems along priority transportation corridors. Roadways present both challenges and opportunities to reduce stormwater runoff. Transportation corridors with high traffic volumes represent relatively significant amounts of connected impervious cover (and thus generate larger quantities of stormwater runoff compared to roads less travelled). In addition, these same corridors typically include adjacent commercial properties with parking lot drainage inlets and pipes connected to the transportation storm sewer system. The situation is compounded by factors such as other utilities located along the road, safety design considerations, and installation costs for runoff reduction BMPs (both financial and construction-related disruptions). The connectivity of the transportation network to drainage systems, the proximity of large commercial parking lots to high traffic volume roadways, and the number of jurisdictions involved collectively warrants an integrated management approach to successfully reducing the rate and amount of stormwater runoff from these source areas.

3. Utilize asset management to implement cost-effective stormwater runoff reduction solutions. Infrastructure plays a vital role in determining how and where stormwater runoff is conveyed throughout the Pebble Creek HUC-12 watershed. Key assets to consider in implementing this management measure include stormwater inlets, drainage pipes, outfalls, road corridors, culverts/ bridges at stream crossings, and treatment systems (e.g., ponds, storage vaults, constructed wetlands, etc.). An important part of the field inventory work in the Pebble Creek HUC-12 watershed evaluated asset management information included in GIS data layers obtained from Farmington Hills, Southfield, and Oakland County (both OCWRC and RCOC). The review of this information revealed both gaps and opportunities that could significantly improve the process of identifying runoff reduction projects in critical areas. For example, drainage pipe diameter data coupled with corresponding outfall locations provides a mechanism to estimate the relative magnitude that source areas contribute to receiving waters. Drainage pipe diameter information is also helpful in prioritizing potential parking lots for green infrastructure implementation.

Asset management data also highlights multi-jurisdictional coordination and public/private partnership opportunities. Finally, drainage complaint information (e.g., flooding) plus operations and maintenance (O&M) needs (e.g., problems identified in CIP plans) highlight other opportunities to utilize asset management to support cost-effective implementation of runoff reduction projects.

Asset management information provides opportunities to improve the process of identifying cost-effective runoff reduction projects in critical areas.

4. <u>Protect riparian corridors and restore floodplain/wetland functions; promote use of natural areas</u>. Native vegetation has significant root systems that promote runoff infiltration. Large open areas traditionally managed as turf may be easily converted to native plant grow zones. These may include large highway medians and cloverleaf areas around on- and off-ramps for highways. Grow zones are also feasible in linear vegetated areas adjacent to roadway impervious surfaces.

Table 3. Management measure summary for Pebble Creek HUC-12 watershed critical areas

Catchment Group	Critical Area ID (General Location)		Management Measure Category: Parking Lot Runoff Reduction	Transportation Corridor Runoff Reduction	Asset Management Runoff Reduction	Natural Area Protection / Restoration	Other
A (Upper Pebble)	00.a	Orchard Place	●●	●●	●●	○	○
	00.b	Orchard Lake/S. Pebble	◗	●●	◗	○	○
	00.c	Jacobs Drain	◗	●●	◗	○	○
	00.d	East Pebble Drain	●●	●●	●●	○	○
	00.e	Glen Oaks	◗	○	◗	◗	○
	00.f	13-Mile & Middlebelt	●●	◗	◗	○	○
B (Lower Pebble/ Pernick)	10.a	Coy Drain	◗	●●	◗	○	○
	10.b	Hollander Drain	●●	◗	◗	○	○
	11.a	Peterson Drain	●●	●●	●●	○	○
	11.b	W.B. Pernick	◗	●●	◗	○	○
	11.c	Pernick/Lockdale	●●	●●	●●	○	○
G (Main Rouge)	60.a	Jilbert Drain	◗	◗	●●	◗	○
	60.b	Telegraph/12-Mile area	●●	●●	●●	●●	○
	60.c	Dearborn Drain	●●	◗	●●	●●	○
	60.d	Telegraph/10-Mile area	●●	●●	●●	●●	○
	60.e	Telegraph/Denso area	●●	◗	◗	●●	○

<u>Notes</u>: ●● High priority BMP ◗ Medium priority BMP ○ Provide general benefit for load reduction

5.2 Technical and Financial Assistance

Proposed projects consider stakeholder perspectives, funding options, benefits to the community, and scheduling realities.

The success of the Pebble Creek HUC-12 WMP depends upon consistent involvement and support from Farmington Hills, Southfield, West Bloomfield Township, and Oakland County, as well as state agencies, non-profit organizations, educational institutions, local businesses and citizens. While each community has unique situations that require case-by-case consideration, many of the implementation recommendations in this WMP will require collaboration and coordination among all communities and stakeholders in the watershed.

Financial resource needs to address urban stormwater problems tend to exceed the amount of available funding. Rating criteria for critical areas allow examination and comparison of various implementation strategies (Table 3). Considerations in developing these criteria include proximity to receiving waters, project feasibility (physical site suitability, access, easements, location relative to utilities, etc.), costs, design/build time, and maintenance requirements. Cost estimates have been developed using the USEPA National Stormwater Calculator (Appendix D).

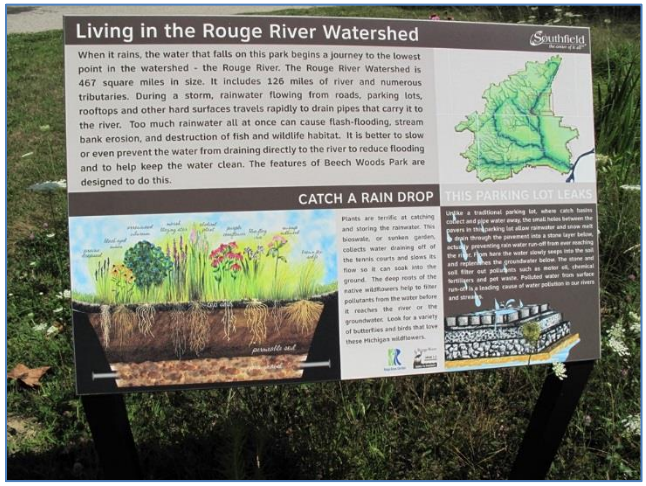
Proposed projects will continually be reviewed to reflect stakeholder input, funding options, community benefits, and scheduling realities. Funding is one of the greatest challenges facing local communities. For example, urban watersheds present some unique challenges with respect to determining whether proposed projects are grant eligible. Non-grant funding sources may also be available that can be used to support stormwater management programs or finance individual projects. Included are taxes/general funds, fees, stormwater utilities, credits/incentive programs, bonds, loans, and public – private partnerships (USEPA, 2014). In addition, use of multi-objective technical and financial assistance options can be explored. Some possibilities are described in Southfield's CMP including Property Assessed Clean Energy (PACE) projects or use of the Corridor Improvement Authority Public Act (Southfield, 2016).

5.3 Information and Education

Information and education (I&E) is vital to the success of the Pebble Creek WMP. The I&E strategy targets specific audiences to educate them regarding their potential impacts on water quality. The importance of this component is recognized by the local community as evidenced by activities that supported development of the Rouge River Watershed Management Plan. This plan was created by the Alliance of Rouge Communities (ARC) Public Involvement and Education (PIE) Committee, a group of communities, citizens, counties, non-profit organizations and stewardship groups that meet quarterly to implement and review public education activities in the Rouge River Watershed.

Over the years, the ARC and their partners have engaged the public through workshops, hands-on river stewardship activities, newsletters, public service announcements and focused initiatives (e.g., fertilizer reduction campaigns, grow zone projects). The resultant strategy based on the ARC experience, which forms the basis for I&E in the Pebble Creek WMP, outlines major educational opportunities and actions needed to successfully maintain and improve water quality (ARC 2012, Appendix E).

The ARC continues to provide an institutional mechanism to encourage watershed-wide cooperation and mutual support to meet water quality permit requirements and to restore designated uses of the Rouge River and its tributaries to area residents (ARC, 2012). Other institutional partners include non-profit organizations, educational institutions and others who are working together to reduce the individual costs of restoring the Rouge River. The ARC Technical and Public Involvement and Education Committees are comprised of a variety of stakeholders, such as government, non-profit organizations, stewardship groups, educational institutions, consultants, and others focused on a specific initiative to address storm water pollution.



Information & education for the Pebble Creek plan will be conducted in concert and as part of I&E activities described in the approved Rouge River WMP.

Future educational activities regarding the watershed management plan and related activities continue to be monitored and assessed by the ARC's Public Involvement and Education Committee. I&E is vital to the success of the Pebble Creek HUC-12 WMP. The I&E strategy targets specific audiences to educate them regarding their potential impacts on water quality.

In summary, this WMP includes a priority recommendation to develop an updated I&E strategy for the Pebble Creek watershed that includes the following:

- Focus on priority pollutants and sources
- Focus on critical areas
- Identify target audiences
- Identify key messages and delivery mechanisms
- Develop evaluation criteria

5.4 Schedule

The Pebble Creek WMP is envisioned to occur over a 20-year period; staging activities in three phases (short-, mid-, and long-term) that will ultimately achieve needed stormwater runoff and bacteria reductions (Table 4). Short-term efforts (Year 1-3) include implementing practices in critical areas so that stormwater runoff volumes, peak flow rates, and high-risk bacteria sources to Pebble Creek and the Main Rouge are significantly reduced. This approach is consistent with the direction currently pursued by Southfield, Farmington Hills, Oakland County, and West Bloomfield Township in conjunction with other local partners (e.g., SEMCOG, ARC, FOTR). Mid-term efforts (Year 4-10) are intended to build on the results of short-term implementation activities. This includes evaluating the success of Phase 1 projects installed (success rate, BMP performance, stormwater runoff and pollutant reductions realized, actual costs, etc.). Long-term efforts (Year 11-20) are those implementation activities that result in the Main Rouge and Pebble Creek in full attainment with Michigan's WQS.

Table 4. Schedule overview for Pebble Creek HUC-12 watershed critical areas

Project #	Management Measure(s)	Project Type	Lead Organization(s)	Time Frame		
				Phase 1 *(2019-21)*	Phase 2 *(2022-28)*	Phase 3 *(2029-38)*
Catchment 00						
00.a1	1	Parking Area Flow Reduction	Farmington Hills	●●		
00.*2	1,2	Roadway corridor flow reduction	FH, RCOC		●●	
00.a3	1,2,3	Asset management flow reduction	FH, RCOC, OCWRC	●●		
00.c3	1,2,3	Asset management flow reduction	FH, RCOC, OCWRC, MDOT		●●	
00.d1	1	Parking Area Flow Reduction	Farmington Hills	●●		
00.d2	1,2	Roadway corridor flow reduction	FH, RCOC, MDOT			●●
00.d3	1,2,3	Asset management flow reduction	FH, RCOC, MDOT		●●	
00.e1	1	Parking Area Flow Reduction	OCPR		●●	
00.f1	1	Parking Area Flow Reduction	Farmington Hills		●●	
Catchment 10						
10.a1	1	Parking Area Flow Reduction	Farmington Hills		●●	
10.a2	1,2	Roadway corridor flow reduction	FH, RCOC, MDOT			●●
10.b1	1	Parking Area Flow Reduction	Southfield		●●	
10.b2	1,2	Roadway corridor flow reduction	Southfield, RCOC		●●	
Catchment 11						
11.a1	1	Parking Area Flow Reduction	Southfield	●●		
11.*2	1,2	Roadway corridor flow reduction	Southfield, RCOC, MDOT		●●	
11.a3	1,2,3	Asset management flow reduction	Southfield, RCOC, MDOT	●●		
11.b1	1	Parking Area Flow Reduction	Southfield	●●		
11.b3	1,2,3	Asset management flow reduction	Southfield, RCOC, MDOT		●●	
11.c1	1	Parking Area Flow Reduction	Southfield	●●		
11.c3	1,2,3	Asset management flow reduction	Southfield, RCOC, MDOT	●●		
Catchment 60						
60.a1	1	Parking Area Flow Reduction	Southfield			●●
60.a3	1,2,3	Asset management flow reduction	Southfield, OCWRC		●●	
60.b1	1	Parking Area Flow Reduction	Southfield	●●		
60.b2	1,2	Roadway corridor flow reduction	Southfield, RCOC, MDOT			●●
60.b3	1,2,3	Asset management flow reduction	Southfield, RCOC, MDOT		●●	
60.*4	4	Rouge Green Corridor restoration	Southfield		●●	
60.c1	1	Parking Area Flow Reduction	Southfield	●●		
60.c3	1,2,3	Asset management flow reduction	Southfield		●●	
60.d1	1	Parking Area Flow Reduction	Southfield	●●		
60.d2	1,2	Roadway corridor flow reduction	Southfield, RCOC, MDOT			●●
60.d3	1,2,3	Asset management flow reduction	Southfield, RCOC, MDOT		●●	
60.e1	1	Parking Area Flow Reduction	Southfield		●●	

Two overarching actions include information / education (I&E) and monitoring. A general awareness of water quality issues exists within the community; the result of strong local involvement in development of the River Rouge WMP. For that reason, general watershed education activities are not specifically included in the 20-year schedule. Instead, I&E is incorporated into each priority action and varies as plan implementation moves through each phase. Basic I&E activities associated with individual priority actions during each phase include:

- ✓ *Phase 1*: awareness, 1-on-1 meetings, leverage cost-share opportunities
- ✓ *Phase 2*: 1-on-1 meetings, cost-share, follow-up & monitor Phase 1 results
- ✓ *Phase 3*: 1-on-1 meetings, cost-share, follow-up, monitor results, evaluate plan effectiveness, adjust as needed

Short-term implementation activities also include monitoring in the Pebble Creek HUC-12 watershed conducted by ARC and FOTR. Related to both monitoring and I&E, the short-term schedule includes exploring efforts to initiate a locally led monitoring program. In addition to elevating public awareness, information from this program would provide a technical basis to guide locally generated, cost-effective solutions.

An important aspect of watershed plan development is to identify and encourage activities, which can be quickly implemented and produce measurable results. As with many watersheds of comparable size, the Pebble Creek HUC-12 watershed faces a variety of implementation challenges. These challenges include how to assess the benefits of a variety of stormwater management strategies, how to select the optimal combination of BMPs that minimize costs, how to be consistent with community goals and characteristics, and how to meet reductions needed to achieve WQS.

To meet these challenges and ensure the watershed implementation plan is outcome-based with local support, it is important to evaluate water quality, pollutant source, and drainage system information at a level detailed enough to recommend specific actions and responsibilities. This is accomplished in stages building on the field inventory and critical areas for BMP implementation. The plan is re-evaluated through each phase of implementation and program adjustments made as new information becomes available.

A generalized outcome-based strategic planning framework is presented in Appendix F. The primary focus is to take advantage of local input to address stormwater runoff reduction needs by continuing to identify implementation opportunities in each phase that will produce measurable results. Available Pebble Creek HUC-12 watershed information is reviewed during each phase of plan implementation as it relates to each of USEPA's Nine Minimum Elements. Data gaps are identified, and priorities established at the watershed scale.

6. Accountability Structure

The ultimate measure of program success will be documented changes in water quality, showing improvement over time. However, potential barriers to achieving this goal must be considered in implementation planning. Positive environmental feedback from even the most persistent efforts may be several years in the future due to the lead time needed to implement BMPs throughout the watershed. Stakeholders must set realistic expectations about the amount of time needed to implement projects or programs while waiting for positive results.

6.1 Interim Milestones

Interim milestones associated with priority stormwater runoff reduction activities are incorporated into the schedule (Table 5). These interim milestones emphasize: 1) documenting BMP implementation through each phase; 2) ensure that information collected will guide effective critical area planning in subsequent phases using adaptive management, as described under "Progress Benchmarks" and "Monitoring"; and 3) other implementation activities will be identified and conducted simultaneously to meet goals/objectives of other programs being implemented in the Pebble Creek HUC-12 watershed (e.g., MS4 permit requirements, CMP/CIP activities). As noted in Section 5, priority actions will occur over a 20-year period with staging activities in three phases (short-, mid-, and long-term) that will ultimately achieve needed stormwater runoff and bacteria reductions (Appendix G).

Table 5. Interim priority stormwater runoff reduction milestones

Activity	Critical Area(s)	Timeframe [a]	Interim Milestones
Priority Parking Lot Stormwater Reduction	00.a, 00.d, 11.a, 11.b, 11.c, 60.b, 60.c, 60.d	Phase 1	0.31 million-ft³ stormwater runoff volume reduction from connected parking lots
	all of above plus 00.e, 00.f, 10.a, 10.b, 60.e	Phase 2	1.25 million-ft³ stormwater runoff volume reduction from connected parking lots
	all of above plus 60.a	Phase 3	2.50 million-ft³ stormwater runoff volume reduction from connected parking lots
Priority Road Corridor Stormwater Reduction	00.a, 11.a	Phase 1	0.31 million-ft³ stormwater runoff volume reduction from either DCIC in road ROW or on parking lots connected to transportation storm sewer system
	all of above plus 00.b, 11.b, 11.c	Phase 2	0.93 million-ft³ stormwater runoff volume reduction from either DCIC in road ROW or on parking lots connected to transportation storm sewer system
	all of above plus 00.c, 00.d, 10.a, 60.b, 60.d	Phase 3	1.86 million-ft³ stormwater runoff volume reduction from either DCIC in road ROW or on parking lots connected to transportation storm sewer system
Stormwater Asset Management	00.a, 11.a, 11.c	Phase 1	0.31 million-ft³ stormwater runoff volume reduction from either DCIC in road ROW or on parking lots connected to transportation storm sewer system
	all of above plus 00.c, 00.d, 11.b 60.a, 60.b, 60.c, 60.d	Phase 2	0.93 million-ft³ stormwater runoff volume reduction from either DCIC in road ROW or on parking lots connected to transportation storm sewer system
	all of above	Phase 3	1.86 million-ft³ stormwater runoff volume reduction from either DCIC in road ROW or on parking lots connected to transportation storm sewer system
Notes: [a] Phase 1 (2019-21); Phase 2 (2022-28); Phase 3 (2029-38)			

6.2 Progress Benchmarks

Implementation activities for the Pebble Creek HUC-12 watershed are staged in three phases using outcome-based strategic planning and an adaptive management approach. Phase 2 (mid-term) and Phase 3 (long-term) are designed to build on results from the preceding phase. In order to guide actual plan implementation through each phase using adaptive management, water quality benchmarks are identified to track progress towards attaining water quality standards.

These interim targets (Appendix H) are intended to reflect the time it takes to implement management practices, as well as the time needed for water quality indicators to respond. In addition to water column indicators (e.g., TSS and *E. coli*), habitat and macroinvertebrate community evaluations conducted by MDEQ are included. These indicators will likely to respond more quickly to watershed changes that result from implementation of management practices.

6.3 Monitoring

Consistent with the Rouge River WMP that was developed at a larger scale, a well-planned evaluation process will provide measures of the effectiveness of implementation of this Watershed Management Plan and achieving its goals. The evaluation of this Watershed Management Plan will be accomplished through the Rouge River five-year monitoring plan updated in 2012. A component of ARC's long-term monitoring plan includes partnering with Friends of the Rouge (FOTR).

The FOTR benthic monitoring program is a cost-effective way to monitor improvements in water quality by monitoring the diversity of aquatic life in the river and its tributaries. Additionally, effectiveness will be gauged by flow and water quality monitoring. Another component of monitoring will include tracking land cover changes from impervious to green infrastructure, tree canopy, and native vegetation.

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Appendix A. Causes and Sources

Objective

Describe the watershed including impaired waterbodies and locate major causes/sources of impairment in the planning area.

Intent

The plan should set goals to meet (or exceed) the appropriate water quality standards for pollutant(s) that threaten or impair the physical, chemical, or biological integrity of the watershed. This element includes an accounting of the significant point and nonpoint sources in addition to the natural background levels that make up the pollutant loads causing problems in the watershed.

Key Questions

- Are water body use designations (from relevant Water Quality Standards) listed for waters in the planning area?
- Are water quality criteria (from relevant Water Quality Standards) for the use designations cited?
- Are impaired, partially impaired, and/or threatened uses (from state 303[d] or integrated report) listed by water segment or area?
- Are specific causes and sources (303[d]) of impairments and/or threats (if applicable) listed by waterbody segment or area?
- Are causes of impairment (or threats) listed as loads, WQC exceedance amounts/ percentages, or via other quantifiable method?
- Are sources of impairments/threats (if applicable) mapped or identified by area, category/subcategory, facility type, etc.?
- Are contributions from each source location or category quantified by load, percentage, priority, or other method?
- Are estimates, assumptions, or data used in the analysis presented or cited? Do they appear reasonable?

Discussion

Waterbody designations (from relevant WQS) are listed for waters in the planning area.

At a minimum, all surface waters of the state are designated and protected for all of the following designated uses: agriculture, navigation, industrial water supply, warmwater fishery, other indigenous aquatic life and wildlife, partial body contact recreation, total body contact recreation (May 1 to October 31), and fish consumption (R 323.1100, Designated Uses, of the Part 4 rules, Water Quality Standards, promulgated under Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended [Act 451]).

The impaired designated uses for the Pebble Creek watershed addressed by this implementation plan are the *warmwater fishery*, *other indigenous aquatic life and wildlife*, and *partial and total body contact recreation* uses [R 323.1100(1)(d, e, and f), and R 323.1100(2)], due to biological impairments (specifically poor macroinvertebrate community scores) and elevated bacteria levels.

Water quality criteria (from relevant WQS) for the use designations are cited.

The narrative criteria for the Pebble Creek Watershed Implementation Plan are based on Michigan's Procedure 51 (P51) biological assessment protocol (MDEQ, 1990). The biological assessment target is the reestablishment of fish and macroinvertebrate communities that result in a consistent *"acceptable"* or *"excellent"* rating. Macroinvertebrate and fish surveys will continue to be conducted following implementation of projects described in this plan, which are intended to stabilize runoff discharges, extremes in stream flow conditions, and minimize sediment loadings in the watershed.

While the primary target is the restoration of acceptable biological communities, the Part 4 Rules contain provisions that may be used to develop secondary targets that address documented impairments. For example, R 323.1050 (Rule 50) states that *"surface waters of the state shall not have any of the following physical properties in unnatural quantities which are or may become injurious to any designated use: turbidity, color, oil films, floating solids, foams, settleable solids, suspended solids, deposits"*. Several TMDLs developed by the MDEQ, including one developed for the Rouge (Goodwin 2007), used total suspended solids (TSS) as a secondary numeric target to address aquatic life impairments.

Use of TSS as a secondary numeric target is intended to help guide proper control of excessive sediment loads from runoff. This indicator can also address problems associated with runoff discharge rates and volumes that lead to channel instability, stream bank erosion, and thus increased TSS concentrations. In addition, the use of TSS as a numeric target connects a measurable in-stream parameter to hydrologic changes in the watershed, which can result in habitat changes that are adversely affecting biological communities.

The impaired designated recreational uses addressed by the Pebble Creek Watershed Implementation Plan are total body contact (TBC) and partial body contact (PBC). The designated use rule (Rule 100 [R 323.1100] of the Part 4 rules, WQS, promulgated under Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act (NREPA), 1994 PA 451, as amended) states that this water body be protected for TBC recreation from May 1 through October 31 and PBC recreation year-round. The target levels for these designated uses are the ambient *E. coli* standards established in Rule 62 of the WQS as follows:

> R 323.1062 Microorganisms.
>
> Rule 62. (1) All waters of the state protected for total body contact recreation shall not contain more than 130 *E. coli* per 100 milliliters (mL), as a 30-day geometric mean. Compliance shall be based on the geometric mean of all individual samples taken during five or more sampling events representatively spread over a 30-day period. Each sampling event shall consist of three or more samples taken at representative locations within a defined sampling area. At no time shall the waters of the state protected for total body contact recreation contain more than a maximum of 300 *E. coli* per 100 mL. Compliance shall be based on the geometric mean of three or more samples taken during the same sampling event at representative locations within a defined sampling area.
>
> (2) All surface waters of the state protected for partial body contact recreation shall not contain more than a maximum of 1,000 *E. coli* per 100 ml. Compliance shall be based on the geometric mean of 3 or more samples, taken during the same sampling event, at representative locations within a defined sampling area.

Sanitary wastewater discharges have an additional target:

Rule 62. (3) Discharges containing treated or untreated human sewage shall not contain more than 200 fecal coliform bacteria per 100 ml, based on the geometric mean of all of five or more samples taken over a 30-day period, nor more than 400 fecal coliform bacteria per 100 ml, based on the geometric mean of all of three or more samples taken during any period of discharge not to exceed seven days. Other indicators of adequate disinfection may be utilized where approved by the Department.

Impaired, partially impaired and/or threatened uses are listed by water segment or area.

The Pebble Creek watershed appears on Michigan's list of impaired waters (Goodwin, et. al., 2017*)* as not meeting the Other Indigenous Aquatic Life and Wildlife (OIALW) designated use because of biological impairments in two assessment unit identifier (AUID) stream segments (Table A-1). Two Pebble Creek watershed AUIDs are also not meeting total and partial body contact recreational designated use due to bacteria (040900040404-01 and 040900040404-02).

Table A-1. Pebble Creek watershed impaired waters

Subwatershed: 040900040404	**Waterbody name:** **Pebble Creek – River Rouge**
Includes:	River Rouge [AUID 040900040404-01], Pebble Creek [AUID 040900040404-02], Unnamed Tributaries to Pebble Creek [AUID 040900040404-02], Unnamed Tributaries to Pebble Creek [AUID 040900040404-02]
Impaired Designated Uses:	Total Body Contact Recreation (TBC) [AUID 040900040404-01, 040900040404-02] Partial Body Contact Recreation (PBC) [AUID 040900040404-01, 040900040404-02] Other Indigenous Aquatic Life and Wildlife (OIALW) [AUID 040900040404-01, 040900040404-02]
Cause:	*Escherichia coli* (TBC and PBC uses) Other flow regime alterations, sedimentation/siltation (OIALW use)
Size:	AUID 040900040404-01: 43.7 miles AUID 040900040404-02: 30.3 miles
Year Placed on §303(d) List: 2000	**TMDL Year:** Completed in 2007

Specific causes and sources are listed by waterbody segment or area.

Bioassessments. Specific causes of the impairments by AUID are included in Table A-1. The causes and sources are also described in more detail in MDEQ bioassessment reports (Goodwin 2002, Goodwin 2009), MDEQ TMDL documents (Goodwin 2007, MDEQ 2007), and in the Rouge River WMP (ARC 2012). Source areas were initially identified based on land use and impervious cover information. To identify potential sources by area and category (e.g., land use, impervious cover type), the Pebble Creek HUC-12 watershed was divided into catchments using delineations provided by MDEQ. This is described more fully in a subsequent section of this Appendix (see discussion associated with Table A-6 and Figure A-5).

Macroinvertebrate community data provide the most significant basis for identifying non-attainment of the OIALW designated use in the Pebble Creek HUC-12 watershed. The MDEQ biological survey Procedure 51 (P51) for wadeable streams was used to evaluate conditions in the Pebble Creek HUC-12 watershed *(MDEQ, 1997)*. P51 uses metrics that rate macroinvertebrate communities from excellent (+5 to +9) to poor (-5 to -9). Scores from +4 to -4 are rated acceptable.

The individual P51 metrics for bioassessment locations in the Pebble Creek HUC-12 watershed are summarized in Table A-2. The relatively high percentage of dominant taxa at many of the Pebble Creek HUC-12 bioassessment sites is also indicative of degraded conditions. A community dominated by relatively few taxa typically indicates environmental stress. The dominant taxa vary between sites as shown in Table A-3. Similarly, metric 8 reflect the presence of a high number of pollution tolerant organisms in the Pebble Creek HUC-12 watershed.

Channel Conditions. In addition to the P51 biological surveys, MDEQ conducted a channel condition assessment in 2016 to provide background data prior to possible storm water control or channel restoration activities in the future. Four locations were surveyed to provide geographic coverage of the watershed (Figure A-1). Two of the four surveyed locations (Eleven Mile Road and Ten Mile Road) were MDEQ P51 bioassessment sites, one of which (Eleven Mile Road) is a long-term trend monitoring site. Bank erosion hazard index (BEHI) and near-bank stress calculations were performed for each cross-section location.

Table A-2. Pebble Creek Procedure macroinvertebrate data summary

Stream	Location	Year	Procedure 51 Metric								
			1	2	3	4	5	6	7	8	9
Pebble Creek	Westgate Road	2010	23	**1**	**3**	**0**	**0.57**	19.83	**40.23**	**7.37**	0.57
	Middlebelt Road	2005	19	**1**	**1**	**0**	**8.51**	21.28	21.28	7.45	6.38
	11-Mile Road	2010	14	**0**	**1**	**0**	**0.00**	**2.83**	28.34	**25.91**	0.40
		2015	19	1	**1**	**0**	**0.78**	7.39	**38.52**	**14.79**	0.78
	10-Mile Road	2005	20	**1**	**1**	**0**	5.43	32.61	32.61	3.26	6.52
		2010	16	**1**	**1**	**0**	**2.33**	10.85	30.23	**21.71**	6.20
Main Rouge	13-Mile Road	2000	14	**1**	**1**	**0**	6.93	49.5	**49.5**	**2.97**	2.97
		2005	21	2	1	**0**	7.45	9.57	15.96	**19.15**	4.26
	7-Mile Road	2000	**8**	1	1	**0**	10.00	30.00	32.00	8.00	0.00
		2005	14	**1**	**0**	**0**	8.60	**0.00**	26.88	**20.43**	3.21
Note on cell shading:		(light green)	Light green cell indicates that the macroinvertebrate community is performing better than the average condition typically found in this ecoregion (above two standard deviations).								
		(light diagonal)	Light diagonal cell in **bold** indicates that the macroinvertebrate community is performing less than the average condition typically found in this ecoregion (below two standard deviations).								

Table A-3. Dominant taxa at Pebble Creek subwatershed macroinvertebrate sites

Site	Dominant Taxa	Percentage
Pebble Creek at Westgate Road *(2010)*	Calopterygidae (damselflies)	40.2
Pebble Creek at Middlebelt Road *(2005)*	Hydropsychidae (caddisflies)	21.3
Pebble Creek at 11-Mile Road *(2010)*	Elmidae (beetles)	38.5
Pebble Creek at 10-Mile Road *(2010)*	Calopterygidae (damselflies)	30.2
Main Rouge at 13-Mile Road *(2005)*	Diptera (Chironomidae)	16.0
Main Rouge at 7-Mile Road *(20050)*	Diptera (Chironomidae)	26.9

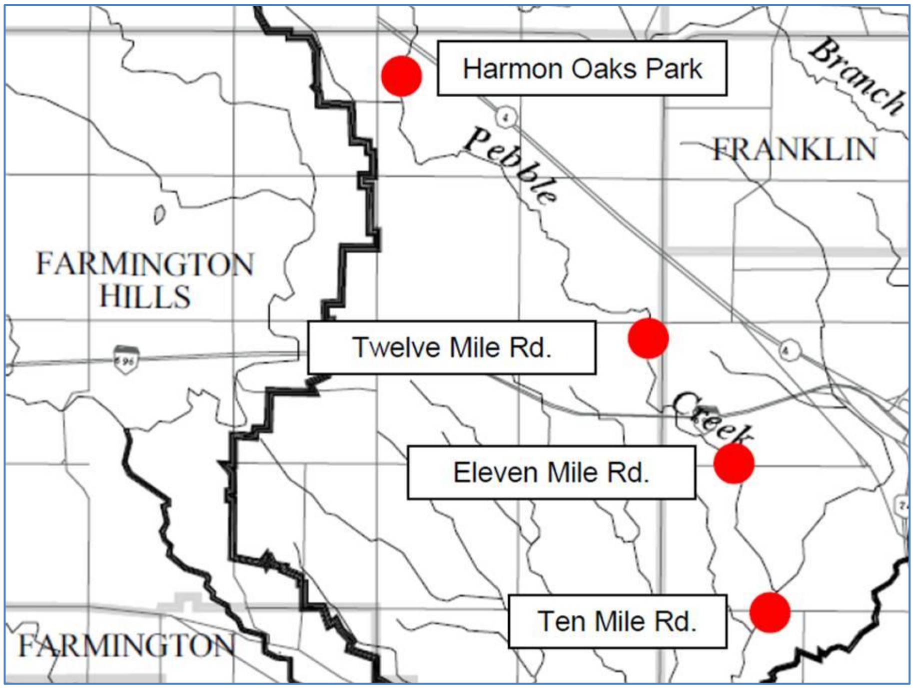


Figure A-1. Location of MDEQ Pebble Creek channel condition survey sites

The channel at each surveyed location appeared over-wide and incised; common in much of the Rouge River watershed. Steep, bare, eroded banks were common, and the channel generally lacked in-stream habitat features such as riffles and pools. BEHI scores ranged from "Moderate" to "Extreme" with the upstream-most location exhibiting the lowest bank erosion risk (Table A-4). Factors increasing the BEHI scores included channel incision (i.e., estimated bankfull elevation was lower than the top of the stream bank), minimal vegetation on the bank surface, and little surface protection (i.e., non-vegetation bank protection).

Best management practices that would improve stream channel stability in Pebble Creek include storm water management retention or infiltration, or modifying the channel to improve floodplain access (e.g., a "2-stage" channel). Maintaining the existing riparian forests will also benefit channel stability.

Table A-4. Pebble Creek bank erosion hazard index survey results

Site	Bank *(facing downstream)*	BEHI Results	
		Total Score	***Rating***
Pebble Creek at Harmon Oaks Park	Left	27.5	Moderate
	Right	25.6	Moderate
Pebble Creek below 12-Mile Road	Left	51.5	Extreme
	Right	38.0	High
Pebble Creek above 11-Mile Road	Left	43.0	Very High
	Right	41.6	Very High
Pebble Creek at 9-Mile Road	Left	37.5	High
	Right	37.5	High

Causes of impairment are listed as loads, WQC exceedance amounts, or other quantifiable method.

The macroinvertebrate community structure data indicate that siltation due to excess TSS loads is the *cause* of the biological impairments (Goodwin, 2007). The poor macroinvertebrate community is also attributed to a lack of suitable habitat for colonization (due to past channel alterations). In addition, high storm water flows that runoff from impervious surface *sources* likely bring additional pollutant and sediment loads to the stream that further degrades the habitat. The following describes the relationship between aquatic biology, hydrology, and impervious cover used to quantify the cause of impairment in the context of stream flashiness, impervious cover, and excess stormwater volume; all measures that can guide development of meaningful NPS implementation efforts.

Hydrology can be a major factor that affects aquatic communities, thus influencing bioassessment scores (Figure A-2). Stable flow regimes support the establishment of healthy macroinvertebrate populations. Flashy flows (e.g., due to excessive urban runoff) disrupt aquatic community structure and increase the transport of TSS loads that cause downstream siltation problems. Flashiness is an indicator of the frequency and rapidity of short-term changes in stream flow, particularly during runoff events (Baker et al. 2004). Increased flashiness is typically associated with unstable watersheds and degraded habitat that adversely affect aquatic life.

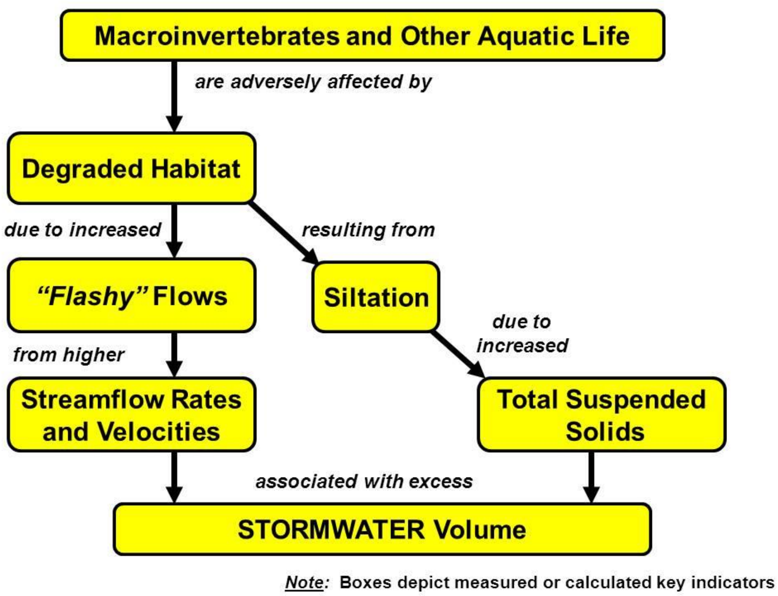


Figure A-2. Relationship between key indicators in identifying stormwater volume targets

A list of sites was assembled with a watershed area of less than 30 square miles based on an MDEQ study (Fongers et al. 2012). The sites examined include several streams located in southeast Michigan. As an initial evaluation, stream flashiness for these sites was compared to P51 bioassessment scores reported by MDEQ. In addition, the Richards-Baker Flashiness Index (R-B Index) was examined relative to several P51 component metrics.

Local organizations in the SEMCOG area are engaged in volunteer monitoring efforts to foster stewardship and encourage action. These organizations include the Friends of the Rouge, the Alliance of Rouge Communities, the Clinton River Watershed Council, and the Huron River Watershed Council. Several locations monitored by these groups coincide with streams where flow gaging data exists.

Collectively, this information can be used to further estimate the relationship between stream flashiness and macroinvertebrates (Figure A-3). Patterns using the volunteer data are like those observed based on MDEQ bioassessment surveys; the condition of the macroinvertebrate community decreases with increased stream flashiness.

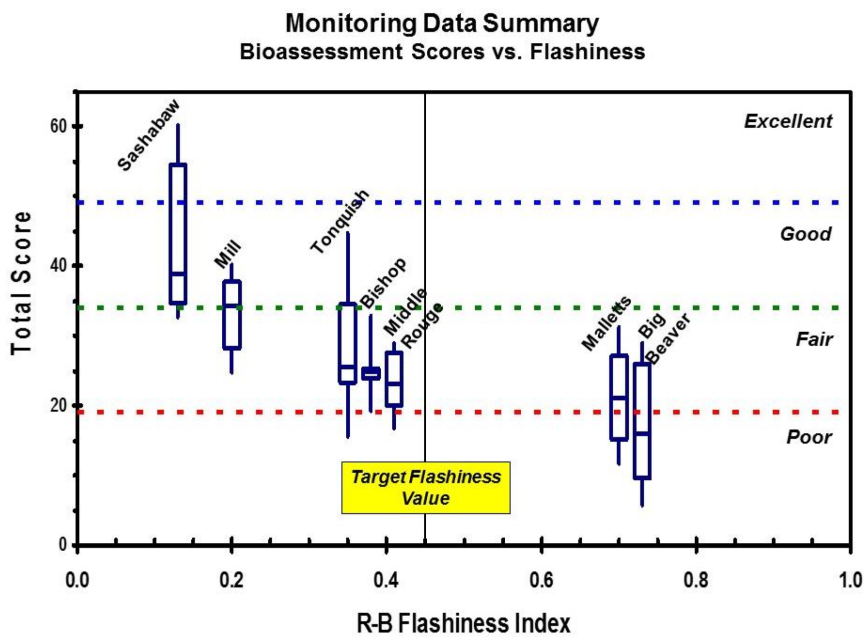


Figure A-3. Comparison of R-B Index to several southeast Michigan volunteer monitoring sites

Causes of impairment are connected to stormwater volume reduction needs based on the relationship between aquatic biology and hydrology. An assessment of macroinvertebrate data and stream flashiness shows a general range above which bioassessment scores reflect poor conditions for aquatic life. An R-B Index value of 0.45 is used as a quantifiable flashiness target for this WMP (Figure A-3); values above this level reflect impaired conditions based on southeast Michigan data. The R-B Index is calculated using daily average flow values (as opposed to stormwater volume). For this reason, a rainfall–runoff model, which generates daily average flow estimates, is used to examine the volume reduction benefits derived from implementing different urban stormwater BMPs relative to improved R-B Index values.

Models are particularly useful tools to evaluate the effect that different land uses may have on any receiving water. A basic watershed model allows consideration of unique features that influence local hydrology; both natural factors (e.g., soils, topography, vegetation) and alterations (e.g., increased impervious cover). Principles behind the Loading Simulation Program C++ (LSPC) can be coupled with precipitation information to examine the effect of land use on runoff. Rainfall–runoff analysis in LSPC is based on algorithms from the Hydrologic Simulation Program FORTRAN (HSPF); a model widely used to support watershed analysis.

One major advantage of a modeling approach is that it provides a platform for consistent comparisons that show the relative effect of significant factors on key hydrologic indicators (e.g., increase in impervious cover associated with land use changes, infiltration rates dependent on soil types). An important focus of stormwater management is the role impervious cover plays in altering flow patterns. LSPC, for example, enables an analysis of the *relative* effect of changing impervious cover on hydrology when all other variables are held constant.

Table A-5 summarizes modeled changes for several key hydrologic indicators as impervious cover increases. Included is the two-year, 24-hour runoff volume; a measure often indicative of bankfull flows used to evaluate channel stability or protection. Because flashiness affects aquatic organisms, the relationship between directly-connected impervious cover (DCIC) and the R-B Index is shown in Figure A-4. As indicated in Table A-5 and Figure A-4, the greatest increase in stream flashiness occurs at DCIC levels somewhere between 10 and 15 percent. This is consistent with other studies, which indicate that streams often show signs of degradation and become stressed when the DCIC exceeds these levels.

Table A-5. Modeled relative effect of impervious cover on key hydrologic indicators

Directly-connected Impervious Cover *(%)*	**Hydrologic Indicator**		
	R-B Index	**Average Annual Runoff Volume** *(inches)*	**2-year, 24-hour Runoff Volume** *(inches)*
0	0.16	12.6	0.273
5	0.28	13.5	0.336
10	0.41	14.4	0.436
15	0.53	15.3	0.502
20	0.64	16.2	0.568
30	0.82	18.0	0.779
40	0.97	19.8	0.982
60	1.20	23.5	1.342
80	1.37	27.1	1.749
100	1.49	30.7	2.144

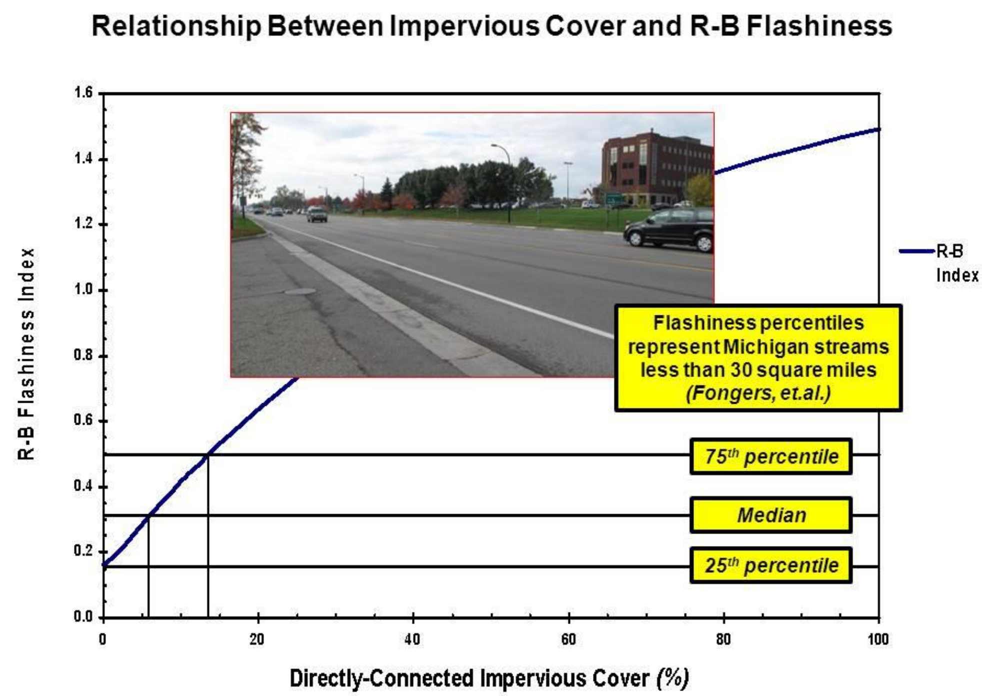


Figure A-4. Relative effect of directly-connected impervious cover on R-B Flashiness Index

Map impairment sources by area, category/subcategory.

Specific causes of the impaired aquatic life uses are associated with increased stream flashiness because of excessive stormwater runoff from source areas connected to increased impervious cover on developed land in the Pebble Creek HUC-12 watershed. To identify potential sources by area and category (e.g., land use, impervious cover type), the Pebble Creek HUC-12 watershed was divided into catchments using delineations provided by MDEQ's Hydrologic Studies Unit. Several MDEQ catchments were clustered based on size considerations and land use similarities.

Land use information for the Pebble subwatershed is summarized in Table A-6 and shown in Figure A-5. The summary presented in Table A-6 highlights land use categories in each catchment that exceed the subwatershed average; a useful indicator to target priority source areas for implementation planning.

In benchmarking the amount of green infrastructure needed in southeast Michigan, SEMCOG evaluated land cover information from 2010 aerial imagery (Figure A-6). This analysis included a compilation of impervious cover type across the Pebble Creek HUC-12 watershed (Table A-7). The SEMCOG impervious cover estimates are based on evaluation of parcel-scale data including transportation corridors, parking lot locations, and building footprints. SEMCOG's building data layer represents the digital footprint of each building in southeast Michigan, as of April 2015.

Table A-6. Pebble Creek land use

Catchment ID		Area *(acres)*	Land Use *(percent)*								Total Impervious Area
			Single-family Residential	*Multi-family Residential*	*Commercial*	*Institutional*	*Industrial*	*Road ROW*	*Parks, Open*	*Other*	
A	**00** -- *Upper Pebble*	2,959	55%	4%	14%	5%	---	15%	5%	0%	39%
B	**10** -- *Middle Pebble*	1,159	48%	0%	16%	8%	---	18%	10%	1%	27%
	11 -- *Pernick*	2,318	35%	10%	18%	16%	0%	17%	3%	0%	38%
C	**20** -- *Ravines (east)*	1,652	56%	4%	4%	15%	---	18%	2%	1%	31%
D	**30** -- *Ravines (middle)*	1,160	62%	0%	4%	13%	---	19%	3%	0%	31%
E	**40** -- *Ravines (upper west)*	1,448	76%	2%	3%	3%	0%	15%	1%	0%	29%
F	**50** -- *Ravines (lower west)*	909	66%	1%	5%	5%	0%	16%	7%	0%	32%
G	**60** -- *Main Rouge (Telegraph)*	2,300	51%	4%	11%	7%	0%	20%	7%	0%	34%
H	**70** -- *Main Rouge (Gage)*	666	77%	0%	1%	5%	2%	14%	1%	---	20%
	TOTAL	14,571	55%	4%	10%	9%	0%	17%	4%	0%	33%

Note: **Yellow highlighted cells** identify land use categories in each catchment that exceed the subwatershed average.

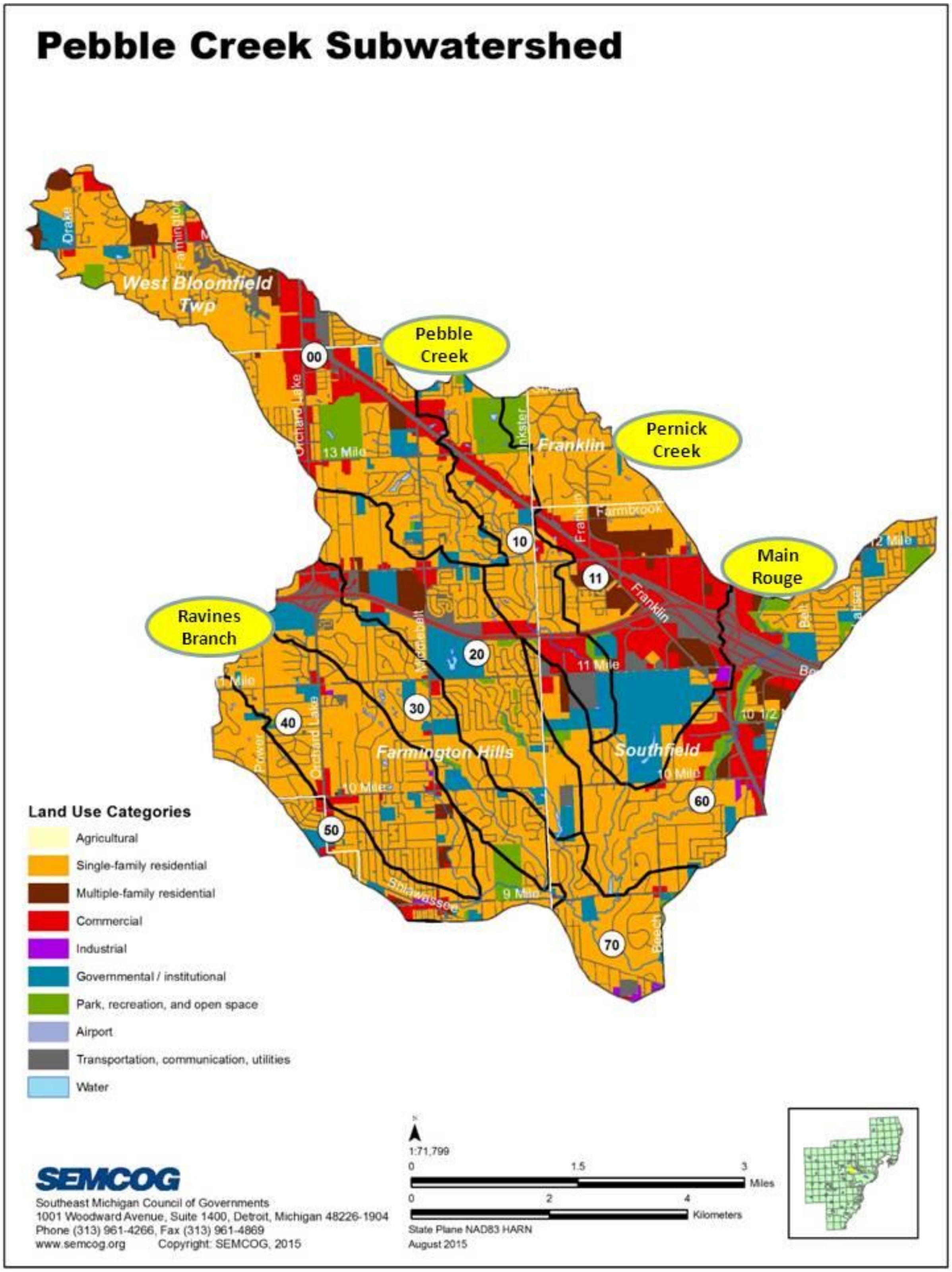


Figure A-5. Land use -- Pebble Creek subwatershed

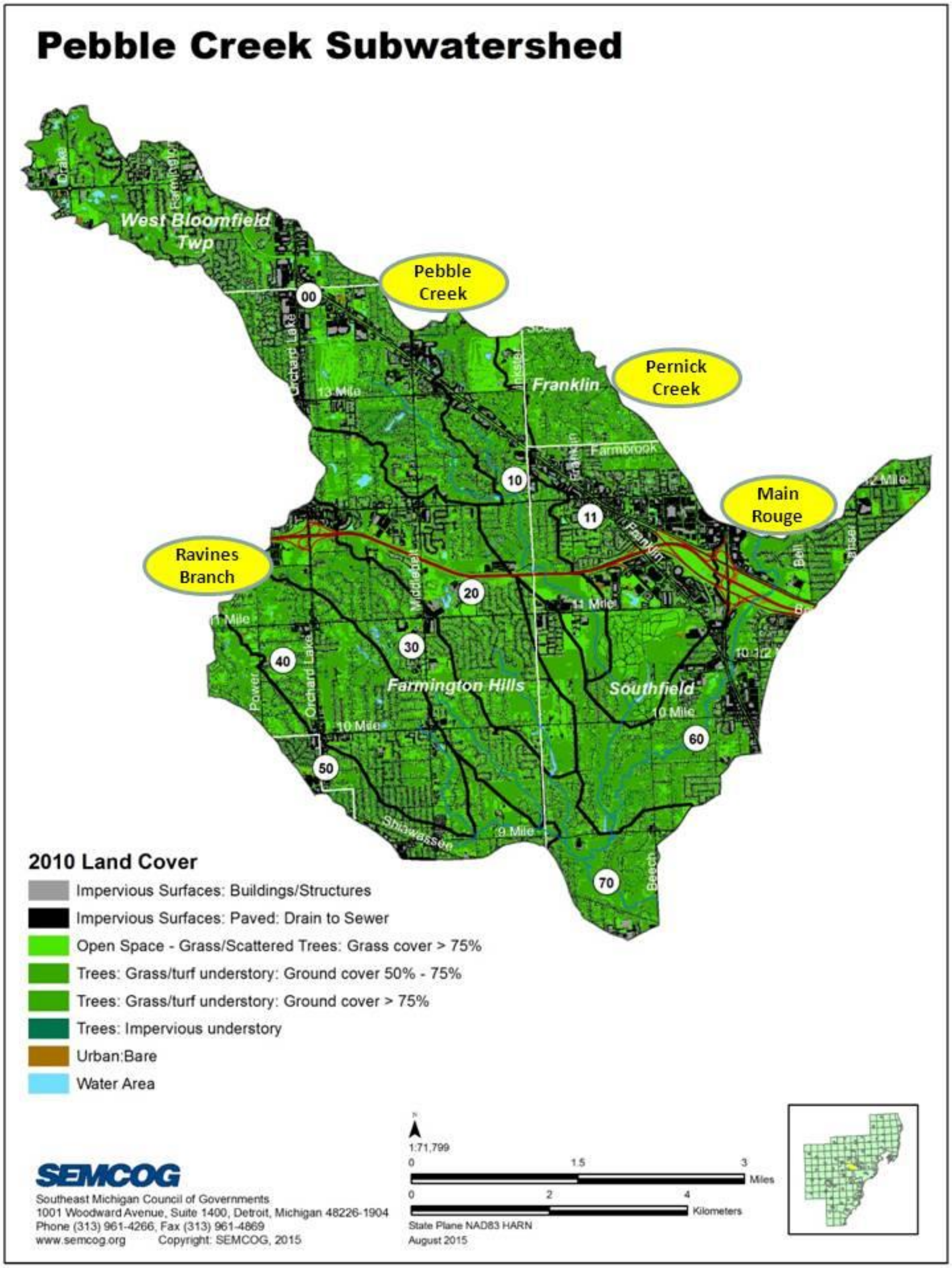


Figure A-6. Land cover -- Pebble Creek subwatershed

Table A-7. Pebble Creek land cover by land use category

Land Use Category	Area *(acres)*	Pervious Area		Impervious Surface Types			
		Open	*Tree Canopy*	*Building*	*Pavement* [a]	*Building (acres)*	*Pavement* [a] *(acres)*
Single-family residential	8,025	*25%*	*52%*	*9%*	*13%*	**722** [b]	**1,043** [c]
Multi-family residential	557	*21%*	*21%*	*19%*	*37%*	106	206
Commercial	1,463	*14%*	*16%*	*16%*	*53%*	234	**775** [c]
Industrial	40	*13%*	*20%*	*29%*	*37%*	12	15
Institutional	1,304	*33%*	*39%*	*5%*	*21%*	65	274
Road ROW	2,492	*29%*	*19%*	---	*51%*	---	**1,271** [c]
Parks, Open Space	640	*46%*	*45%*	*1%*	*7%*	6	45
Other	50	*20%*	*26%*	*1%*	*3%*	1	2
TOTAL	14,571	*26%*	*41%*	*8%*	*25%*	1,146	3,631

NOTE: [a] Pavement includes road surface, parking, driveways, sidewalks, etc.
[b] Indicates that not all single-family residential roof runoff is connected (portion directed into yards).
[c] **Yellow highlighted cells** identify greatest amount of potentially connected impervious surface types by land use.

Contributions from each source location or category quantified by load, percentage, or other method.

Source areas were initially identified based on land use and impervious cover information. Numerous studies have shown that as the level of impervious cover increases, water quality problems associated with stormwater also increase. Due to the decreased ability of areas infiltrate water, rain falling on impervious surfaces produces higher volumes of stormwater runoff. Runoff from impervious areas also pick up contaminants (e.g., sediment, nutrients, metals, petroleum hydrocarbons) that accumulate on these surface types (e.g., roads, parking lots) resulting in increased pollutant loads delivered to receiving waters. In addition, higher stormwater runoff volumes lead to increased stream flashiness and place more shear stress on natural streams. These conditions result in channel incision, bank erosion, siltation, and general aquatic habitat degradation.

Identifying outcomes for watershed planning depends on an understanding of conditions relative to sources of stormwater runoff. Developing this understanding is the focus of the drainage assessment, which describes aspects related to the generation and conveyance of stormwater in the watershed. The drainage assessment identifies priority locations where BMP implementation will be most effective, thus defining project opportunities. The drainage assessment evaluates stormwater sources with an emphasis on land use and impervious cover, specifically paved surfaces, which affect stream flashiness and stormwater runoff volume.

The SEMCOG land use/land cover data provides detailed information on impervious surface composition, which is used to prioritize stormwater sources and provide an estimate of the relative stormwater runoff contribution. An impervious surface composition summary for the Pebble Creek HUC-12 watershed is presented in Figure A-7. This chart conveys two types of information useful for evaluating stormwater sources in the drainage assessment; the quantity of impervious area for each land use category and the density of impervious cover in each catchment group. The quantity aspect identifies the catchment groups that contain higher amounts of total impervious area. The value in the oval for each subwatershed represents the percent impervious cover (or density aspect).

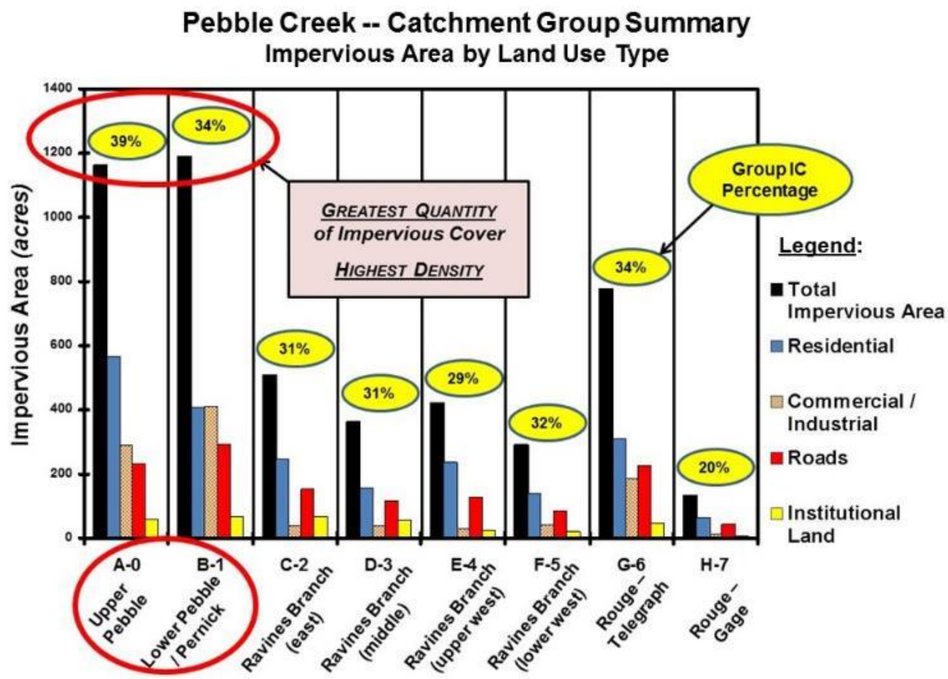


Figure A-7. Impervious surface composition -- Pebble Creek

The quantity and density of total impervious area points to Upper Pebble (group A), Lower Pebble / Pernick (group B), and Rouge – Telegraph (group G) as high priority stormwater source areas. The greatest amount of total impervious area is in Lower Pebble / Pernick (group B); mostly associated with commercial / residential land use followed by roads. A nearly equal amount of total impervious area exists in Upper Pebble (group A), where the density (39 percent) is the highest of all groups. Although group A also contains significant amounts commercial and road impervious surfaces, single-family residential is the dominant land use.

A quick analysis of Table A-7 highlights two land use categories of interest: commercial and road ROW. Though somewhat lower in the amount of total impervious cover than single-family residential, the relative density for these two categories is higher: 71 percent for commercial (18 percent building, 53 percent pavement) and 51 percent for road ROW.

The SEMCOG parcel data shows the location of parking lots in the Pebble subwatershed (Figure A-8). Coupled with road information by jurisdiction (Figure A-9, Figure A-10), two general commercial areas warrant special attention in group A: the Orchard Lake corridor near 14-Mile, and the corridor along Northwestern Highway. Although single-family residential land use has the highest total impervious area, the density is 31 percent; noticeably lower than the other two categories. Urban stormwater BMP implementation in these residential areas, while still important, is a lower priority.

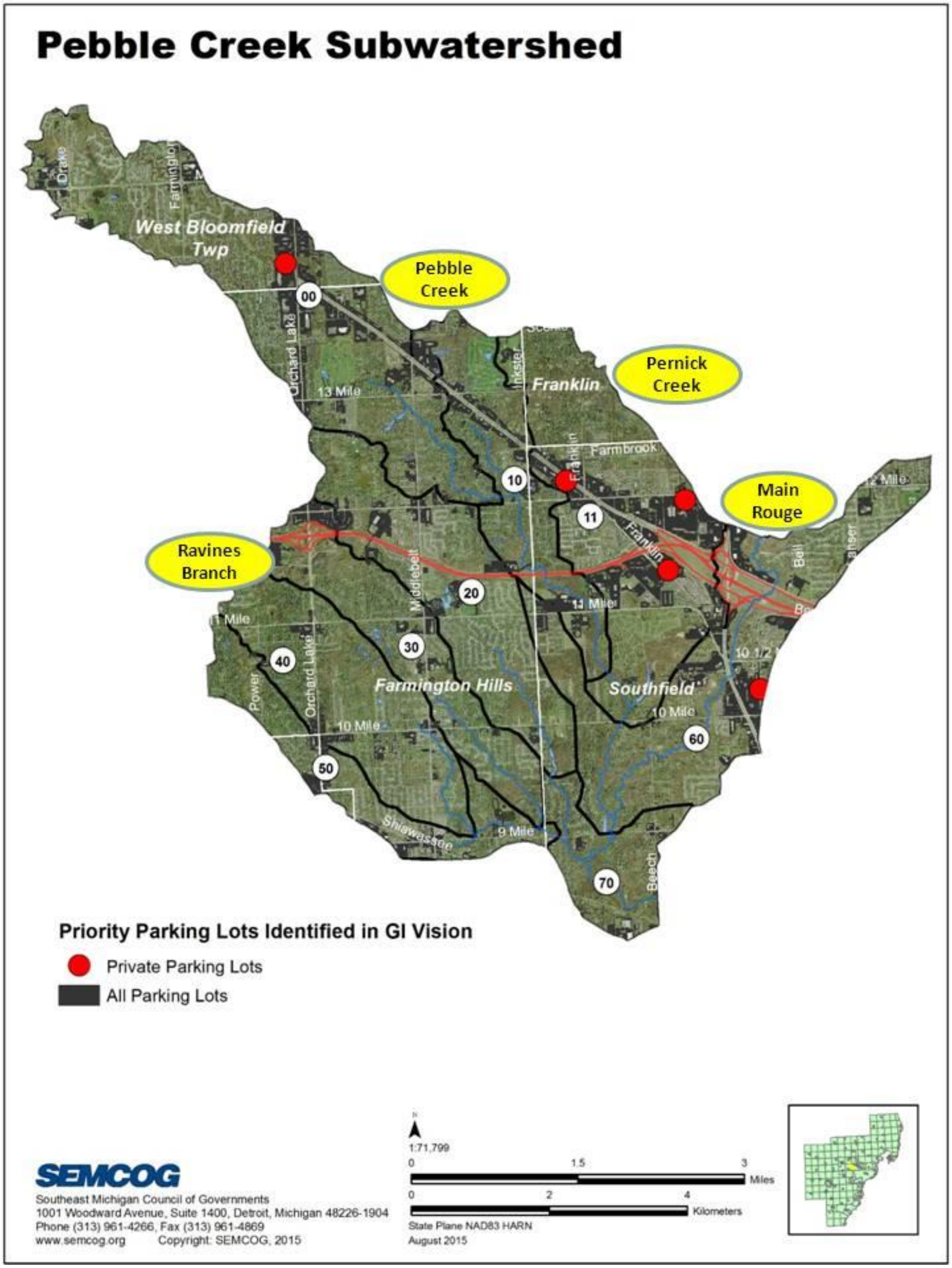


Figure A-8. Green Infrastructure Vision -- Pebble subwatershed priority parking lots

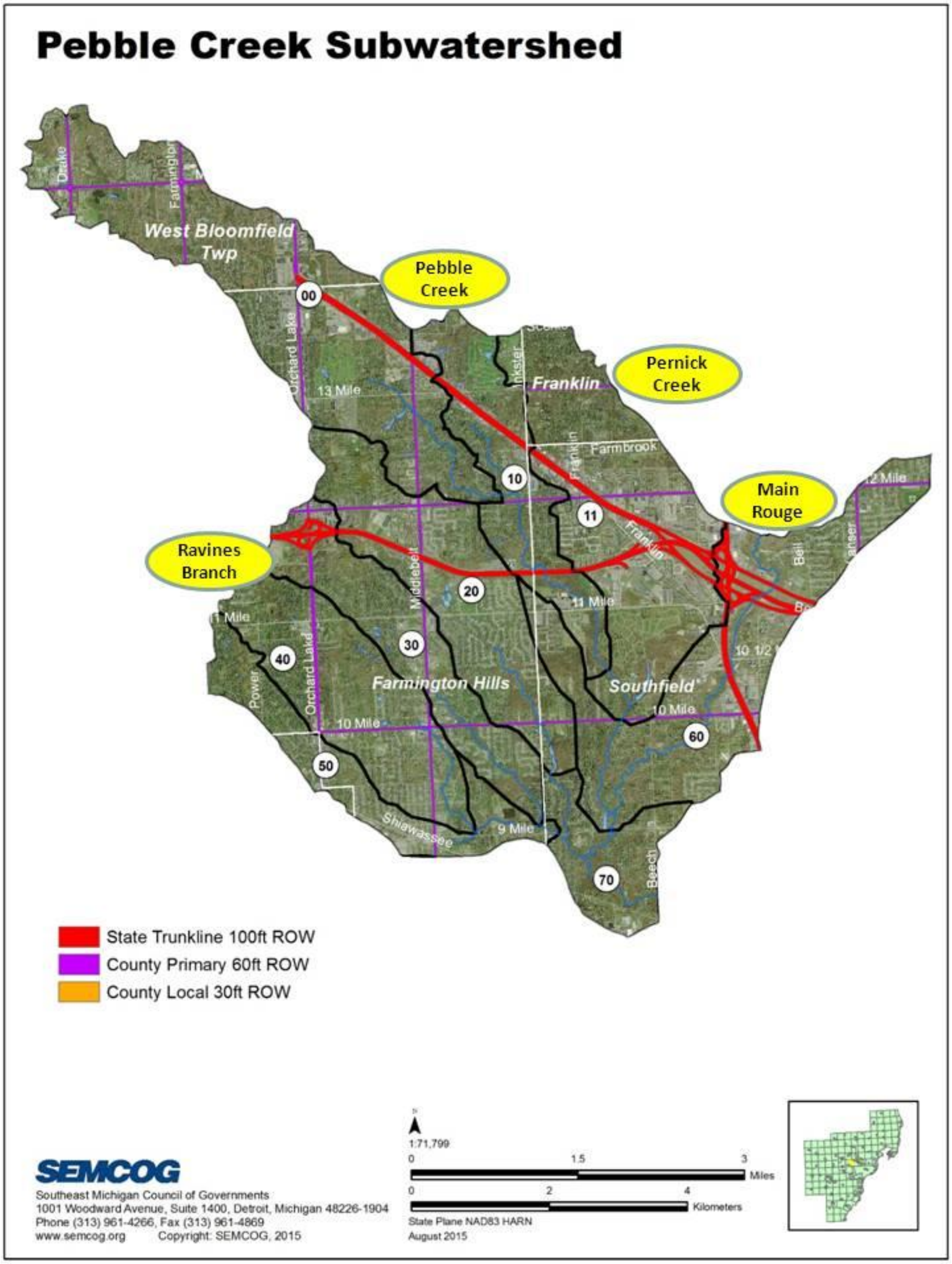


Figure A-9. Pebble Creek roadways

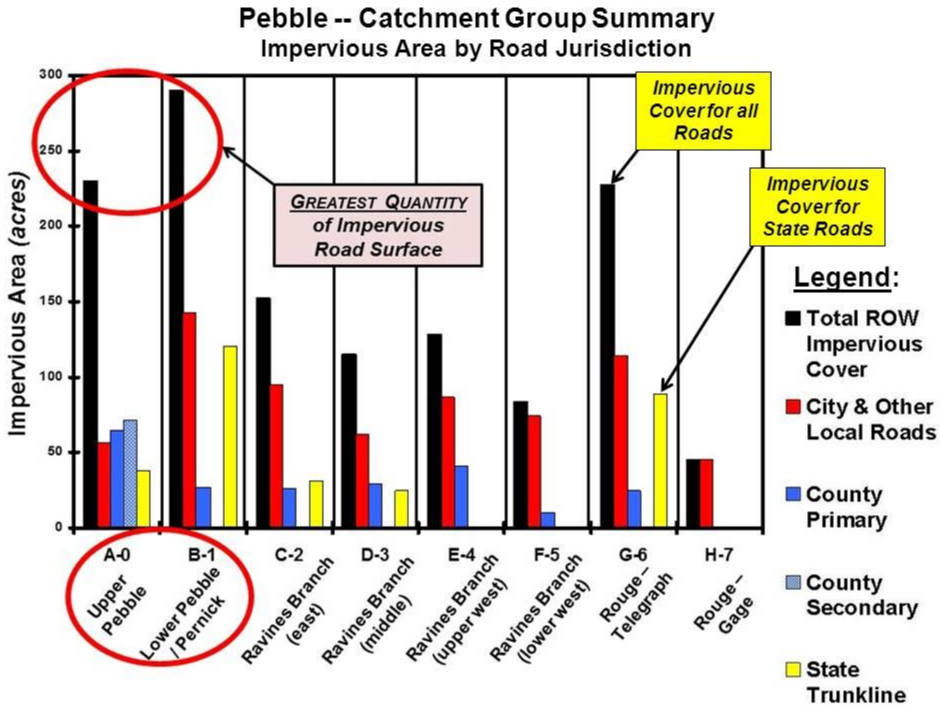


Figure A-10. Roadway impervious surface by jurisdiction -- Pebble subwatershed

Contributions from each priority catchment can be expressed as stormwater volumes using estimates of DCIC based on a two-year, 24-hour storm event (Appendix B). Assumptions based on empirical equations developed by Sutherland (1995, 2000) provide a consistent, documented method that has been used to determine reasonable estimates of DCIC across a range of different land uses (Table A-8 and Figure A-11). Applying the Sutherland empirical equations to the land use composition data provides an estimate of the DCIC for the Pebble Creek HUC-12 watershed. This information, in turn, is used to determine the approximate runoff contribution from each priority catchment and source category (e.g., critical area parking lots and roads) expressed as stormwater volumes based on a two-year, 24-hour storm event (Table A-9).

Table A-8. Sutherland equations to estimate connected impervious area

Type	Description	Land Use Classes	Sutherland Equation
Totally Connected	100% storm-sewered with all impervious area connected	Commercial, Industrial	DCIA = IA
Highly Connected	Mostly storm-sewered with curb & gutter Residential rooftops directly connected	Commercial, Industrial High Density Residential	$DCIA = 0.4 (IA)^{1.2}$
Average	Mostly storm-sewered with curb & gutter Residential rooftops not directly connected	Commercial, Industrial Medium Density Residential	$DCIA = 0.1 (IA)^{1.5}$
Somewhat Connected	50% not storm-sewered; Residential rooftops not directly connected; Open roads with grassy swales	Low Density Residential	$DCIA = 0.04 (IA)^{1.7}$
Mostly Disconnected	Small percentage of urban area is storm-sewered 70% + of impervious area infiltrate / disconnected	Agricultural, Wooded	$DCIA = 0.01 (IA)^{2}$

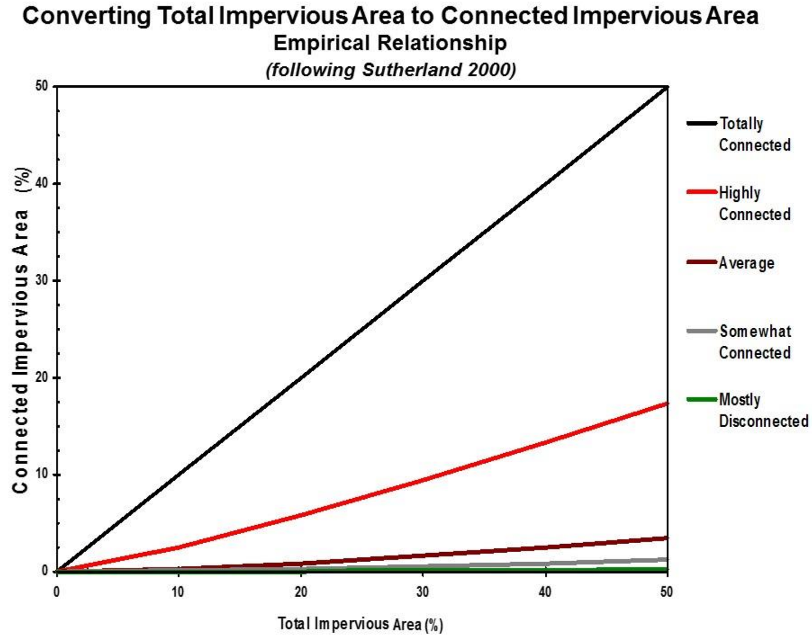


Figure A-11. Sutherland equations to estimate connected impervious area

Again, it is important to note that the directly-connected impervious cover is less than the total impervious area summarized in Table A-6. The DCIC amount acknowledges that not all impervious surface runoff reaches the stream. For example, a portion of storm runoff from residential roofs likely flows to yards where it infiltrates into the ground. Similarly, some storm runoff from roads without curb and gutter or well-defined ditch systems may simply flow from pavement to pervious areas and infiltrate into the ground.

Table A-9. Pebble Creek HUC-12 watershed stormwater runoff volume estimates

Location	Total Area *(acres)*	Directly-Connected Impervious Area *(acres)*			Two-year, 24-hour Stormwater Runoff Volume *(million-ft^3)*		
		Total [a]	Critical Area Parking Lots	Critical Area Roads	Total	Critical Area Parking Lots	Critical Area Roads
Overall Pebble HUC-12 watershed	14,571	2,200	590	444	15.4	4.13	3.11
● **00** ***(Upper Pebble)***	2,959	520	165	152	3.64	1.15	1.07
● **10** ***(Middle Pebble)***	1,159	150	36	25	1.05	0.25	0.17
● **11** ***(Lower Pebble/Pernick)***	2,318	470	202	140	3.29	1.42	0.98
● **60** ***(Main Rouge/Telegraph)***	2,300	360	187	127	2.52	1.31	0.89

Note: [a] Mid-point of estimated directly-connected impervious area range (±20%) using Sutherland equations and impervious surface composition data.

Appendix B. Load Estimates and Expected Reductions

Objective

Determine reductions needed to meet water quality standards on the basis of the existing source loads estimated for Element A.

Intent

After identifying the various management measures that will help to reduce the pollutant loads (Element C), the load reductions expected as a result of implementing these management measures will be estimates (recognizing the difficulty in precisely predicting the performance of management measures over time). Estimates should be provided at the same level as that required in the scale and scope described in Element A.

Key Questions

- Are reductions needed to address impairments listed, and quantified by weight, concentration, percentage reduction needed, etc.?
- Are listed reduction estimates linked to each cause and source location or category?
- Will reductions achieve water quality criteria, address threats (if applicable), or achieve other goals?
- Are estimates, assumptions, or data used in the analysis presented or cited? Do they appear reasonable?

Discussion

Reductions listed and quantified by weight, concentration, percent needed, etc.

An R-B Flashiness Index value of 0.45 is the target for this WMP (Figure A-3); values above this level reflect impaired in-stream biological conditions based on southeast Michigan data. Elevated flashiness contributes to channel instability, degraded stream habitat, increased siltation, and higher TSS loads. In urban settings, such as Pebble Creek, increased R-B Index values result from higher amounts of impervious surfaces. The estimated directly-connected impervious cover for the Pebble Creek HUC-12 watershed is 2,200 acres (Table A-9), or approximately 15 percent. Based on the relationship between directly-connected impervious cover and stream flashiness using Detroit area precipitation data, the current estimated R-B Index for the Pebble Creek HUC-12 is 0.53 (Table A-5). In order to achieve the R-B Index target of 0.45, a <u>*15 percent reduction*</u> in stream flashiness is needed [i.e., (0.53-0.45)/0.53].

In 2005, MDEQ sampled bacteria across the entire Rouge watershed. Locations monitored include several sites in Pebble Creek. Results of this survey are used to determine needed reduction percentages based on water quality concentration exceedance percentages (Table B-1). After MDEQ's sampling and development of the Rouge River *E. coli* TMDL (MDEQ, 2007), the communities have continued work to reduce bacteria levels in the watershed through their MS4 permit efforts (Figure B-1).

Table B-1. Main Rouge and Pebble Creek water quality concentration exceedance percentages

Catchment		Monitoring Location		Total Suspended Solids		*E. coli*	
ID	Cumulative Site Area *(sq.mi.)*	ID	Location	*Median (mg/L)*	*Needed Reduction*	*Geometric Mean (#/100mL)*	*Needed Reduction*
10	6.23	G-60	Pebble Creek at 11-Mile	---	---	586	*78%*
11	2.62	G-61	Pernick Creek at Franklin Road	---	---	825	*84%*
11	10.1	G-47	Pebble Creek at 10-Mile	17	---	714	*82%*
60	66.1	G-59	Main Rouge at 10-Mile	27	*7%*	896	*85%*
70	89.9	US-5	Main Rouge at Beech Road	40	*38%*	929	*86%*

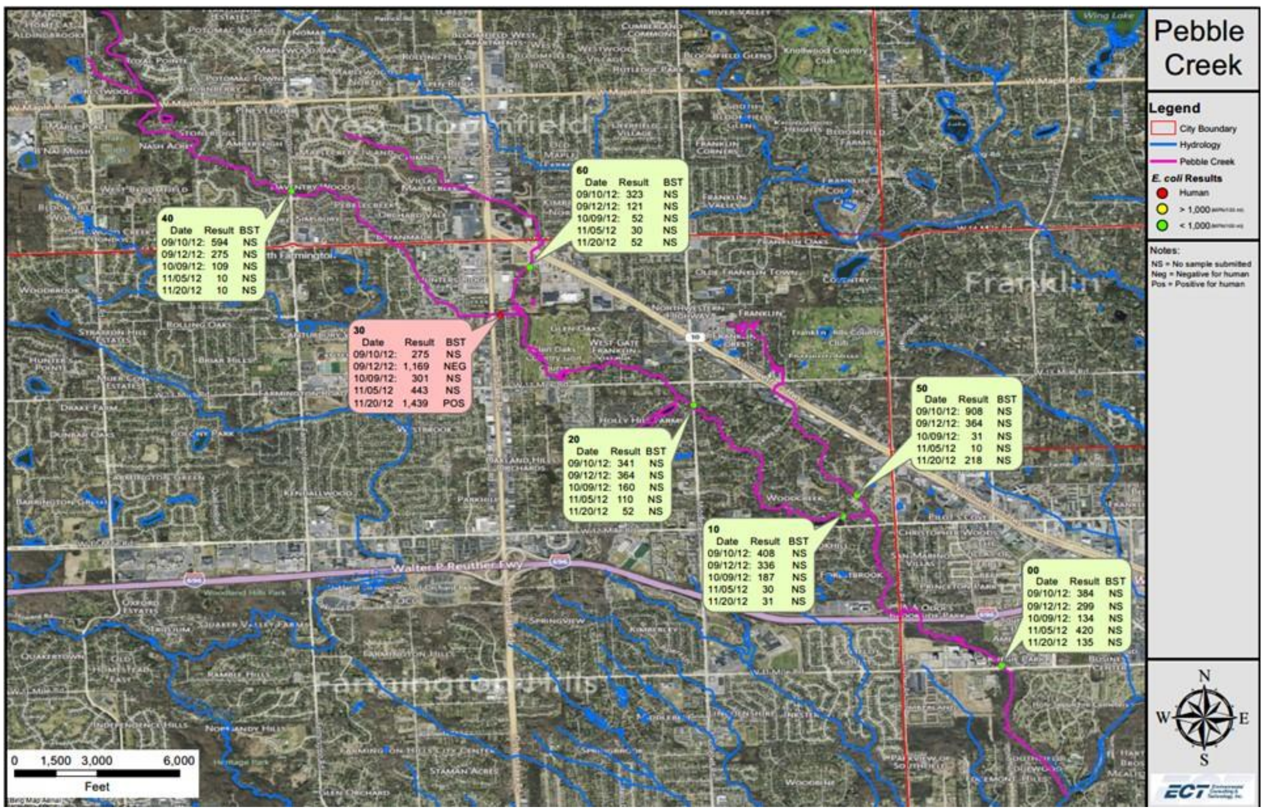


Figure B-1. Mapped results of Pebble Creek E. coli sampling

Reduction estimates linked to each cause and source location or category.

The R-B Index provides a good indicator showing the relationship between hydrology and the cause of aquatic life use impairments (e.g., macroinvertebrate conditions as assessed using P51). However, stream flashiness is not particularly well suited to evaluate reductions that will be realized from specific stormwater runoff mitigation practices targeted at source locations or categories (e.g., areas with higher amounts of directly-connected impervious cover). This is because projects are generally implemented at smaller scales (i.e., site, parking lot, road segment, or catchment level as opposed to the watershed scale). In addition, projects are often designed using a one-day storm event (in contrast to longer time scales used to calculate R-B Index or annual average volume values).

The *Low Impact Development Manual for Michigan* (SEMCOG 2008) describes methods to estimate the level of volume control needed to manage stormwater. The approach emphasizes BMP designs based on mimicking pre-development hydrology -- as defined by groundwater recharge, stream channel stability, and flooding. MDEQ guidance suggests that the channel protection performance standard for managing runoff from multiple sites or for watershed-wide design will also reduce stream flashiness to levels that protect aquatic biology. This approach results in management strategies that retain the volume produced by the two-year, 24-hour storm and maintain release rates in a pre-development condition. This value is determined by calculating the pre- and post-development the two-year, 24-hour runoff volume, as described in Michigan's guidance (MDEQ, 2014).

Relationships between different hydrologic parameters can be examined to determine if one or more indicators are particularly well suited for target development that would address multiple concerns. In the case of the Pebble Creek HUC-12 WMP, the relationship between R-B Index and two-year, 24-hour runoff values is of particular interest. Forty USGS gage sites in southeast Michigan, which have a sufficient number of flow records to examine hydrologic relationships, were used as part of a green infrastructure targeting project (SEMCOG 2016). Information from this effort shows a correlation between the R-B Index and two-year, 24-hour runoff values for Detroit area watersheds (Figure B-2).

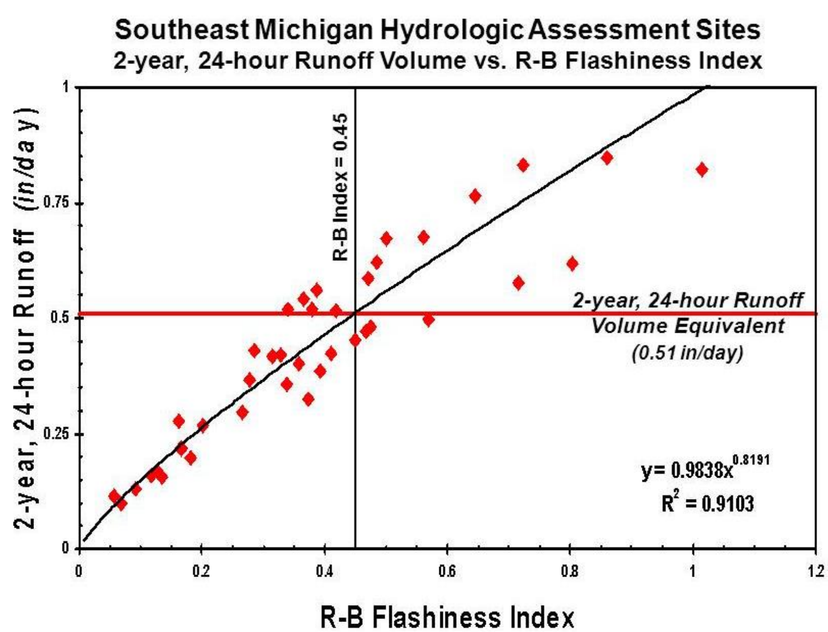


Figure B-2. Relationship between R-B Index and 2-year, 24-hour runoff values

The strong relationship between the R-B Index and two-year, 24-hour runoff values confirms that MDEQ's channel protection performance metric can be used to link reduction source locations and categories. Michigan's MS4 guidance document provides reference to a spreadsheet available on the MDEQ Web-site, which is designed to assist with the calculations. Runoff volumes based on the MDEQ spreadsheet are derived using the Natural Resources Conservation Service (NRCS) curve number (CN) method. Michigan's guidance document indicates that other runoff estimate methods are also acceptable, such as the Storm Water Management Model (SWMM).

The primary cause and source category in need of reductions are directly-connected impervious surfaces, particularly parking lots and roadways. A reduction estimate linked to this source category can be developed based on the relationship shown in Figure B-2, namely the 0.51 inch per day two-year, 24-hour runoff value that corresponds to the 0.45 R-B Index target. To account for uncertainties associated with the relationship between the R-B Index target and biological responses, a composite CN of 65 is used based on soils information for the Pebble Creek HUC-12 watershed. This results in a 0.21 inch per day two-year, 24-hour runoff value for pre-development site conditions.

The reduction needed, expressed as the two-year, 24-hour runoff volume to be retained, is 1.72 inches per day. This is based on the runoff generated from directly-connected impervious surfaces using a CN of 97 (or 1.93 inches per day); slightly less than a value of 98 in the MDEQ spreadsheet, but well within the range for impervious surfaces described in NRCS documentation, and reasonable given the marginal condition of Pebble Creek HUC-12 parking lots (see Appendix J for a summary of the parking lot field inventory information). This reduction need is graphically depicted in Figure B-3.

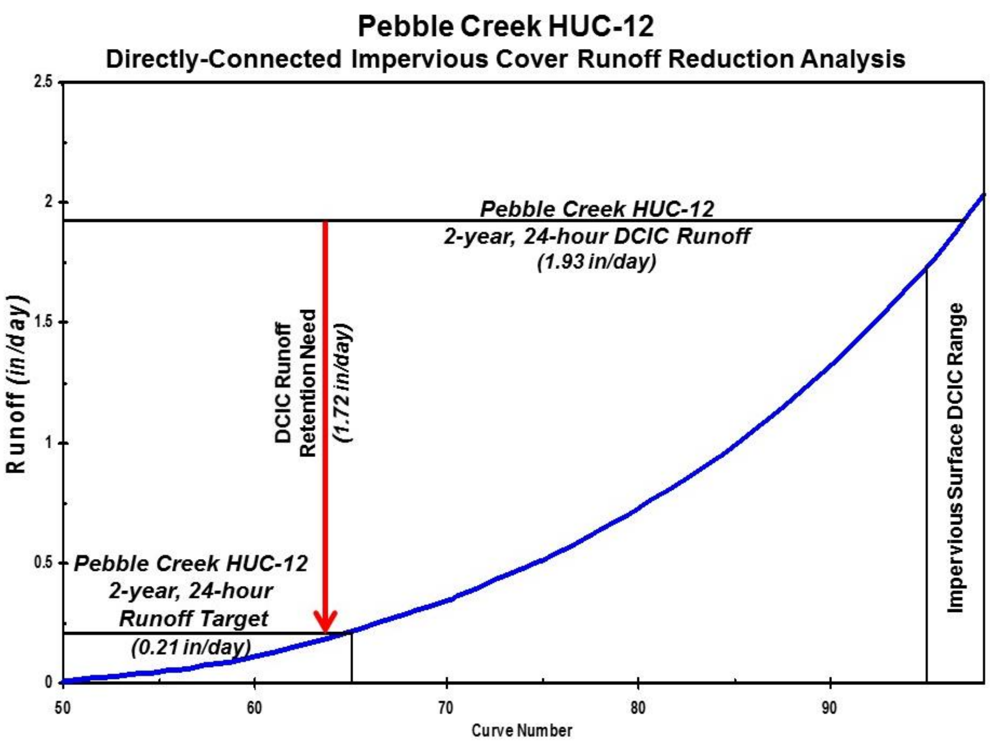


Figure B-3. Pebble Creek HUC-12 directly-connected impervious cover runoff reduction analysis

Reductions will achieve water quality criteria, address threats, or achieve other goals.

Applying the Sutherland empirical equations to land use composition data provides an estimate of DCIC for the Pebble Creek HUC-12 watershed (Table A-9). This information, in turn, is used to determine the volume reduction needed in each priority catchment and critical area that will work towards meeting the WQS in the Pebble Creek HUC-12 watershed. These volume reduction targets (Table B-2) for managing stormwater runoff are estimates that connect stream flashiness to aquatic biology and stream channel protection concerns.

Table B-2. Pebble Creek HUC-12 watershed volume reduction needs summary

Location	Total Area *(acres)*	Directly-Connected Impervious Area *(acres)* [a]	DCIC Runoff *(million-ft³)* [b]	Pre-Development Target *(million-ft³)* [b]	Reduction Need *(million-ft³)* [b]
Overall Pebble HUC-12 watershed	14,571	2,200	15.4	1.70	13.7
● **00** ***(Upper Pebble)***	2,959	520	3.64	0.40	3.24
● **10** ***(Middle Pebble)***	1,159	150	1.05	0.12	0.93
● **11** ***(Lower Pebble/Pernick)***	2,318	470	3.28	0.36	2.92
● **60** ***(Main Rouge/Telegraph)***	2,300	360	2.52	0.28	2.24

Note:
[a] Estimate using Sutherland equations and total impervious surface composition data.
[b] Based on two-year, 24-hour runoff event.

There are multiple ways to implement urban stormwater BMPs that meet the retention depth volume reduction target, which will provide adequate channel protection and achieve the stream flashiness target (i.e., R-B Index value). A retention depth volume reduction target can guide the design of site-specific BMPs. However, by itself, a retention depth volume reduction target does not help determine the amount and type of BMPs that need to be implemented to meet water quality criteria at the watershed-scale, particularly in critical areas.

Urban stormwater BMP planning centers on achieving runoff volume reduction targets by managing the effect of directly-connected impervious cover across the watershed. Targeting efforts in southeast Michigan use the concept of green infrastructure area (GIA) to guide development of implementation strategies (SEMCOG 2016). The GIA is the amount of land needed to manage stormwater runoff from directly-connected impervious surfaces within a subwatershed, catchment, or critical area. This metric provides another indicator that can help guide local communities in their efforts to implement watershed scale strategies, which will achieve water quality criteria and other goals.

The utility of GIA as a metric is based on the findings of studies, which have examined the relationship between the level of urban stormwater BMP implementation and volume reduction (SEMCOG 2016, Tetra Tech 2012). Stormwater runoff volume reduction BMPs typically include methods such as infiltration, direct capture (e.g., green roofs, pervious pavement), and/or approaches that reduce the applicable curve number (e.g., grow zones, runoff disconnection, increased tree canopy). As illustrated in Figure B-4, information derived from desktop screening analyses can help guide project planning decisions regarding the suitability of different stormwater volume reduction strategies (e.g., grow zones versus infiltration facilities) or data needs (e.g., soil bore tests).

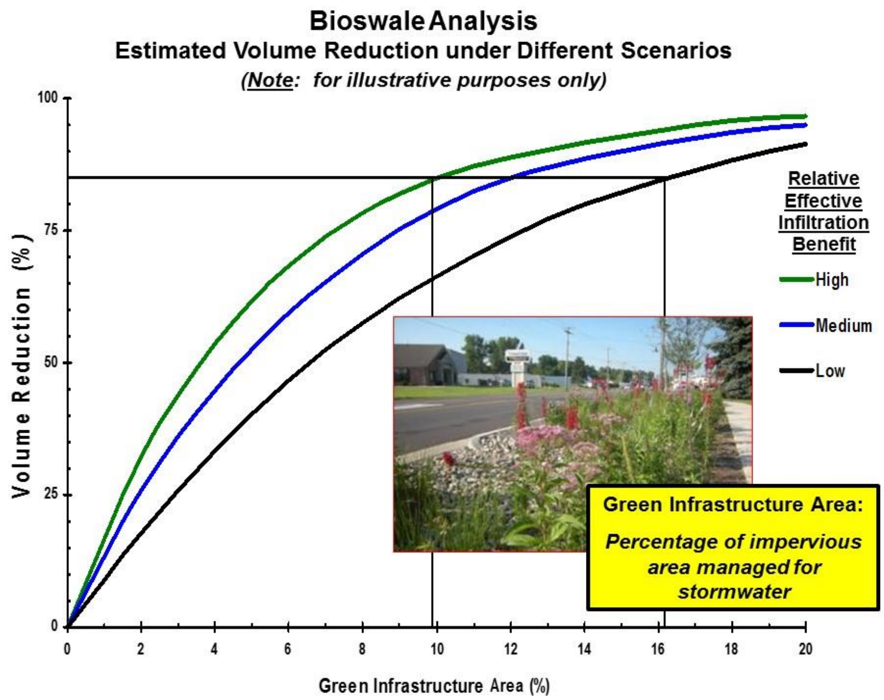


Figure B-4. Bioswale volume reduction estimate at different infiltration rates

It is important to understand that the GIA simply represents another indicator to help guide runoff volume reduction activities in critical areas within the Pebble Creek HUC-12 watershed. In some situations, for instance, the site-specific GIA needed to achieve the desired R-B Index value may be lower than the overall watershed average (e.g., high infiltration rate soils implying the need for less aggressive site BMPs). In other cases, a larger amount of green infrastructure area may be required to achieve a comparable in-stream outcome. This would include critical areas with low infiltration rates in pervious areas, which will require a greater level of volume reduction to achieve the same R-B Index target than those with higher infiltration rates.

In addition, the use of GIA can help steer follow-up on-site investigations, field inventory analyses, and drainage assessments in a direction that maximizes the use of limited resources needed to meet stormwater runoff volume reduction targets. This follow-up provides an understanding of watershed conditions and drainage networks, which is needed to implement those BMPs in critical areas that will be most effective in achieving water quality objectives.

Appendix C. Management Measures

Objective

Describe the system of measures that need to be implemented to achieve the load reductions estimated under Element B, as well as other watershed management objectives (e.g., habitat restoration and protection).

Intent

Pollutant loads vary even within land use types, so the plan should identify the critical areas in which those systems will be needed to implement the plan. These systems are designed to meet landowner/operator requirements and site-specific needs. The description should be detailed enough to guide implementation activities throughout the watershed and can be greatly enhanced by developing an accompanying map with priority areas and systems. Thought should also be given to the possible use of measures that protect important habitats (e.g. wetlands, vegetated buffers, and forest corridors) and other non-polluting areas of the watershed. In this way, waterbodies would not continue to degrade in some areas of the watershed while other parts are being restored.

Key Questions

- Are management systems needed to address each cause and source of pollution or impairment (or threat) listed, described, and prioritized?
- Are critical locations or high-priority sites for each management measure mapped or described?
- Are proposed management measures feasible?
- Are load reductions linked to each management system listed and quantified via reasonable estimates?

Discussion

Management Measures Prioritization.

Management measures needed to address each impairment cause and source in the Pebble Creek watershed focus on an integrated approach, which considers the range of factors associated with urban stormwater. This integrated approach follows Michigan's guidance that describes the preferred steps for urban stormwater management (MDEQ, 2017). These implementation action categories, ranked in order of importance, are the foundation of the strategy that will bring Pebble Creek back into attainment with water quality standards, which include:

1) Prevention/Minimization/Infiltration
2) Treatment
3) Mitigation
4) Conveyance
5) Storage

These urban stormwater implementation categories with example BMPs are summarized in Table C-1.

Table C-1. Urban stormwater implementation action categories with example BMPs

Practice	Implementation Action Category(s)	Description
Bioretention	1,2	Bioretention (or rain gardens) are shallow depressions filled with an engineered mix that supports vegetative growth. This BMP provides opportunity to store and infiltrate captured runoff and retain water for plant uptake.
Infiltration Basin	1,2	Infiltration basins are shallow depressions filled with grass or other natural vegetation that captures runoff from adjoining areas and allows it to infiltrate into the soil.
Street Planter	1,2	Street planters consist of concrete boxes filled with an engineered soil that supports vegetative growth. Beneath the soil is a gravel bed that provides additional storage as captured runoff infiltrates into the native soil below.
Porous Pavement	1,2	Porous pavement systems are excavated areas filled with gravel and paved over with a porous concrete or asphalt, or with modular porous blocks. Rainfall passes through the pavement into the gravel storage layer below where it can infiltrate into the native soil.
Green Roofs	1,2	Green roofs are bioretention systems placed on roof surfaces that capture and temporarily store rainwater in a soil medium. They consist of a layered system of roofing designed to support plant growth and retain water while preventing ponding.
Capture / Re-use	1	Capture/re-use (or rain harvesting) systems collect runoff collect runoff and conveys it to a storage tank where it can be used for non-potable water or on-site infiltration.
Grow Zones	1,2,3	Pervious areas converted to native vegetation with significant root systems that promote runoff infiltration, improve water quality, and reduce runoff volumes.
Wet Pond	2,5	This indicates a combination of permanent pool storage and extended detention storage above the permanent pool to provide additional water quality or rate control.
WQ Device	2	Structural BMP that varies in size and function, but utilizes some form of filtration, settling, or hydrodynamic separation to remove pollutants from overland or piped flow.
Constructed Wetland	2,3,5	Similar wet pond, differing mainly by the variety of water depths and associated vegetation. They require slightly more surface area than wet ponds for the same contributing drainage area. These are constructed BMPs, not natural wetlands.
Infiltration Trench	1,2,4	An excavated trench lined with filter fabric and backfilled with stone to allow a portion of the stormwater to infiltrate into subsurface soils while the remainder is conveyed.
Two-stage Ditch	4	A two-stage ditch converts a straightened channel into a more natural configuration, providing an effective means to convey increased flow volumes during heavy precipitation events while improving bank stability.
Dry Pond	5	Dry pond is a temporary storage structure designed solely to attenuate runoff peaks. This BMP has no permanent pool, relies only upon extended detention storage, is highly susceptible to sediment resuspension, and generally only useful for rate control.
Implementation Action Categories: 1) Prevention/Minimization/Infiltration; 2) Treatment; 3) Mitigation; 4) Conveyance; 5)Storage		

Michigan's urban stormwater BMP guidance places a priority on infiltrating, preventing, or minimizing the generation of stormwater. If no stormwater is generated, no further steps are needed—no treatment of contaminated stormwater prior to discharge, nor mitigation of downstream adverse effects (e.g., erosion, siltation). The concept of "low-impact design" (LID) is based on a similar approach to stormwater management, with the emphasis on minimization or prevention (SEMCOG 2008). When the generation of stormwater is inevitable, it should be managed with the "treatment train" approach, which is treating runoff using stormwater management practices placed in series, where each practice targets specific pollutants, and/or regulates a specific aspect of the runoff hydrology.

The priority measures listed below consider important aspects of stormwater management needed to achieve Michigan's bioassessment criteria for the Pebble Creek watershed (e.g., reduce volume, decrease peak flow rate, improve quality). In addition, the use and restoration of natural features (e.g., riparian areas such as the Rouge Green Corridor, wetlands, original topography, open spaces) are an integral part of the Pebble Creek WMP.

1. <u>Reduce the rate and amount of stormwater runoff from priority parking lots</u>. Parking lots offer the greatest opportunities for stormwater volume and rate reduction in the Pebble Creek watershed. A total of 516 parking lots have been digitized that comprise approximately 1,059 acres of paved surfaces (or over seven percent of the watershed). More than half of the inventoried parking lots are located in 16 critical areas within four priority catchments. An array of BMPs (e.g., green infrastructure) can be implemented within parking lots, which reduce stormwater runoff volume and decrease peak flow rates. Available practices can be applied either individually or as a treatment train (MDEQ 2017).

Opportunities exist on commercial and/or industrial parking lots adjacent to roads that could provide overall stormwater reduction benefits.

2. <u>Install integrated stormwater management systems along priority transportation corridors</u>. Roadways present both challenges and opportunities to reduce stormwater runoff. Transportation corridors with high traffic volumes represent relatively significant amounts of connected impervious cover (and thus generate larger quantities of stormwater runoff compared to roads less travelled). In addition, these same corridors typically include adjacent commercial properties with parking lot drainage inlets and pipes connected to the transportation storm sewer system. The situation is compounded by factors such as other utilities located along the road, safety design considerations, and installation costs for runoff reduction BMPs (both financial and construction-related disruptions). The connectivity of the transportation network to drainage systems, the proximity of large commercial parking lots to high traffic volume roadways, and the number of jurisdictions involved collectively warrants an integrated management approach to successfully reducing the rate and amount of stormwater runoff from these source areas.

The configuration within the transportation corridor affects the potential amount of stormwater runoff from roads that is connected and contributes to local receiving waters, as well as highlights BMP implementation opportunities (Table C-2). This can clearly be a major factor in prioritizing critical areas. For example, storm drains and inlet structures channel road runoff into the transportation storm sewer system, which ultimately discharge to local streams. While land use and road data provide an estimate of the amount of impervious cover by transportation agency (e.g., state, county, city), systematic information on road configuration is often lacking. In addition to improving estimates of each road jurisdiction's contribution to local stream conditions, knowledge of road configurations benefits subsequent drainage assessments that are part of project scoping. This includes not only surface level data (e.g., curb and gutter, ditch network, sheet flow to vegetated median or outside ROW border), but also storm sewer and outfall information.

Table C-2. General road configurations and example implementation opportunities

Area within ROW	General Configurations	Considerations or Example Implementation Opportunities
Driving Lanes	Number of lanes -- width per driving lane coupled with paved shoulder width(s).	Determines roadway impervious surface area to be managed.
Center Corridor	Center turn lane	Adds to roadway impervious surface area.
	Grassed median -- sheet flow to median	Grow zones to enhance the infiltration capacity of grassed pervious areas.
	Grassed median -- curb and gutter along shoulder	Curb cuts to bioretention cells that reduce flow to drainage inlets and storm sewer system.
	Concrete barrier and gutter	Infiltration compartments below drainage inlets to reduce flow to storm sewer system.
ROW Border	Vegetated zone -- sheet flow to ROW border	Grow zones to enhance infiltration capacity of grassed pervious areas.
	Vegetated zone -- curb and gutter along shoulder	Curb cuts to bioretention cells that reduce flow to drainage inlets and storm sewer system.
	Sloped embankment -- curb and gutter along shoulder	Bioretention cells incorporated into terraces along slope to reduce runoff to shoulder area.
	Vertical retaining wall and gutter	Infiltration compartments below drainage inlets to reduce flow to storm sewer system.

Adjacent land to the ROW also affects the amount of runoff transportation-related storm sewer systems contribute to area streams; again, a significant consideration for prioritizing critical areas. Provisions generally exist for local jurisdictions, commercial and / or industrial properties, or other private land owners to tap into the transportation-related stormwater conveyance system through a permit process. The transportation agency is ultimately responsible for discharges to state waters from its stormwater conveyance system. However, the presence of storm sewer tap-ins determines the relative effect any given road has on receiving waters (as well as corresponding reduction needs).

The transportation corridor configuration affects the potential amount of stormwater runoff from roads that contribute to receiving water concerns.

In cases where transportation agency options in the ROW are constrained, opportunities may exist on adjacent lands to implement green infrastructure that could provide overall stormwater volume reduction benefits. For example, incorporating bioretention into an adjacent parking lot would be more cost-effective than acquiring ROW for retention / detention.

3. Utilize asset management to implement cost-effective stormwater runoff reduction solutions. Infrastructure plays a vital role in determining how and where stormwater runoff is conveyed throughout the Pebble Creek HUC-12 watershed. Key assets to consider in implementing this management measure include stormwater inlets, drainage pipes, outfalls, road corridors, culverts/ bridges at stream crossings, and treatment systems (e.g., ponds, storage vaults, constructed wetlands, etc.). Recognizing needs and gaps, Michigan's Governor signed Executive Directive 2017-1, which created the Regional Asset Management Pilot; a first step toward developing an integrated system to help communities make more informed, strategic decisions and coordinated investments. SEMCOG was one of two regional planning agencies selected to execute the pilot.

Asset management information provides opportunities to improve the process of identifying cost-effective runoff reduction projects in critical areas.

An important part of the field inventory work in the Pebble Creek HUC-12 watershed evaluated asset management information included in GIS data layers obtained from Farmington Hills, Southfield, and Oakland County (both OCWRC and RCOC). The review of this information revealed both opportunities and gaps that could significantly improve the process of identifying runoff reduction projects in critical areas. For example, drainage pipe diameter data coupled with corresponding outfall locations provides a mechanism to estimate the relative magnitude that source areas could contribute to receiving waters. Examples include a 66-inch storm main tributary to upper Pebble Creek, several separate 60-inch storm mains tributary to Pernick Creek, and a 78-inch storm main tributary to the main Rouge. Pipe diameter data is also helpful in prioritizing potential parking lots for green infrastructure implementation.

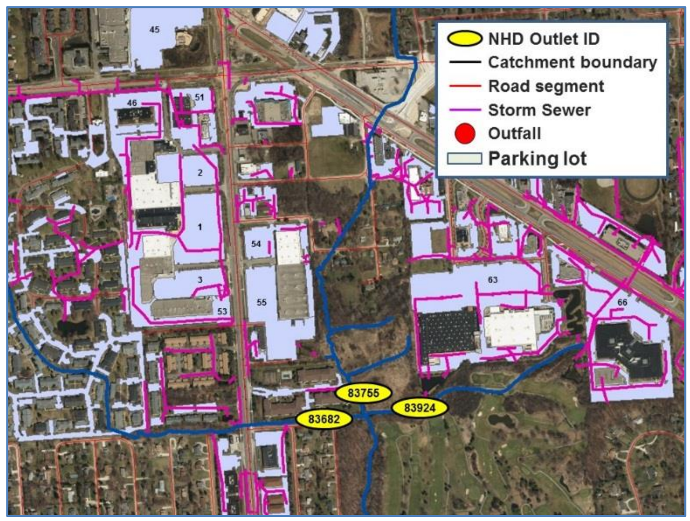
In addition, asset management information highlights opportunities for multi-jurisdictional coordination, as well as public/private partnership opportunities. Another example is a 42-inch storm main that appears to outlet under a parking lot adjacent to a high traffic volume roadway corridor nearly 1,000 feet from Pebble Creek. Further investigation could reveal that this pipe actually discharges to the transportation storm sewer (which was not part of the GIS data layers available as the field inventory was conducted). Finally, drainage complaint information (e.g., flooding associated with capacity issues) plus operations and maintenance (O&M) needs (e.g., detention pond problems identified in CIP plans) highlight other opportunities to utilize asset management to support cost-effective implementation of runoff reduction projects.

4. Protect riparian corridors and restore floodplain/wetland functions; promote use of natural areas. Native vegetation has significant root systems that promote runoff infiltration. The term *grow zone* was coined by Wayne County as they began converting large-scale park areas to native planting areas for improving water quality and habitat and reducing stormwater runoff volumes. Grow zones work best in adjacent roadside areas where roadway runoff is directed via sheet flow. Large open areas that have been traditionally managed as turf may be easily converted to native plant grow zones. These may include large highway medians and cloverleaf areas around on- and off-ramps for highways. Grow zones are also feasible in linear vegetated areas adjacent to roadway impervious surfaces.

Critical Areas.

Targeting critical areas for implementation projects in the Pebble Creek watershed recognizes that BMPs placed at these locations can help treat small areas, which produce disproportionate amounts of stormwater runoff and pollution. Critical areas are prioritized based on an analysis of pathways, delivery mechanisms, and connectivity to the stream system. The connectivity between the impervious surfaces (i.e., where stormwater is generated), the conveyance system (e.g., ditches, storm sewers, outfalls), and the receiving water (e.g., channel network) are major factors within the drainage assessment for analyzing runoff delivery mechanisms and evaluating stormwater management options.

Land use and impervious surface composition pointed to four high priority catchments in the Pebble Creek watershed (Table A-6, Figure A-7). An important aspect of moving from priority catchments to critical areas is the field inventory. Watershed observations enable critical areas to be identified and prioritized for BMP implementation. Asset management is also a major consideration for targeting specific project needs in critical areas. In addition to degraded water quality, biology, and stream habitat, problems that result from excessive stormwater runoff include flooding, threats to infrastructure, and loss of property due to bank erosion. Other assets that factor into the process include existing treatment.



Compiling field inventory information for the Pebble Creek HUC-12 watershed included an evaluation of GIS data layers and air photos coupled with windshield surveys in priority catchments.

The process of compiling field inventory information for the Pebble Creek HUC-12 watershed included an evaluation of available GIS data layers and air photos coupled with windshield surveys. Key NHD outlet locations were used as a starting point to identify critical areas within priority catchments. These outlet locations were based on a combination of reported channel condition problems and field observations. Stormwater asset information was incorporated into the field inventory analysis with a focus on outfalls larger than 30 inches in diameter that discharge to critical area NHD outlets.

The GIS transportation network data from SEMCOG enabled identification of high traffic volume roadway corridors tributary to critical area NHD locations. Parking lot boundaries delineated by MDEQ were also a vital component of the field inventory analysis. Summary tables were developed for each critical area describing NHD outlets, key stormwater assets, primary road corridors, and parking lots.

Critical areas in high priority catchment groups are summarized in Table C-3 and shown in Figure C-1 through Figure C-5. Recommended management measure categories are also included in Table C-3.

Table C-3. Management measure summary for Pebble Creek HUC-12 watershed critical areas

Catchment Group	Critical Area ID *(General Location)*		Management Measure Category				
			Parking Lot Runoff Reduction [a]	Transportation Corridor Runoff Reduction [b]	Asset Management Runoff Reduction [c]	Natural Area Protection / Restoration [d]	Other [e]
A *(Upper Pebble)*	00.a	Orchard Place	●●	●●	●●	○	○
	00.b	Orchard Lake/S. Pebble	◗	●●	◗	○	○
	00.c	Jacobs Drain	◗	●●	◗	○	○
	00.d	East Pebble Drain	●●	●●	●●	○	○
	00.e	Glen Oaks	◗	○	◗	◗	○
	00.f	13-Mile & Middlebelt	●●	◗	◗	○	○
B *(Lower Pebble/ Pernick)*	10.a	Coy Drain	◗	●●	◗	○	○
	10.b	Hollander Drain	●●	◗	◗	○	○
	11.a	Peterson Drain	●●	●●	●●	○	○
	11.b	W.B. Pernick	◗	●●	◗	○	○
	11.c	Pernick/Lockdale	●●	●●	●●	○	○
G *(Main Rouge)*	60.a	Jilbert Drain	◗	◗	●●	◗	○
	60.b	Telegraph/12-Mile area	●●	●●	●●	●●	○
	60.c	Dearborn Drain	●●	◗	●●	●●	○
	60.d	Telegraph/10-Mile area	●●	●●	●●	●●	○
	60.e	Telegraph/Denso area	●●	◗	◗	●●	○

Notes: ●● High priority BMP ◗ Medium priority BMP ○ Provide general benefit for load reduction

[a] Design and install runoff reduction BMPs (e.g., green infrastructure) in priority parking lots.
[b] Assess road configuration & adjacent properties, examine options & constraints, plan & implement projects.
[c] Examine stormwater/transportation asset data, identify opportunities, develop projects, and implement.
[d] Includes riparian & wetland restoration/protection projects.
[e] Other BMPs not part of runoff reduction measures (e.g., pet waste clean-up, septic system repair).

The following sections provide a short description of each priority catchment/critical area along with a summary of field inventory data (e.g., NHD outlet ID, key assets, number/size of parking lots, relevant note information). A project overview table is presented for each critical area to help guide project planning. Implementation strategies emphasize stormwater runoff reduction practices associated with parking lots and roadway corridors, with an initial focus on multi-jurisdictional asset management.

A cross-reference to NPS program goal(s) is also provided that reflects Michigan's statewide water resources program, which describes three general strategies intended to reduce or eliminate priority NPS pollutants and causes of impairment in urban areas (MDEQ 2015). These include:

- Hydrologic Alteration Cause Reduction (Goal II-2)
- Urban NPS Source Reduction (Goal II-4); and
- Transportation NPS Source Reduction (Goal II-5).

CATCHMENT 00: Upper Pebble

High stormwater flows in upper Pebble Creek through the Glen Oaks Golf Course require expensive measures to protect property at this location.

Upper Pebble Creek originates in West Bloomfield Township, flowing in a southeast direction where it enters the City of Farmington Hills at 14-Mile Road (Figure C-1). Upon crossing Orchard Lake Road, Pebble Creek is managed under the jurisdiction of Oakland County Water Resources Commission (OCWRC), where it is designated as Pebble Creek Drain. Prior to flowing into Glen Oaks Golf Course, Pebble Creek Drain is joined by two tributaries: Jacobs Drain from the north and an east branch just south of the Home Depot on Northwestern Highway. While most of this primary system consists of natural watercourses, several reaches have been modified over the years. Most of these projects have been performed to serve the primary objective of conveying storm water for a 10-year design storm (Wayne County RPO, 2001).

Six critical areas have been identified in Catchment 00, which are briefly described in the following paragraphs. Important summary information for these critical areas is provided in Table C-4.

Table C-4. Field inventory summary *(Catchment 00)*

Critical Area		NHD Outlet	Key Asset(s)	Major Road Corridor(s)	Parking Lots		Notes
ID	Size *(acres)*				Total Number	Size *(acres)*	
00.a	200	78845	450137 *(42" pipe)* 3835 *(culvert)*	Orchard Lake Road	12	38.3	Orchard Place
00.b	50	78845	3835 *(culvert)*	Orchard Lake Road	9	11.3	OLR/Harmon Oaks area
00.c	215	83755	4311 *(culvert)*	Orchard Lake Road	17	48.0	Jacobs Drain
00.d	180	83924	442916 *(66" pipe)*	Northwestern Highway	13	30.3	East Pebble Drain
00.e	10	83651	2330 *(culvert)*	13-Mile Road	1	3.1	Glen Oaks Golf Course
00.f	110	83651	2349 *(culvert)*	Northwestern Highway	17	33.9	NWH – Middlebelt area

Critical Area 00.a: The Orchard Place critical area, located in northcentral Farmington Hills, encompasses mostly commercial business properties along Orchard Lake Road. It includes the area stretching south from the intersection of 14-Mile Road and Northwestern Highway to the Pebble Creek stream crossing on Orchard Lake Road. This critical area drains about 200 acres; parking lots and paved roads comprise around 80 acres.

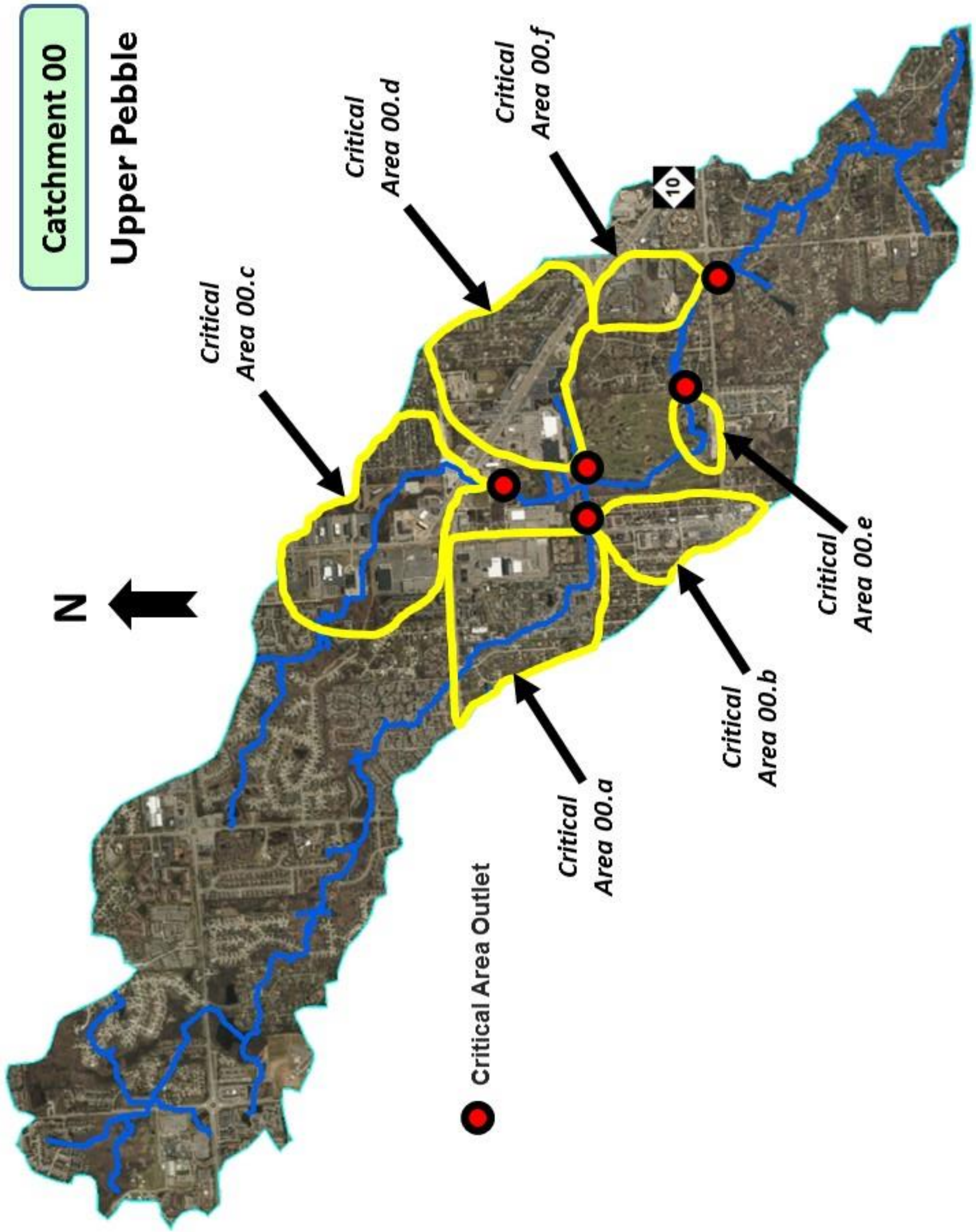


Figure C-1. Aerial view of catchment 00 critical areas *(00.a, 00.b, 00.c, 00.d, and 00.e)*

A major reason for the focus on asset management is because portions of critical area 00.a fall under three jurisdictions. In addition to Farmington Hills, Orchard Lake Road is part of the RCOC transportation network, while Pebble Creek Drain is under the jurisdiction of OCWRC. In part because of the dominance of commercial businesses within this critical area, Orchard Lake Road is a high traffic volume corridor; one that warrants an integrated approach to stormwater management. However, the multi-jurisdictional nature of both drainage and conveyance systems in this area indicates that the connections between stormwater and transportation assets should be examined first.

An example is shown in Figure C-2. A GIS data layer from the City of Farmington Hills provides information regarding the drainage system under the Orchard Place shopping complex. Included are pipe size (e.g., diameter, length), inlets, and outlet points. In conducting the field inventory, it was noted that a sizable portion of storm sewer system beneath the roughly 18 acres of parking space in this shopping complex drains to a 42-inch pipe relatively close to Orchard Lake Road. Though not completely clear from the GIS data layers available for the field inventory, it is reasonable to assume that this outlet is likely connected to the RCOC storm sewer system.

In summary, the asset management flow reduction measure in the Pebble Creek HUC-12 WMP is designed to examine key stormwater/transportation information, evaluate drainage connections, fill any data gaps, identify opportunities, develop projects, and implement.

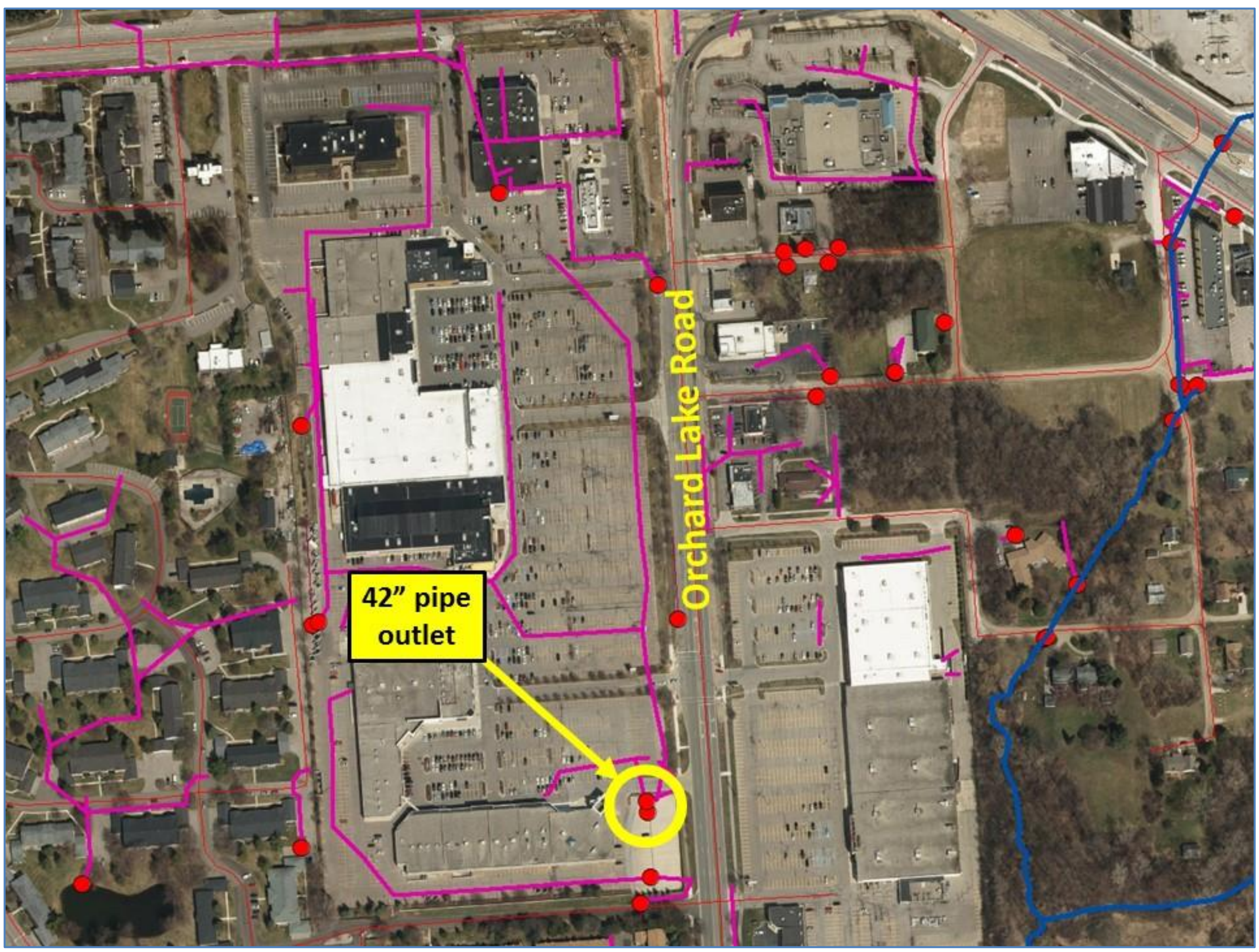
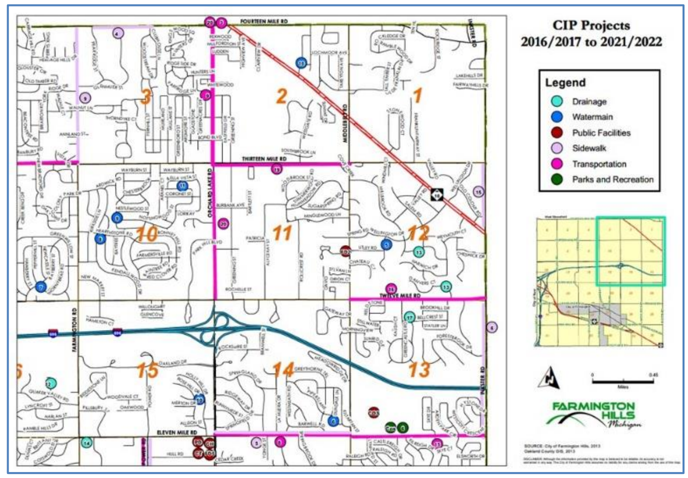


Figure C-2. Aerial view of critical area 00.a and need for asset management evaluation

Critical Area 00.b: This critical area centers on the Orchard Lake Road corridor west of Harmon Oaks Park. The area consists of a number of small commercial establishments along Orchard Lake Road from 13-Mile Road north to the Pebble Creek stream crossing. This critical area drains about 50 acres; parking lots and paved roads comprise around 20 acres.



Farmington Hills CIP offers an opportunity to pursue multi-objective projects including flow reduction along Orchard Lake Road.

The implementation strategy for this critical area is based on an integrated approach towards stormwater runoff reduction needs and benefits along the Orchard Lake Road corridor. Specifically, this approach assesses the road configuration including its relationship to adjacent properties, examines options along with constraints (e.g., location of utilities), works with key parties to plan projects, and follows through with implementation. The current Farmington Hills CIP identifies the road segment as a priority for improvements, which offers an opportunity to pursue multi-objective projects that could include flow reduction.

Critical Area 00.c: This critical area centers on the Orchard Lake Road corridor that is tributary to Jacobs Drain. The area is dominated by commercial businesses along Orchard Lake Road from Maple Road south to 14-Mile Road. This critical area drains about 215 acres; parking lots and paved roads comprise around 90 acres. The implementation strategy for this critical area is based on an integrated approach towards stormwater runoff reduction needs and benefits along the Orchard Lake Road corridor.

Critical Area 00.d: This critical area centers on the Northwestern Highway corridor that is tributary to East Pebble Creek Drain. This is area is dominated by commercial businesses along Northwestern Highway from just east of its intersection with 14-Mile and Orchard Lake Roads. This critical area drains about 180 acres; parking lots and paved roads comprise around 70 acres. Stormwater runoff from this critical area affecting the overall HUC-12 watershed is mostly channeled to East Pebble Drain, which is formed at the outlet of a 66-inch outfall. The field inventory indicated some parking lot runoff is directed to detention ponds that mitigate peak flow rates.

Critical Area 00.e: This critical area centers around the Glen Oaks Golf Course clubhouse and parking lot. This critical area drains about ten acres; parking lots and paved roads comprise around five acres. The implementation strategy for this critical area emphasizes stormwater runoff reduction practices associated with the clubhouse parking lot. The portion of the golf course itself within this critical area includes a storm water retention facility that holds up to seven million gallons for 24-hours during large storm event.

<u>Critical Area 00.f</u>: This critical area includes stormwater runoff from mixed-use land mostly west of Middlebelt Road between Northwestern Highway and 13-Mile Road. It drains about 110 acres; parking lots and paved roads comprise around 60 acres.

<u>Overview of Proposed Projects -- Catchment 00</u>: A general overview of proposed projects for critical areas in the Upper Pebble catchment is provided in Table C-5 based on current information, which considers relative priorities and the challenges associated with stormwater runoff reduction in urban settings. These proposed projects and evaluation needs are ones believed to be needed to restore and maintain water quality in the Pebble Creek HUC-12 watershed. This WMP is envisioned to be a document that is easily updated through modifications to these project overview tables as projects are implemented (or modified) and as new projects are developed.

The following paragraphs summarize highlights for several proposed projects including some rationale.

Projects 00.a1 and 00.d1 are short-term efforts (2019-21) that will review parking lot field inventory information for this critical area, identify one or more specific locations to implement green infrastructure practices, and design/build a runoff reduction project.

Projects 00.a3 and 00d3 are short-term multi-jurisdictional efforts (2019-21) involving Farmington Hills, Oakland County, and MDOT. These efforts will review stormwater and transportation assets directly connected to Pebble Creek, identify runoff reduction opportunities, prioritize options based on a cost/benefit analysis, and explore potential funding mechanisms. Recommended implementation projects will occur as part of Phase 2 (2022-28) through design/build activities.

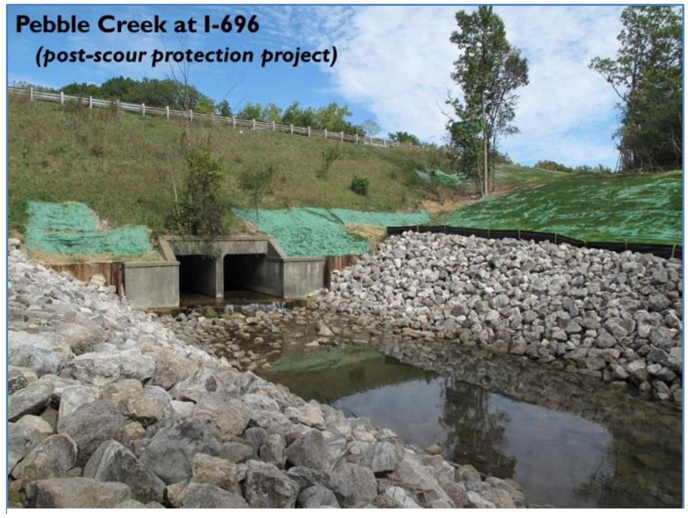
Project 00.*2 is a mid-term multi-jurisdictional effort (2022-28) involving Farmington Hills, Oakland County, and MDOT. This project will build on information from projects 00.a3 and 00.d3, which will review stormwater and transportation assets directly connected to Pebble Creek, identify runoff reduction opportunities, prioritize options based on a cost/benefit analysis, and explore potential funding mechanisms. Recommended implementation projects will occur as part of Phase 3 (2029-38) through design/build activities.

Table C-5. Project overview table *(Catchment 00)*

NPS Program Goal(s)	Management Measure(s)	Project #	Project Title *(Criteria G)*	Lead Organization *(Criteria D)*	Time Frame *(Criteria F)*	Estimated Cost *(Criteria D)*	Potential/Actual Funding Source *(Criteria D)*
Critical Area 00.a							
II-2 II-4	1	00.a1	Orchard Place Parking Area Flow Reduction *(Candidate lots identified in Appendix J)*	Farmington Hills	Phase 1 *(2019-21)*	$1,330K – $2,460K	§319,GLRI,Water Pollution Control Revolving Fund (WPCRF), public-private partnership(PPP), Corridor Improvement District (CID), tax credits
II-2 II-5	1,2	00.*2	Orchard Lake roadway corridor flow reduction	Farmington Hills, RCOC	Phase 2 *(2022-28)*		
II-2 II-5	1,2,3	00.a3	Orchard Lake asset management flow reduction	Farmington Hills, RCOC, OCWRC	Phase 1 *(2019-21)*		
Critical Area 00.b							
II-2 II-5	1,2	00.*2	Orchard Lake roadway corridor flow reduction	Farmington Hills, RCOC	Phase 2 *(2022-28)*	$360K – $670K	§319,GLRI, WPCRF,PPP, CID, tax credits
Critical Area 00.c							
II-2 II-5	1,2	00.*2	Orchard Lake roadway corridor flow reduction	West Bloomfield, RCOC	Phase 2 *(2022-28)*	$1,540K – $2,860K	§319,GLRI, WPCRF,PPP, CID, tax credits
II-2 II-5	1,2,3	00.c3	Jacobs Drain asset management flow reduction	West Bloomfield, RCOC,OCWRC	Phase 2 *(2022-28)*		
Critical Area 00.d							
II-2 II-4	1	00.d1	E. Pebble Drain Parking Area Flow Reduction *(Candidate lots identified in Appendix J)*	Farmington Hills, OCWRC	Phase 1 *(2019-21)*	$1,120K – $2,080K	§319,GLRI, WPCRF,PPP, CID, tax credits
II-2 II-5	1,2	00.d2	Northwestern Highway roadway corridor flow reduction	Farmington Hills, MDOT	Phase 3 *(2029-38)*		
II-2 II-5	1,2,3	00.d3	East Pebble Creek Drain asset management flow reduction	Farmington Hills, MDOT, OCWRC	Phase 2 *(2022-28)*		
Critical Area 00.e							
II-2 II-4	1	00.e1	Glen Oaks Parking Area Flow Reduction *(Lot 104)*	OCWRC, OCP&R	Phase 2 *(2022-28)*	$90K – $160K	§319,GLRI
Critical Area 00.f							
II-2 II-4	1	00.f1	13-Mile & Middlebelt Parking Area Flow Reduction *(Candidate lots identified in Appendix J)*	Farmington Hills	Phase 2 *(2022-28)*	$950K – $1,750K	§319,GLRI, WPCRF,PPP, CID, tax credits

<u>CATCHMENT 10</u>: Middle Pebble

The Middle Pebble Catchment includes the reach from Danvers Pond in Farmington Hills to its confluence with Pernick Creek at the Holy Sepulchre Cemetery in Southfield (Figure C-3). Pebble Creek, north of the confluence with Pernick Creek, can be characterized as a deep ravine. High stormwater flows through this reach can be very erosive, as evidenced by the severe scour problem that developed in Pebble Creek immediately downstream from the I-696. A scour protection project at this location was implemented by MDOT in 2017; cost was approximately $400,000.



High stormwater flows through middle Pebble Creek can be very erosive, necessitating expensive repairs to critical components of the Region's infrastructure.

The major tributary to Pebble Creek in the catchment is the North Branch. This tributary headwaters at Coy Drain, which is under the jurisdiction of OCWRC. Two critical areas have been identified in Catchment 10, which are briefly described in the following paragraphs. Important summary information for these critical areas is provided in Table C-6.

Table C-6. Field inventory summary *(Catchment 10)*

Critical Area		NHD Outlet	Key Asset(s)	Major Road Corridor(s)	Parking Lots		Notes
ID	Size *(acres)*				Total Number	Size *(acres)*	
10.a	120	81549	4355 *(culvert)*	Northwestern Highway	8	13.0	Coy Drain
10.b	65	83679	SC7113 *(42" pipe)*	11-Mile Road	6	22.8	Hollander Drain

<u>Critical Area 10.a</u>: This critical area centers on Coy Drain; a tributary to the north branch of Pebble Creek. It is located in Farmington Hills around the intersection of Northwestern Highway and 13-Mile Road. This critical area drains about 120 acres; parking lots and paved roads comprise around 30 acres.

<u>Critical Area 10.b</u>: The Hollander Drain, constructed in 1973, flows along Eleven Mile Road. The drain is maintained by the City of Southfield, but the culvert at Eleven Mile Road is under the jurisdiction of the Oakland County Road Commission (OCRC). The deep valley of Pebble Creek downstream of 11-Mile Road allows for a free outfall and the elimination of backwater conditions in this portion of the stream. This critical area drains about 65 acres; parking lots and paved roads comprise around 30 acres.

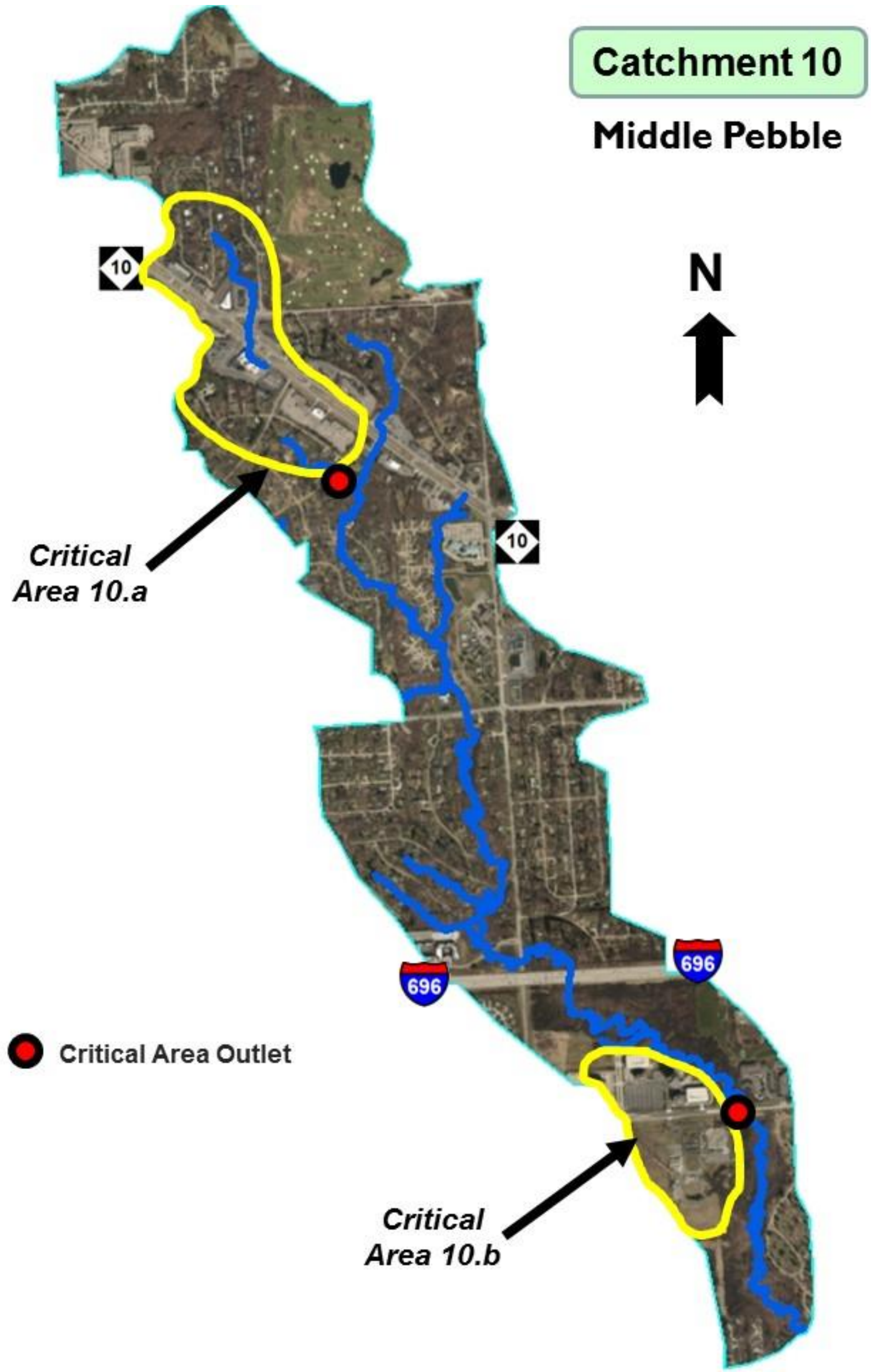


Figure C-3. Aerial view of catchment 10 critical areas *(10.a and 10.b)*

Overview of Proposed Projects -- Catchment 10: A general overview of proposed projects for critical areas in the Upper Pebble catchment is provided in Table C-7 based on current information, which considers relative priorities and the challenges associated with stormwater runoff reduction in urban settings. These proposed projects and evaluation needs are ones believed to be needed to restore and maintain water quality in the Pebble Creek HUC-12 watershed. This WMP is envisioned to be a document that is easily updated through modifications to these project overview tables as projects are implemented (or modified) and as new projects are developed.

The following paragraph summarizes highlights for several proposed projects including some rationale.

Projects 10.a1 and 10.b1 are mid-term efforts (2022-28) that will review parking lot field inventory information for this critical area, identify one or more specific locations to implement green infrastructure practices, and design/build a runoff reduction project.

Table C-7. Project overview table *(Catchment 10)*

NPS Program Goal(s)	Management Measure(s)	Project #	Project Title *(Criteria G)*	Lead Organization *(Criteria D)*	Time Frame *(Criteria F)*	Estimated Cost *(Criteria D)*	Potential/Actual Funding Source *(Criteria D)*
Critical Area 10.a							
II-2 II-4	1	10.a1	Coy Drain Parking Area Flow Reduction *(Candidate lots identified in Appendix J)*	Farmington Hills	Phase 2 *(2022-28)*	$500K – $920K	§319,GLRI, WPCRF,PPP, CID, tax credits
II-2 II-5	1,2	10.a2	Northwestern Highway roadway corridor flow reduction	Farmington Hills, MDOT	Phase 3 *(2029-38)*		
Critical Area 10.b							
II-2 II-4	1	10.b1	Hollander Drain Parking Area Flow Reduction *(Candidate lots identified in Appendix J)*	Southfield	Phase 2 *(2022-28)*	$540K – $1,000K	§319,GLRI, WPCRF,PPP, CID, tax credits
II-2 II-5	1,2	10.b2	11-Mile roadway corridor flow reduction	Southfield, RCOC	Phase 2 *(2022-28)*		

CATCHMENT 11: Lower Pebble / Pernick

Excessive stormwater runoff and flashy, highly erosive flows to Pernick Creek have resulted in extensive siltation in Lake Genesareth.

Lower Pebble Creek is a natural stream that flows into the Main Branch of the Rouge River north of Nine Mile Road (Figure C-4). Lower Pebble Creek extends north and northwesterly from its outlet at the Rouge through Southfield and into Farmington Hills (Catchment 10). Lower Pebble historically has been free of flooding but does experience surcharging within its floodplain.

Pernick Creek, a major tributary of Pebble Creek, flows southerly from its headwaters in the Franklin to join the Pebble Creek within the Holy Sepulchre Cemetery. Enclosed storm sewer systems north of I-696 converge and discharge into Pernick Creek. Urbanization has also increased flows, pollutants and loss of natural habitats. Erosion problems have been reported within the Holy Sepulchre property and continue upstream to where the creek parallels Northwestern Highway. Pernick Creek flows through Lake Genesareth, which discharges over a dam constructed in 1927, into Pebble Creek within the Holy Sepulchre Cemetery just north of 10 Mile Road. Due to upstream urban development, a large amount of sediment now exists in Lake Genesareth and in the surrounding floodplains.

Three critical areas have been identified in Catchment 11, which are briefly described in the following paragraphs. Important summary information for these critical areas is provided in Table C-8.

Table C-8. Field inventory summary *(Catchment 11)*

Critical Area		NHD Outlet	Key Asset(s)	Major Road Corridor(s)	Parking Lots		Notes
ID	Size *(acres)*				Total Number	Size *(acres)*	
11.a	320	79209	SC3882 *(60" pipe)*	Franklin Road 12-Mile Road Northwestern Highway	29	61.9	Peterson Drain
11.b	150	81656	SC8972 *(42" pipe)*	Franklin Road 12-Mile Road	31	48.9	West Branch Pernick
11.c	345	84998	SC6346 *(60" pipe)*	12-Mile Road	25	91.4	Lockdale Drain

Critical Area 11.a: Peterson Drain is one of three critical areas in the Pernick Creek catchment. Peterson Drain, under the jurisdiction of the OCWRC, was constructed in 1974. Peterson Drain flows along Franklin Road to its intersection with I-696 and eventually outlets into Pernick Creek. This critical area drains about 320 acres; parking lots and paved roads comprise around 120 acres.

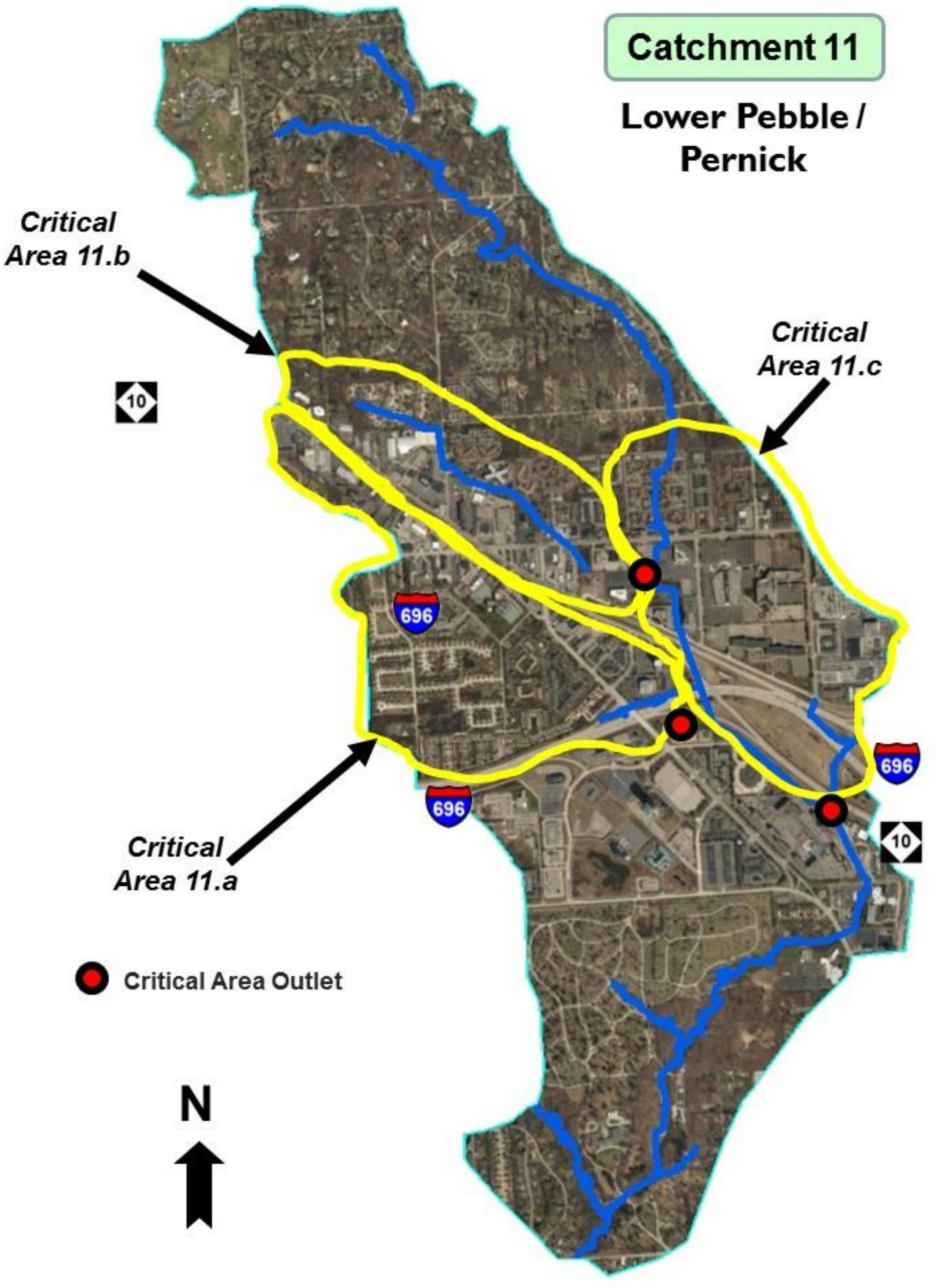
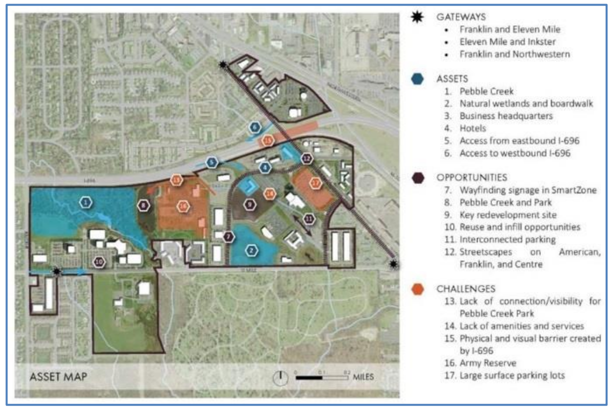


Figure C-4. Aerial view of catchment 11 critical areas *(11.a, 11.b, and 11.c)*

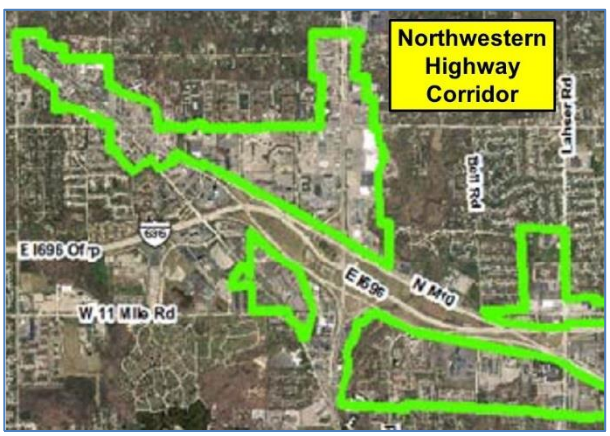
Potential projects for the Peterson Drain critical area stem, in part, from information presented in Southfield's most recent CMP (City of Southfield, 2016); one that recognizes the importance a physical design that encourages healthy lifestyles and attitudes. Southfield's CMP promotes good site design, naturalized approaches to landscaping, and the use of well-designed BMPs to reduce pollution. A portion of Peterson Drain lies within the Southfield Smart Zone; a priority sub-area identified in the City's CMP that is a 384-acre certified technology park and key development district.



The Southfield Smart Zone development district offers opportunities to pursue multi-objective projects including Peterson Drain flow reduction.

Critical Area 11.b: The West Branch Pernick Creek is under the jurisdiction of Southfield. The stream parallels Northwestern Highway on the north side starting just east of Inkster Road. After crossing Franklin Road, it enters a pipe shortly before crossing 12-Mile Road, briefly becomes an open channel south of 12-Mile, and eventually joins Pernick Creek through a 42-inch storm main east of Case Avenue. This critical area drains about 150 acres; parking lots and paved roads comprise around 75 acres.

Similar to Peterson Drain, potential projects for this critical area stem, in part, from information presented in Southfield's CMP. The West Branch Pernick Creek lies within the Southfield Smart Zone; a priority sub-area identified in the City's CMP that is a 384-acre certified technology park and key development district.



Southfield's Northwestern Highway Corridor CMP sub-area overlaps with several critical areas offering opportunities for partnerships and collaboration on multi-objective projects.

Critical Area 11.c: The Lockdale Road Drain is an enclosed storm sewer that runs from Twelve Mile Road to Northwestern Highway along Lockdale Road. The drain has been historically free of flooding. The drain discharges into the open channel system along and under Northwestern Highway via a storm water pumping station and ultimately flows into Pernick Creek. Moderate erosion problems have been reported along the open channel downstream of this drain. The Lockdale Road Drain is under the jurisdiction of the City of Southfield. This critical area drains about 345 acres; parking lots and paved roads comprise around 150 acres.

Overview of Proposed Projects -- Catchment 11: A general overview of proposed projects for critical areas in the Upper Pebble catchment is provided in Table C-9 based on current information, which considers relative priorities and the challenges associated with stormwater runoff reduction in urban settings. These proposed projects and evaluation needs are ones believed to be needed to restore and maintain water quality in the Pebble Creek HUC-12 watershed. This WMP is envisioned to be a document that is easily updated through modifications to these project overview tables as projects are implemented (or modified) and as new projects are developed.

The following paragraphs summarize highlights for several proposed projects including some rationale.

Projects 11.a1, 11.b1, and 11.c1 are short-term efforts (2019-21) that will review parking lot field inventory information for this critical area, identify one or more specific locations to implement green infrastructure practices, and design/build a runoff reduction project.

Projects 11.a3 and 11.c3 are short-term multi-jurisdictional efforts (2019-21) involving Southfield, Oakland County, and MDOT. These efforts will review stormwater and transportation assets directly connected to Peterson Drain and Pernick Creek, identify runoff reduction opportunities, prioritize options based on a cost/benefit analysis, and explore potential funding mechanisms. Recommended implementation projects will occur as part of Phase 2 (2022-28) through design/build activities.

Project 11.*2 is a mid-term multi-jurisdictional effort (2022-28) involving Southfield, Oakland County, and MDOT. In addition to Franklin Road, the upstream portion of Peterson Drain includes stormwater runoff from 12-Mile Road and Northwestern Highway. For this reason, the roadway corridor plan to be developed and implemented for project 11.*2 is intended to address concerns associated with Critical Areas 11.b and 11.c. This project will build on information from projects 11.a3 and 11.c3, which will review stormwater and transportation assets directly connected to Peterson Drain, identify runoff reduction opportunities, prioritize options based on a cost/benefit analysis, and explore potential funding mechanisms. Recommended implementation projects will occur as part of Phase 3 (2029-38) through design/build activities.

Table C-9. Project overview table *(Catchment 11)*

NPS Program Goal(s)	Management Measure(s)	Project #	Project Title *(Criteria G)*	Lead Organization *(Criteria D)*	Time Frame *(Criteria F)*	Estimated Cost *(Criteria D)*	Potential/Actual Funding Source *(Criteria D)*
Critical Area 11.a							
II-2 II-4	1	11.a1	Peterson Drain Parking Area Flow Reduction *(Candidate lots identified in Appendix J)*	Southfield	Phase 1 *(2019-21)*	$1,990K – $3,690K	§319,GLRI, WPCRF,PPP, CID, tax credits
II-2 II-5	1,2	11.*2	Northwestern Highway / 12-Mile / Franklin roadway corridor flow reduction	Southfield, RCOC, MDOT	Phase 1 *(2019-21)*		
II-2 II-5	1,2,3	11.a3	Peterson Drain asset management flow reduction	Southfield, OCWRC, RCOC, MDOT	Phase 3 *(2029-38)*		
Critical Area 11.b							
II-2 II-4	1	11.b1	W.B. Pernick Parking Area Flow Reduction *(Candidate lots identified in Appendix J)*	Southfield	Phase 1 *(2019-21)*	$1,270K – $2,360K	§319,GLRI, WPCRF,PPP, CID, tax credits
II-2 II-5	1,2	11.*2	Northwestern Highway / 12-Mile / Franklin roadway corridor flow reduction	Southfield, RCOC, MDOT	Phase 1 *(2019-21)*		
II-2 II-5	1,2,3	11.b3	W.B. Pernick asset management flow reduction	Southfield, RCOC, MDOT	Phase 3 *(2029-38)*		
Critical Area 11.c							
II-2 II-4	1	11.c1	Lockdale Drain Parking Area Flow Reduction *(Candidate lots identified in Appendix J)*	Southfield	Phase 1 *(2019-21)*	$2,570K – $4,760K	§319,GLRI, WPCRF,PPP, CID, tax credits
II-2 II-5	1,2	11.*2	Northwestern Highway / 12-Mile / Franklin roadway corridor flow reduction	Southfield, RCOC, MDOT	Phase 1 *(2019-21)*		
II-2 II-5	1,2,3	11.c3	Lockdale Drain asset management flow reduction	Southfield, RCOC, MDOT	Phase 3 *(2029-38)*		

CATCHMENT 60: Main Rouge / Telegraph

The Main Rouge drainage district extends north to south through the entire city: it is bordered by Eight Mile Road on the south, 12 ½ Mile Road on the north, Lahser Road on the east and Beech Road on the west (Figure C-5). Approximately 9.5 miles of the Main Branch of the Rouge River flows through this catchment. Land uses in this catchment consist of mostly single-family residential, but also include multiple-family residential, commercial, open space, parks and institutional usage. Approximately 4,500 acres of the Main Rouge drainage area are within the City of Southfield.

Generally, storm water detention is not provided in the single-family residential zones; and occasional and limited detention is provided in the commercial developments (Southfield, 2012). Historically, many areas along the Main Rouge River have experienced erosion problems. In some cases, the erosion is severe enough to expose utilities, building foundations and roadways. In addition, the Main Rouge River catchment experiences typical urban watershed problems, such as NPS pollution, illicit discharges, high flow variability, loss of habitat, bank scouring, and severe streambank erosion. The major drains within this catchment are the Jilbert Drain, the Gronkowski Drain, the Dearborn Drain, and the Beech Road / Nine Mile Road Drain.

Five critical areas have been identified in Catchment 60, which are briefly described in the following paragraphs. Important summary information for these critical areas is provided in Table C-10.

Table C-10. Field inventory summary *(Catchment 60)*

Critical Area		NHD Outlet	Key Asset(s)	Major Road Corridor(s)	Parking Lots		Notes
ID	Size *(acres)*				Total Number	Size *(acres)*	
60.a	260	82052	SC15974 *(60" pipe)*	12-Mile Road Lahser Road	7	20.5	Jilbert Drain
60.b	80	83512	SC5382 *(48" pipe)*	Telegraph Road	3	16.1	Tel-Twelve Mall storm main
60.c	95	83526	SC669 *(78" pipe)*	Civic Center Drive	8	38.3	Dearborn Drain
60.d	165	83534	SC3945/SC6878 *(2X - 36" pipe)*	Telegraph Road	22	41.0	Telegraph twin storm mains
60.e	105	83534	SC2572 *(36" pipe)*	Telegraph Road	15	31.1	Denso storm main

Critical Area 60.a: The Jilbert Drain is under the jurisdiction of both the City of Southfield and the OCWRC. It is a 54-inch diameter enclosed pipe located along Lahser Road (between Los Palmos and Potomac Roads) and an open channel west of Bell Road. The enclosed portion has a limited capacity downstream of Lahser Road (Southfield 2012). In addition to the capacity problems of the enclosed portion, the open portion of the Jilbert Drain is badly eroded, causing damage to residential yards and loss of trees. This critical area drains about 260 acres; parking lots and paved roads comprise around 70 acres.

Critical Area 60.b: This critical area encompasses mostly commercial business properties along the east side of Telegraph Road south of Twelve-Mile Road. It drains about 80 acres; parking lots and paved roads comprise around 70 acres.

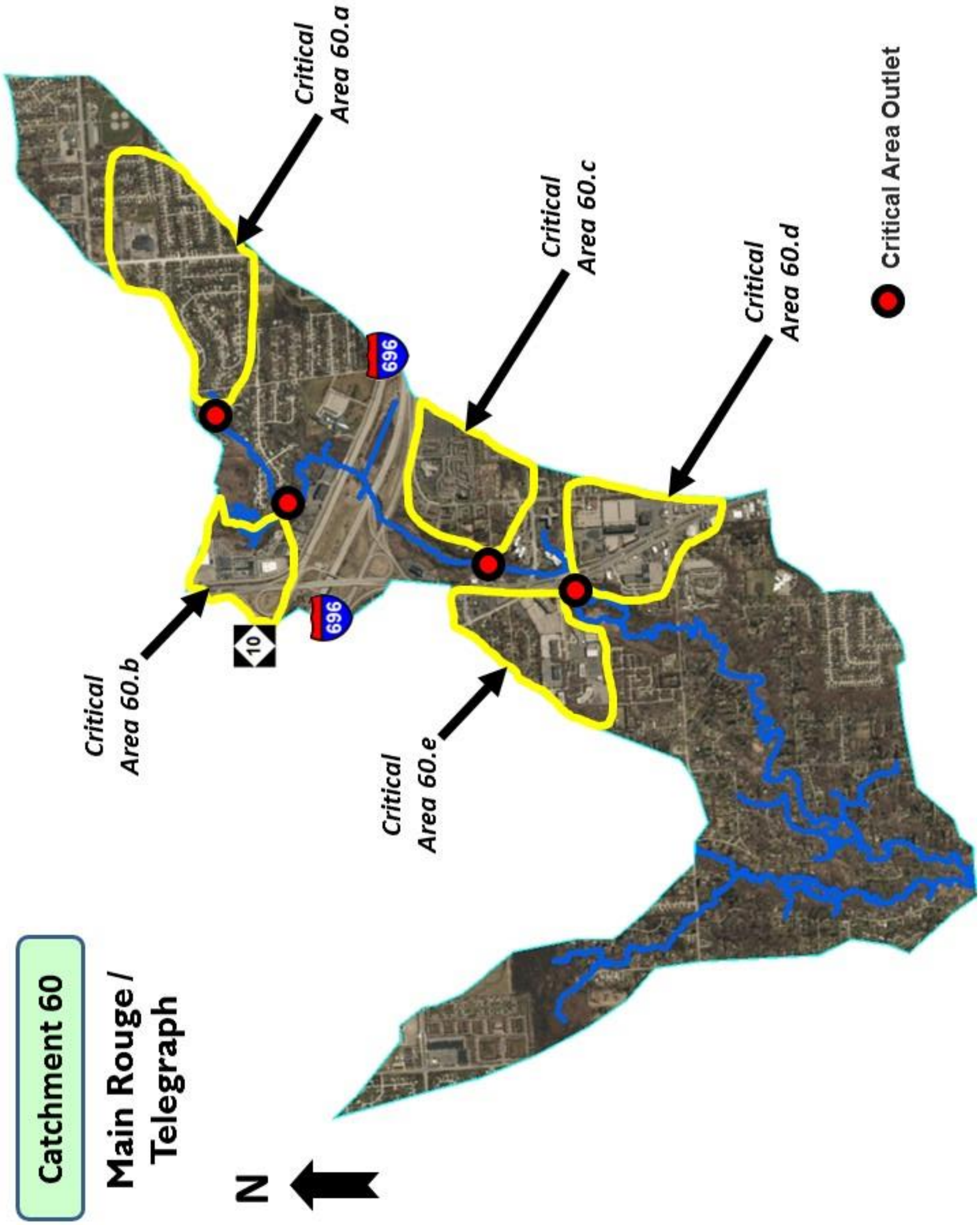


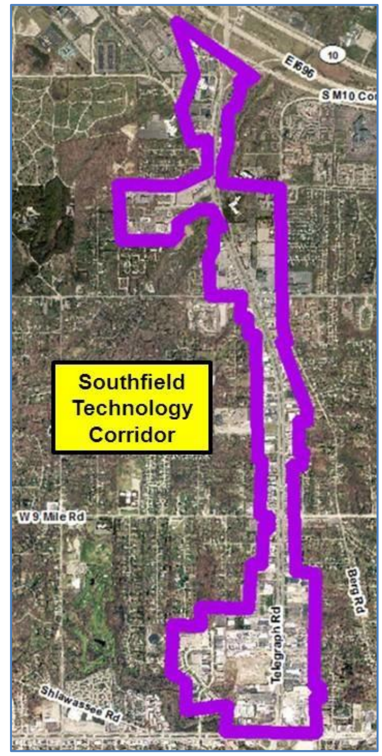
Figure C-5. Aerial view of catchment 60 critical areas *(60.a, 60.b, 60.c, and 60.d)*

Critical Area 60.c: The Dearborn Drain serves portions of Sections 20 and 21 in Southfield. The drain originates in Section 21 south of I-696, runs parallel to Civic Center Drive and discharges to the Main Rouge River in Section 20 via a 78-inch diameter outfall. The Dearborn Drain is under the jurisdiction of the City of Southfield. This critical area drains about 95 acres; parking lots and paved roads comprise around 55 acres.

Critical Area 60.d: This critical area encompasses mostly commercial business properties along both sides of Telegraph Road where it intersects 10-Mile Road. It area drains about 165 acres; parking lots and paved roads comprise around 70 acres.

Potential projects for this critical area stem, in part, from information presented in Southfield's CMP, which promotes good site design, naturalized approaches to landscaping, and the use of well-designed BMPs to reduce pollution. A portion of this critical area lies within Southfield's Technology Corridor; a priority sub-area identified in the City's CMP that is a key development district. For this reason, the implementation strategy also includes examining partnership and collaboration opportunities for multi-objective projects.

Critical Area 60.e: This critical area encompasses mostly commercial business properties along Denso Drive west of Telegraph Road. It area drains about 105 acres; parking lots and paved roads comprise around 50 acres. This critical area also lies within Southfield's Technology Corridor priority sub-area, which offers opportunities for partnerships and collaboration on multi-objective projects.



Southfield's Technology Corridor CMP sub-area overlaps with several critical areas offering opportunities for partnerships and collaboration on multi-objective projects.

<u>Overview of Proposed Projects -- Catchment 00</u>: A general overview of proposed projects for critical areas in the Upper Pebble catchment is provided in Table C-11 based on current information, which considers relative priorities and the challenges associated with stormwater runoff reduction in urban settings. These proposed projects and evaluation needs are ones believed to be needed to restore and maintain water quality in the Pebble Creek HUC-12 watershed. This WMP is envisioned to be a document that is easily updated through modifications to these project overview tables as projects are implemented (or modified) and as new projects are developed.

The following paragraphs summarize highlights for several proposed projects including some rationale.

Projects 60.b1 and 60.d1 are short-term efforts (2019-21) that will review parking lot field inventory information for this critical area, identify one or more specific locations to implement green infrastructure practices, and design/build a runoff reduction project.

Projects 60.c3 and 60d3 are short-term multi-jurisdictional efforts (2019-21) involving Southfield, Oakland County, and MDOT. These efforts will review stormwater and transportation assets directly connected to the Main Rouge, identify runoff reduction opportunities, prioritize options based on a cost/benefit analysis, and explore potential funding mechanisms. Recommended implementation projects will occur as part of Phase 2 (2022-28) through design/build activities.

Project 60.d2 is a mid-term multi-jurisdictional effort (2022-28) involving Southfield, Oakland County, and MDOT. This project will build on information from projects 60.c3 and 60.d3, which will review stormwater and transportation assets directly connected to the Main Rouge, identify runoff reduction opportunities, prioritize options based on a cost/benefit analysis, and explore potential funding mechanisms. Recommended implementation projects will occur as part of Phase 3 (2029-38) through design/build activities.

Table C-11. Project overview table *(Catchment 60)*

NPS Program Goal(s)	**Management Measure(s)**	**Project #**	**Project Title** *(Criteria G)*	**Lead Organization** *(Criteria D)*	**Time Frame** *(Criteria F)*	**Estimated Cost** *(Criteria D)*	**Potential/Actual Funding Source** *(Criteria D)*
Critical Area 60.a							
II-2 II-4	1	60.a1	Jilbert Drain Parking Area Flow Reduction *(Candidate lots identified in Appendix J)*	Southfield	Phase 3 *(2029-38)*	$1,150K – $2,130K	§319,GLRI, WPCRF,PPP, CID, tax credits
II-2 II-5	1,2,3	60.a3	Jilbert Drain asset management flow reduction	Southfield, OCWRC	Phase 2 *(2022-28)*		
Critical Area 60.b							
II-2 II-4	1	60.b1	Tel-Twelve Mall Parking Area Flow Reduction *(Candidate lots identified in Appendix J)*	Southfield	Phase 1 *(2019-21)*	$1,200K – $2,230K	§319,GLRI, WPCRF,PPP, CID, tax credits
II-2 II-5	1,2	60.b2	Northwestern Highway / 12-Mile / Telegraph roadway corridor flow reduction	Southfield, RCOC, MDOT	Phase 2 *(2022-28)*		
II-2 II-5	1,2,3	60.b3	Telegraph/12-Mile asset management flow reduction	Southfield, RCOC, MDOT	Phase 3 *(2029-38)*		
II-4	4	60.*4	Restore and enhance Rouge Green Corridor	Southfield	Phase 2 *(2022-28)*		
Critical Area 60.c							
II-2 II-4	1	60.c1	Dearborn Drain Parking Area Flow Reduction *(Candidate lots identified in Appendix J)*	Southfield	Phase 1 *(2019-21)*	$950K – $1,750K	§319,GLRI, WPCRF,PPP, CID, tax credits
II-2 II-5	1,2,3	60.c3	Dearborn Drain asset management flow reduction	Southfield	Phase 2 *(2022-28)*		
II-4	4	60.*4	Restore and enhance Rouge Green Corridor	Southfield	Phase 2 *(2022-28)*		
Critical Area 60.d							
II-2 II-4	1	60.d1	Telegraph / 10-Mile Parking Area Flow Reduction *(Candidate lots identified in Appendix J)*	Southfield	Phase 1 *(2019-21)*	$1,200K – $2,230K	§319,GLRI, WPCRF,PPP, CID, tax credits
II-2 II-5	1,2	60.d2	Telegraph / 10-Mile roadway corridor flow reduction	Southfield, RCOC, MDOT	Phase 2 *(2022-28)*		
II-2 II-5	1,2,3	60.d3	Telegraph / 10-Mile asset management flow reduction	Southfield, RCOC, MDOT	Phase 3 *(2029-38)*		
II-4	4	60.*4	Restore and enhance Rouge Green Corridor	Southfield	Phase 2 *(2022-28)*		
Critical Area 60.e							
II-2 II-4	1	60.e1	Denso Parking Area Flow Reduction *(Candidate lots identified in Appendix J)*	Southfield	Phase 2 *(2022-28)*	$850K – $1,580K	§319,GLRI, WPCRF,PPP, CID, tax credits
II-4	4	60.*4	Restore and enhance Rouge Green Corridor	Southfield	Phase 2 *(2022-28)*		

Appendix D. Technical and Financial Assistance

Objective

Describe the financial and technical assistance available to implement the plan (installation of management measures, long-term operation and maintenance, information/education activities, monitoring, program evaluation, etc.).

Intent

Document the organizations that might play a role in implementing the plan including the use of federal, state, local, and private resources that might be available to assist. Identify shortfalls between needs and available resources.

Key Questions

- What are the general types and amounts of technical and financial assistance needed to implement the management measures?
- What are the actual or potential sources of needed technical assistance?

Discussion

General type & amount of assistance needed to implement management measures.

A wide array of partners is available who can provide technical and financial assistance to address water quality concerns in the Pebble Creek HUC-12 watershed. Local agencies within the community include the Cities of Farmington Hills and Southfield, West Bloomfield Township, Oakland County (OCWRC, RCOC, Parks & Recreation), and MDOT. The type of technical expertise these local groups provide includes engineering design, operations & maintenance services, promoting I&E, and identifying / pursuing funding opportunities. The amount needed is described in several documents prepared by the local communities including the Farmington Hills CIP, Southfield's SWMP, and Southfield's CIP. Other technical resources include local recreational and resource interest groups (e.g., ARC, FOTR), local university groups (e.g., Lawrence Tech), and local residents.

Local communities provide technical & financial assistance to implement BMPs in the Pebble Creek watershed (e.g., Southfield's work on the Carpenter Lake Nature Preserve project).

Financial assistance needs can vary depending on a variety of local factors (soil type, site suitability, access issues, location relative to utilities, etc.). USEPA has developed a National Stormwater Calculator (SWC) that provides planning level estimates of capital and maintenance costs, which allows comparison of various green infrastructure implementation strategies for the Pebble Creek HUC-12 watershed.

The SWC uses the Storm Water Management Model as its computational engine to estimate stormwater runoff based on hourly rainfall data over a 20-year period, the volume retention benefit for a mix of green infrastructure practices, and relative costs. The SWC factors in the cost implications of construction feasibility and site suitability. The cost of green infrastructure BMPs are adjusted based on regional differences. For the Pebble Creek HUC-12 watershed, the Detroit Bureau of Labor Statistics Region was used to determine cost adjustment factors.

Although seven green infrastructure practices are available in the SWC, only four were considered suitable in developing cost estimates for the Pebble Creek WMP. These include bioretention (e.g., rain gardens), porous pavement, infiltration basins, and street planters. The other three BMPs available in the SWC include disconnection (e.g., downspouts), rain harvesting (e.g., rain barrels, cisterns), and green roofs.

The cost estimates are based on achieving the green infrastructure area target of ten percent (e.g., the amount of land needed to manage stormwater runoff from directly-connected impervious surfaces). Each BMP used the reasonable set of design parameters assigned by the SWC (which could be modified for use in developing site-specific projects). Unit area costs are summarized in Table D-1.

Table D-1. Cost estimates for green infrastructure BMPs considered in Pebble Creek

Green Infrastructure BMP	**Capital Cost Estimate** *(per green infrastructure area acre)*	**Maintenance Cost Estimate** *(per green infrastructure area acre)*
Bioretention	$225,900 - $303,560	$3,030 - $73,240
Porous Pavement	$353,530 - $424,280	$2,530 - $13,800
Infiltration Basin	$169,770 - $235,440	$2,190 - $79,380
Street Planters	$466,230 - $638,350	$2,020 - $48,000

Possible/potential sources of financial assistance needed to implement management measures.

Financial resources needed to address problems associated with urban stormwater runoff problems tend to exceed the amount of funding available to local communities. Rating criteria, like ones described in Appendix C for critical areas (Table C-3), allow examination and comparison of preliminary implementation strategies. Considerations in developing these criteria include proximity to receiving waters, project feasibility (physical suitability of the site, access, easements, location relative to utilities, etc.), costs, design/build time, and maintenance requirements.

Proposed projects will continually be reviewed to reflect stakeholder input, funding options, community benefits, and scheduling realities. Funding is one of the greatest challenges facing local communities. For example, urban watersheds present some unique challenges with respect to determining whether proposed projects are grant eligible; projects and activities required by an MS4 permit are not eligible for §319 grant funding. However, other funding sources may be available that can be used to support stormwater management programs or finance individual projects (e.g., taxes / general funds, fees, stormwater utilities, credits / incentive programs, bonds, loans, and public – private partnerships).

In addition, use of multi-objective technical and financial assistance options can be explored. Some possibilities are described in Southfield's CMP including Property Assessed Clean Energy (PACE) projects or use of the Corridor Improvement Authority Public Act to reserve tax increment revenues for funding capital improvements (Southfield, 2016).

The 1-800-Law-Firm project is unique in that it is the first PACE financed project in the State of Michigan and also the first to combine multiple renewable energy technologies.


Solar Panels with Car Charging Station

The total project, completed in 2014, is a 150kW combined system which includes solar rooftop, a sun deck on the roof which will provide perfect views of the four (4), 1 kW Wind Turbines on the roof, solar carports in the parking lot which will include 2 Electric Vehicle (EV) charging stations. The project also includes energy optimization measures within the building itself and LED lighting in the parking lot.

(from Southfield CMP)

Appendix E. Information and Education

Objective

Describe the education and outreach activities or actions that will be used to implement the plan.

Intent

These activities may support the adoption and long-term operation and maintenance of management practices and support stakeholder involvement efforts.

Key Questions

- Are information, education, and public participation goals and objectives for the management program listed?
- Is an overall strategy or plan for the public information, education, and participation component provided?

Discussion

Information, education, and public participation goals and objectives for the management program.

Information and education (I&E) is vital to the success of the Pebble Creek WMP. The I&E strategy targets specific audiences to educate them regarding their potential impacts on water quality. The importance of this component is recognized by the local community as evidenced by activities that supported development of the Rouge River Watershed Management Plan. This plan was created by the Alliance of Rouge Communities (ARC) Public Involvement and Education (PIE) Committee, a group of communities, citizens, counties, non-profit organizations and stewardship groups that meet quarterly to implement and review public education activities in the Rouge River Watershed.

Over the years, the ARC and their partners have engaged the public through workshops, hands-on river stewardship activities, newsletters, public service announcements and focused initiatives such as fertilizer reduction campaigns and grow zone projects. The resultant strategy based on the ARC experience, which forms the basis for I&E in the Pebble Creek WMP, outlines major educational opportunities and actions needed to successfully maintain and improve water quality in the watershed to meet the following objectives:

- Educate and engage local elected officials and staff about issues affecting the Rouge River Watershed and the Alliance of Rouge Communities.
- Establish and support a baseline of information available to watershed audiences to assist members in meeting permit requirements and leveraging resources.
- Expand resources by working with other organizations, institutions, businesses and stewardship groups.
- Develop a strategy to educate and involve people who live in the watershed about issues that affect them and how they affect the watershed.
- Continue to educate the public and look for opportunities to enhance programming.
- Evaluate the effectiveness of public education efforts and programs.
- Investigate other funding opportunities specific to public involvement and public education.

Future educational activities regarding the watershed management plan and related activities continue to be monitored and assessed by the ARC's Public Involvement and Education Committee.

An overall strategy or plan for the public information, education, and participation component.

This WMP includes a priority recommendation to develop an updated I&E strategy for the Pebble Creek watershed that includes the following:

- Focus on priority pollutants and sources
- Focus on critical areas
- Identify target audiences
- Identify key messages and delivery mechanisms
- Develop evaluation criteria

Appendix F. Outcome-based Schedule

Objective

Describe the schedule for implementing the management measures outlined in the watershed plan.

Intent

The schedule should reflect the milestones developed for Element G. Implementation should begin as soon as possible. Conducting baseline monitoring and outreach for implementing water quality projects are examples of activities that can start right away. It is important that schedules not be “shelved” for lack of funds or program authorities; instead they should identify steps towards obtaining needed funds as feasible.

Key Questions

- Is an overarching timeline or schedule showing projected dates for developing and implementing each management measure presented?
- Does the timeline or schedule indicates the actions, steps, or accomplishments associated with implementing the management measures in the plan?
- Does the timeline or schedule follows a logical sequence for implementing the management measures?
- Does the timeline or schedule list short-term (up to 3 years) and long-term (up to 10 or more years) implementation steps?

Discussion

Overarching timeline or schedule showing projected dates for implementing each measure.

The Pebble Creek WMP is envisioned to occur over a 20-year period; staging activities in three phases (short-, mid-, and long-term) that will ultimately achieve needed stormwater runoff and bacteria reductions (Table F-1). Short-term efforts (Year 1-3) include implementing practices in critical areas so that stormwater runoff volumes, peak flow rates, and high-risk bacteria sources to Pebble Creek and the Main Rouge are significantly reduced. Mid-term efforts (Year 4-10) are intended to build on the results of short-term implementation activities. This includes evaluating the success of Phase 1 projects installed (success rate, BMP performance, stormwater runoff and pollutant reductions realized, actual costs, etc.). Long-term efforts (Year 11-20) are those implementation activities that result in the Main Rouge and Pebble Creek in full attainment with Michigan’s WQS. This approach is consistent with the direction currently pursued by Southfield, Farmington Hills, Oakland County, and West Bloomfield Township, in conjunction with other local partners (e.g., SEMCOG, ARC, FOTR).

Table F-1. Schedule overview for Pebble Creek HUC-12 watershed critical areas

Project #	Management Measure(s)	Project Type	Lead Organization(s)	Time Frame		
				Phase 1 *(2019-21)*	Phase 2 *(2022-28)*	Phase 3 *(2029-38)*
Catchment 00						
00.a1	1	Parking Area Flow Reduction	Farmington Hills	●●		
00.*2	1,2	Roadway corridor flow reduction	FH, RCOC		●●	
00.a3	1,2,3	Asset management flow reduction	FH, RCOC, OCWRC	●●		
00.c3	1,2,3	Asset management flow reduction	FH, RCOC, OCWRC, MDOT		●●	
00.d1	1	Parking Area Flow Reduction	Farmington Hills	●●		
00.d2	1,2	Roadway corridor flow reduction	FH, RCOC, MDOT			●●
00.d3	1,2,3	Asset management flow reduction	FH, RCOC, MDOT		●●	
00.e1	1	Parking Area Flow Reduction	OCPR		●●	
00.f1	1	Parking Area Flow Reduction	Farmington Hills		●●	
Catchment 10						
10.a1	1	Parking Area Flow Reduction	Farmington Hills		●●	
10.a2	1,2	Roadway corridor flow reduction	FH, RCOC, MDOT			●●
10.b1	1	Parking Area Flow Reduction	Southfield		●●	
10.b2	1,2	Roadway corridor flow reduction	Southfield, RCOC		●●	
Catchment 11						
11.a1	1	Parking Area Flow Reduction	Southfield	●●		
11.*2	1,2	Roadway corridor flow reduction	Southfield, RCOC, MDOT		●●	
11.a3	1,2,3	Asset management flow reduction	Southfield, RCOC, MDOT	●●		
11.b1	1	Parking Area Flow Reduction	Southfield	●●		
11.b3	1,2,3	Asset management flow reduction	Southfield, RCOC, MDOT		●●	
11.c1	1	Parking Area Flow Reduction	Southfield	●●		
11.c3	1,2,3	Asset management flow reduction	Southfield, RCOC, MDOT	●●		
Catchment 60						
60.a1	1	Parking Area Flow Reduction	Southfield			●●
60.a3	1,2,3	Asset management flow reduction	Southfield, OCWRC		●●	
60.b1	1	Parking Area Flow Reduction	Southfield	●●		
60.b2	1,2	Roadway corridor flow reduction	Southfield, RCOC, MDOT			●●
60.b3	1,2,3	Asset management flow reduction	Southfield, RCOC, MDOT		●●	
60.*4	4	Rouge Green Corridor restoration	Southfield		●●	
60.c1	1	Parking Area Flow Reduction	Southfield	●●		
60.c3	1,2,3	Asset management flow reduction	Southfield		●●	
60.d1	1	Parking Area Flow Reduction	Southfield	●●		
60.d2	1,2	Roadway corridor flow reduction	Southfield, RCOC, MDOT			●●
60.d3	1,2,3	Asset management flow reduction	Southfield, RCOC, MDOT		●●	
60.e1	1	Parking Area Flow Reduction	Southfield		●●	

Timeline or schedule indicates actions, steps, or accomplishments associated with each measure.

Priority actions will occur over a 20-year period with staging activities in three phases (short-, mid-, and long-term) that will ultimately achieve needed stormwater runoff and bacteria reductions (Table G-1).

Two overarching actions include information / education (I&E) and monitoring. A general awareness of water quality issues exists within the community; the result of strong local involvement in development of the River Rouge WMP. For that reason, general watershed education activities are not specifically included in the 20-year schedule. Instead, I&E is incorporated into each priority action and varies as plan implementation moves through each phase. Basic I&E activities associated with individual priority actions during each phase include:

- ✓ *Phase 1*: awareness, 1-on-1 meetings, leverage cost-share opportunities
- ✓ *Phase 2*: 1-on-1 meetings, cost-share, follow-up & monitor Phase 1 results
- ✓ *Phase 3*: 1-on-1 meetings, cost-share, follow-up, monitor results, evaluate plan effectiveness, adjust as needed

Short-term implementation activities also include monitoring in the Pebble Creek HUC-12 watershed conducted by ARC and FOTR. Related to both monitoring and I&E, the short-term schedule includes exploring efforts to initiate a locally led monitoring program. In addition to elevating public awareness, information from this program would provide a technical basis to guide locally generated, cost-effective solutions.

Timeline or schedule follows a logical sequence for implementing management measures.

An important aspect of watershed plan development is to identify and encourage activities, which can be quickly implemented and produce measurable results. As with many watersheds of comparable size, the Pebble Creek HUC-12 watershed faces a variety of implementation challenges. These challenges include how to assess the benefits of a variety of stormwater management strategies, how to select the optimal combination of BMPs that minimize costs, how to be consistent with community goals and characteristics, and how to meet reductions needed to achieve WQS.

To meet these challenges and ensure the watershed implementation plan is outcome-based with local support, it is important to evaluate water quality, pollutant source, and drainage system information at a level detailed enough to recommend specific actions and responsibilities (Figure F-1). This is accomplished in stages building on the field inventory and critical areas for BMP implementation. The plan is re-evaluated through each phase of implementation and program adjustments made as new information becomes available.

A generalized outcome-based strategic planning framework is presented in Figure F-1. The primary focus is to take advantage of local input to address stormwater runoff reduction needs by continuing to identify implementation opportunities in each phase that will produce measurable results. In general, the outcome-based strategic planning framework begins with Stage 1, which represents the watershed-scale scoping at the start of each phase. Available Pebble Creek HUC-12 watershed information is reviewed during each phase of plan implementation as it relates to each of USEPA's Nine Minimum Elements. Data gaps are identified, and priorities established at the watershed scale.

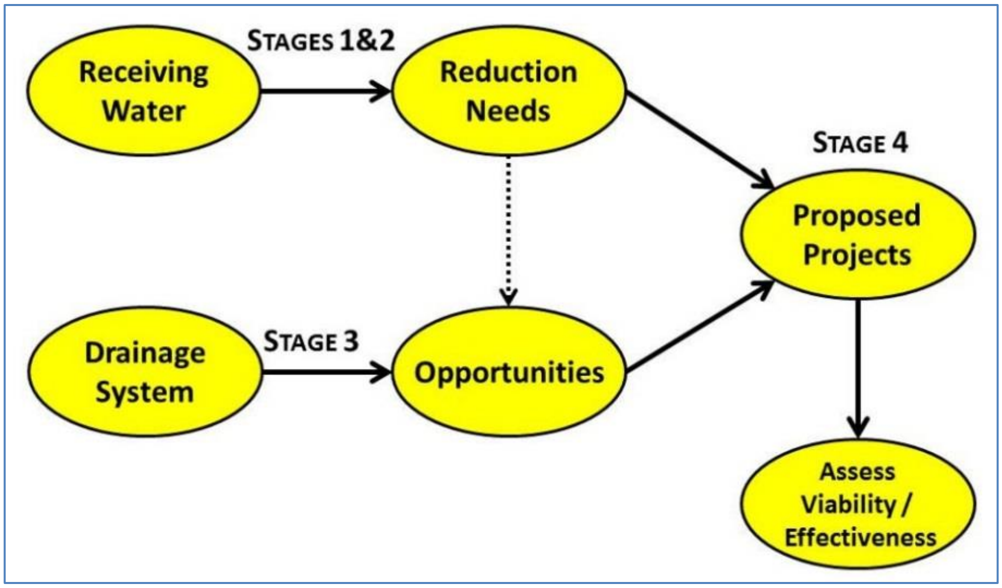


Figure F-1. Outcome-based strategic watershed planning framework

Based on reduction needs information (Figure F-1, Plan Element B), Stage 2 targets critical areas for development of source-specific strategies to address NPS pollution described in "Michigan's Nonpoint Source Program Plan" (MDEQ, 2012). The emphasis in Stage 3 is on examining and prioritizing locations within critical areas where water quality improvements are needed and opportunities to implement BMPs are available. Stage 4 examines potential projects in "areas of opportunity". Key factors are considered including feasibility, constraints, potential effectiveness, and associated benefits.

Again the framework shown in Figure F-1 is intended to be iterative through each phase of the implementation plan using adaptive management; one that continues while better data are collected, results analyzed, and the watershed plan enhanced. In this way, implementation activities can focus on a cumulative reduction in loadings under a plan that is flexible enough to allow for refinement, reflects the current state of knowledge about the system, and is able to incorporate new, innovative techniques.

The relationship between the nine minimum elements and outcome-based scheduling is summarized in Table F-2. This table briefly describes key activities based on priority concerns and implementation opportunities as the adaptive management process iteratively cycles from watershed scale to progressively smaller geographic areas in each stage. This framework provides a platform to identify, prioritize, and target implementation projects in ways that improve the cost-effectiveness of limited resources to address water quality problems in the Pebble Creek HUC-12 watershed. The approach recognizes the dynamic nature of program implementation. As efforts continue, detailed work may reveal additional gaps or discover methods to improve the process.

Timeline or schedule lists short-term (up to 3 years) and long-term implementation steps.

Priority actions will occur over a 20-year period with staging activities in three phases (short-, mid-, and long-term) that will ultimately achieve needed stormwater runoff and bacteria reductions (Table G-1). Short-term efforts (Year 1-3) include implementing practices in critical areas so that stormwater runoff volumes, peak flow rates, and high-risk bacteria sources to Pebble Creek and the Main Rouge are significantly reduced. Mid-term efforts (Year 4-10) are intended to build on the results of short-term implementation activities. This includes evaluating the success of Phase 1 projects installed (success rate, BMP performance, stormwater runoff and pollutant reductions realized, actual costs, etc.). Long-term efforts (Year 11-20) are those implementation activities that result in the Main Rouge and Pebble Creek in full attainment with Michigan's WQS.

Table F-2. Relationship between nine minimum elements and strategic planning stages

<table>
<tr><th rowspan="2" colspan="2">Plan Element</th><th colspan="4">Stage</th></tr>
<tr><th>1 (Subwatershed)</th><th>2 (Critical Areas)</th><th>3 (Opportunities)</th><th>4 (Projects)</th></tr>
<tr><td>A</td><td>Causes and sources</td><td>Summarize available characterization information and identify targeted catchments</td><td>Update & re-assess field inventory to evaluate critical area status. Revise list of critical areas, if needed.</td><td>Evaluate field inventory of critical source areas in the context of potential BMPs that could be implemented</td><td rowspan="3">On-the-ground feasibility assessment of suitable BMPs in critical source areas and develop pre-design information for incorporation into detailed implementation plan</td></tr>
<tr><td>B</td><td>Estimated loading and reductions</td><td>Summarize TMDL information and prioritize catchments based on estimated reduction needs</td><td>Confirm and/or revise source loads and reduction needs based on refined survey information</td><td rowspan="2">Develop opportunity-specific load reduction estimates for potential BMPs located in critical areas guided by field inventory information</td></tr>
<tr><td>C</td><td>Management measures</td><td>Summarize existing applicable BMP information</td><td>Summarize GIS targeting tool data in targeted catchments</td></tr>
<tr><td>D</td><td>Technical and financial assistance</td><td>Review range of assistance programs</td><td>Identify needs to address specific concerns in critical areas</td><td>Engage transportation agencies, businesses, and other technical resources</td><td>Leverage cost-share or partnership opportunities</td></tr>
<tr><td>E</td><td>Information and education</td><td>Review ongoing watershed I&E activities</td><td>1-on-1 meetings with critical area stakeholders</td><td>Work with critical area stakeholders to identify funding & partnership options</td><td>Incorporate lessons learned into farmer-to-farmer network</td></tr>
<tr><td>F</td><td>Schedule</td><td>Review overall framework</td><td>Revise, as needed, based on updated critical area information</td><td>Incorporate planned opportunities info</td><td>Update project implementation info</td></tr>
<tr><td>G</td><td>Measurable milestones</td><td>Review interim milestones from watershed perspective</td><td>1-on-1 meetings with critical area stakeholders relative to milestones</td><td>Engage transportation agencies, businesses, and other technical resources relative to milestones</td><td>Ensure projects are consistent with milestones or vice versa.</td></tr>
<tr><td>H</td><td>Progress benchmarks</td><td>Evaluate monitoring data relative to benchmarks</td><td>1-on-1 meetings with critical area stakeholders relative to benchmarks</td><td>Engage transportation agencies, businesses, and other technical resources relative to benchmarks</td><td>Ensure projects are consistent with benchmarks or vice versa.</td></tr>
<tr><td>I</td><td>Monitoring</td><td>Update assessment. Identify data gaps & prioritize monitoring needs</td><td>Evaluate monitoring data & determine if critical area revisions needed</td><td>Engage transportation agencies, businesses, and other technical resources in monitoring efforts</td><td>Incorporate project info into BMP effectiveness monitoring</td></tr>
</table>

Appendix G. Interim Milestones

Objective

The WMP should include interim, measurable implementation milestones to measure progress in implementing the management measures.

Intent

These milestones are used to track implementation of the management measures (i.e., whether they are being implemented according to the schedule outlined in Element F). In contrast Element H identifies criteria to measure the effectiveness of the management measures (e.g., documenting improvements in water quality). For example, the watershed plan may include milestones for a pollutant found at high levels in a stream. An initial milestone may be a 30% reduction in measured stream concentrations of that pollutant after 5 years and management measures have been implemented in 50 percent of the critical areas. The next milestone could be a 40% reduction after 7 years, when management measures have been implemented in 80 percent of the critical areas. The final goal, which achieves the water quality standard for that stream, may require a 50% reduction in 10 years. Having these waypoints lets the watershed managers know if they are on track to meet their goals, or if they need to re-evaluate treatment levels or timelines.

Key Questions

- Is a list of reasonable and attainable interim milestones, benchmarks, phases, or steps for implementing each group of management measures or control actions provided?
- Is a logical sequence of dates for achieving the milestones, benchmarks, phases, or steps listed?

Discussion

List of interim milestones, benchmarks, phases, or steps for implementing management measures.

Interim milestones associated with each priority activity are shown in Table G-1. In addition, interim milestones in this plan emphasize: 1) documenting BMP implementation through each phase, as described under "BMP Effectiveness Monitoring"; 2) ensure that information collected will guide effective critical area planning in subsequent phases using adaptive management, as described under "Progress Benchmarks" and "Monitoring"; and 3) other implementation activities will be identified and conducted simultaneously to meet goals/objectives of other programs being implemented in the Pebble Creek HUC-12 watershed (e.g., MS4 permit requirements, CMP/CIP activities)

A logical sequence of dates for achieving the milestones, benchmarks, phases, or steps.

Priority actions will occur over a 20-year period with staging activities in three phases (short-, mid-, and long-term) that will ultimately achieve needed stormwater runoff and bacteria reductions (Table G-1). Short-term efforts (Year 1-3) include implementing practices in critical areas so that stormwater runoff volumes, peak flow rates, and high-risk bacteria sources are significantly reduced. Mid-term efforts (Year 4-10) are intended to build on the results of short-term implementation activities. This includes evaluating the success of Phase 1 projects installed. Long-term efforts (Year 11-20) are those implementation activities that result in full attainment with Michigan's WQS.

The 16 critical areas identified in the Pebble Creek HUC-12 WMP total just under 2,500 acres. Although this is only 17 percent of the entire watershed, the estimated connected impervious surface area is 1,045 acres (or 47 percent of the estimated total connected impervious cover). The reduction target from these critical areas is about 6.5 million cubic feet from each priority catchment expressed as stormwater volumes based on a two-year, 24-hour storm event.

Table G-1. Interim milestones

Activity	Source Reduced	Critical Area(s)	Timeframe [a]	Interim Milestones
Priority Parking Lot Stormwater Reduction	Parking Lots	00.a, 00.d, 11.a, 11.b, 11.c, 60.b, 60.c, 60.d	Phase 1	0.31 million-ft^3 stormwater runoff volume reduction from connected parking lots
		all of above plus 00.e, 00.f, 10.a, 10.b, 60.e	Phase 2	1.25 million-ft^3 stormwater runoff volume reduction from connected parking lots
		all of above plus 60.a	Phase 3	2.50 million-ft^3 stormwater runoff volume reduction from connected parking lots
Priority Road Corridor Stormwater Reduction	Parking Lots, Road Corridors	00.a, 11.a	Phase 1	0.31 million-ft^3 stormwater runoff volume reduction from either DCIC in road ROW or on parking lots connected to transportation storm sewer system
		all of above plus 00.b, 11.b, 11.c	Phase 2	0.93 million-ft^3 stormwater runoff volume reduction from either DCIC in road ROW or on parking lots connected to transportation storm sewer system
		all of above plus 00.c, 00.d, 10.a, 60.b, 60.d	Phase 3	1.86 million-ft^3 stormwater runoff volume reduction from either DCIC in road ROW or on parking lots connected to transportation storm sewer system
Stormwater Asset Management	Parking Lots, Road Corridors	00.a, 11.a, 11.c	Phase 1	0.31 million-ft^3 stormwater runoff volume reduction from either DCIC in road ROW or on parking lots connected to transportation storm sewer system
		all of above plus 00.c, 00.d, 11.b 60.a, 60.b, 60.c, 60.d	Phase 2	0.93 million-ft^3 stormwater runoff volume reduction from either DCIC in road ROW or on parking lots connected to transportation storm sewer system
		all of above	Phase 3	1.86 million-ft^3 stormwater runoff volume reduction from either DCIC in road ROW or on parking lots connected to transportation storm sewer system
Natural Area Protection / Restoration	---	60.b, 60.d, 60.e	Phase 1	Restore native vegetation, stabilize eroding tributary gullies, and enhance floodwater storage on 3,000 feet of the Main Rouge
			Phase 2	Restore native vegetation, stabilize eroding tributary gullies, and enhance floodwater storage on 10,000 feet of the Main Rouge
			Phase 3	Restore native vegetation, stabilize eroding tributary gullies, and enhance floodwater storage on 20,000 feet of the Main Rouge
Other	Pet Waste, Failing Septics		Phase 1	Eliminate 15 percent of leaking septic systems in residential areas of Pebble Creek HUC-12 watershed
			Phase 2	Eliminate 50 percent of leaking septic systems in residential areas of Pebble Creek HUC-12 watershed
			Phase 3	Eliminate 100 percent of leaking septic systems in residential areas of Pebble Creek HUC-12 watershed

Notes: [a] Phase 1 (2019-21); Phase 2 (2022-28); Phase 3 (2029-38)

Appendix H. Progress Indicators

Objective

As projects are implemented in the watershed, describe water quality benchmarks to track progress towards attaining water quality standards.

Intent

The *criteria* in Element H are the benchmarks or waypoints to measure against through monitoring. These interim targets can be direct measurements (e.g., fecal coliform concentrations, nutrient loads) or indirect indicators of load reduction (e.g., number of beach closings). These criteria should reflect the time it takes to implement pollution control measures, as well as the time needed for water quality indicators to respond, including lag times (e.g., water quality response as it is influenced by ground water sources that move slowly or the extra time it takes for sediment bound pollutants to break down, degrade or otherwise be isolated from the water column). Indicate how it will be determined whether the WMP needs to be revised if interim targets are not met. These revisions could involve changing management practices, updating the loading analyses, and reassessing the time it takes for pollution concentrations to respond to treatment.

Key Questions

- Are criteria identified that are linked to the causes and/or sources of impairments/threats (if applicable)?
- Do the listed criteria include numeric and/or narrative water quality criteria, instream physical habitat assessment criteria, or other criteria linked to the causes/sources?
- Do listed criteria include those incorporated into any TMDLs developed or to be developed for waterbodies addressed by the plan?
- Are provisions for reviewing progress and revising the plan or any TMDLs involved addressed?

Discussion

Criteria linked to causes and/or sources of impairments/threats.

Implementation activities for the Pebble Creek HUC-12 watershed are staged in three phases using outcome-based strategic planning and an adaptive management approach. Phase 2 (mid-term) and Phase 3 (long-term) are designed to build on results from the preceding phase. In order to guide actual plan implementation through each phase using adaptive management, water quality benchmarks are identified to track progress towards attaining water quality standards.

Criteria include numeric and/or narrative WQC, or other criteria linked to causes/sources (e.g. habitat).

These interim targets (Table H-1) are intended to reflect the time it takes to implement management practices, as well as the time needed for water quality indicators to respond. In addition to water column indicators (e.g., TSS and *E. coli*), habitat and macroinvertebrate community evaluations conducted by MDEQ are included. These indicators will likely to respond more quickly to watershed changes that result from implementation of management practices.

Criteria include those incorporated into any TMDLs developed for waterbodies addressed by the plan.

Criteria described under TMDL Reasonable Assurance *(see approved River Rouge TMDLs for Biota and E. coli)*.

Provisions for reviewing progress and revising the plan or any TMDLs involved are addressed.

Provisions described under TMDL Reasonable Assurance *(see approved River Rouge TMDLs for Biota and E. coli)*.

Table H-1. Progress benchmark summary

Indicator	Assessment Procedure	Implementation Phase	Progress Benchmark
Total Suspended Solids *(mg/L)*	Annual wet-weather average	Phase 1 (Year 1 – 3)	109 [a]
		Phase 2 (Year 4 – 8)	97 [a]
		Phase 3 (Year 9 – 15)	80 [a]
E. coli *(#/100 mL)*	30-day geometric mean (May 1 – October 31)	Phase 1 (Year 1 – 3)	616 [a]
		Phase 2 (Year 4 – 8)	413 [a]
		Phase 3 (Year 9 – 15)	130 [a]
Habitat Rating [a]	MDEQ Procedure 51	Phase 1 (Year 1 – 3)	Marginal [a]
		Phase 2 (Year 4 – 8)	Good [a]
		Phase 3 (Year 9 – 15)	Good [a]
Macroinvertebrate Community Rating [a]	MDEQ Procedure 51	Phase 1 (Year 1 – 3)	Acceptable (-4 to 4) [a]
		Phase 2 (Year 4 – 8)	Acceptable (trending up) [a]
		Phase 3 (Year 9 – 15)	Acceptable (trending up) [a]
Channel Condition [b]	Bank Erosion Hazard Index (BEHI)	Phase 1 (Year 1 – 3)	High (trending down) [b]
		Phase 2 (Year 4 – 8)	Moderate (trending down) [b]
		Phase 3 (Year 9 – 15)	Moderate (trending down) [b]
Notes: [a] all stations [b] MDEQ Benchmark BEHI sites			

Appendix I. Monitoring

Objective

Describe the monitoring component to determine whether progress is being made toward attaining or maintaining the applicable water quality standards for the waterbody(ies) addressed in the plan.

Intent

The monitoring program should be fully integrated with the established schedule and interim milestone criteria. The monitoring component should be designed to assess progress in achieving loading reductions and meeting water quality standards. Watershed-scale monitoring can be used to measure the effects of multiple programs, projects, and trends over time. In-stream monitoring does not have to be conducted for individual BMPs unless that type of monitoring is particularly relevant to the project.

Key Questions

- Is an approach for establishing monitoring sites or procedures and relevant parameters provided, or procedures for acquiring and reviewing other monitoring data described?
- Are non-environmental monitoring parameters are clearly identified and provide a reasonable yardstick for measuring progress toward implementing the management measures?
- Do monitoring parameters include the criteria identified in Element H and the milestones, benchmarks, phases, or steps cited in Element G?
- Is frequency of monitoring or schedules for assessing implementation progress included?
- Are parties responsible for implementing the monitoring program listed?
- Are Quality Assurance Project Plans for water quality parameters referenced or cited?

Discussion

Monitoring is an important part of the Pebble Creek HUC-12 WMP. Ambient monitoring provides the data used to assess progress towards achieving needed load reductions and meeting water quality standards. BMP effectiveness monitoring provides information that determines if planned activities are, in fact, being implemented and if management practices are performing as expected. Together, information from both components guides actual plan implementation through each phase using adaptive management. Under adaptive management, the Pebble Creek HUC-12 WMP is designed to use an iterative approach; one that continues while better data are collected, results analyzed, and the watershed plan enhanced.

Measurements and evaluation are important parts of planning because they can indicate whether or not efforts are successful and provide feedback for improving project implementation as new information is gathered. In continuing to work collaboratively toward goals for the watershed, the ARC and associated communities recognize the importance of long-term environmental monitoring (i.e. water quality, quantity and biological monitoring) and performance monitoring programs that will occur by maintaining active subwatershed advisory groups, ARC committees and collaborative reporting. This monitoring approach will facilitate effective evaluation in order to determine where the ARC and communities should focus resources as they progress toward meeting the goals and objectives.

The evaluation of this WMP will be accomplished through the Rouge River five-year monitoring plan updated in 2012. Monitoring and measuring progress in the watershed is two-tiered including both ARC collaborative approaches and community-specific approaches. The ARC has established a series of committees that are responsible for facilitating and overseeing priority projects on an annual basis. For example, the Technical Committee is responsible for overseeing development and implementation of a quantitative program that monitors progress and effectiveness on a watershed and subwatershed level. A general monitoring strategy summary is provided in Table I-1.

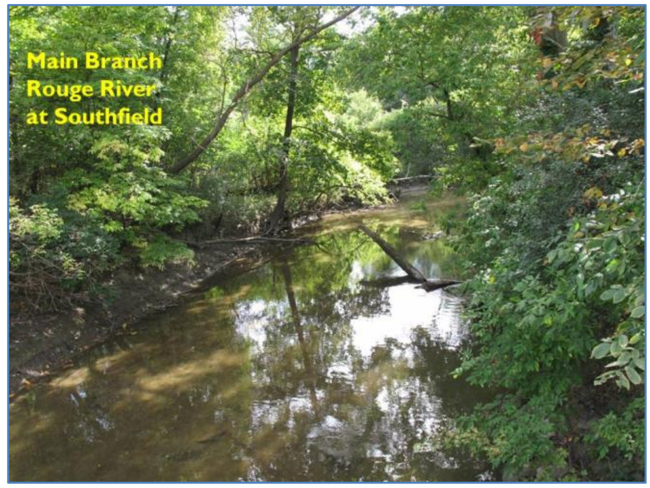
A component of ARC's long-term monitoring plan includes partnering with Friends of the Rouge (FOTR). The FOTR benthic monitoring program is a cost-effective way to monitor improvements in water quality by monitoring the diversity of aquatic life in the river and its tributaries. Recently, ARC partnered with local communities in 2017 to conduct TMDL monitoring across the entire Rouge River drainage. Sampling activities focused on E. coli, TSS, and flow. This monitoring effort included several sites in the Pebble Creek HUC-12 watershed, some of which were sampled in 2012. Funding for this project was supported by a Stormwater, Asset Management, and Wastewater (SAW) grant. Details are described in a Quality Assurance Project Plan (QAPP) prepared for ARC (ECT 2017).

Table I-1. General monitoring strategy summary

Parameter	Frequency	Progress Benchmark
Total Suspended Solids *(mg/L)*	Phase 1 (Annual) Phase 2 (5-year interval) Phase 3 (5-year interval)	Alliance of Rouge Communities
E. coli *(#/100 mL)*	Phase 1 (Annual) Phase 2 (5-year interval) Phase 3 (5-year interval)	Alliance of Rouge Communities Michigan DEQ
Habitat Rating [a]	Phase 2 (5-year interval) Phase 3 (5-year interval)	Michigan DEQ
Macroinvertebrate Community Rating [a]	Phase 2 (5-year interval) Phase 3 (5-year interval)	Friends of the Rouge Michigan DEQ
Channel Condition (BEHI) [b]	Phase 2 (5-year interval) Phase 3 (5-year interval)	Michigan DEQ

Notes: [a] all stations
[b] MDEQ Benchmark BEHI sites

Appendix J. Support Material

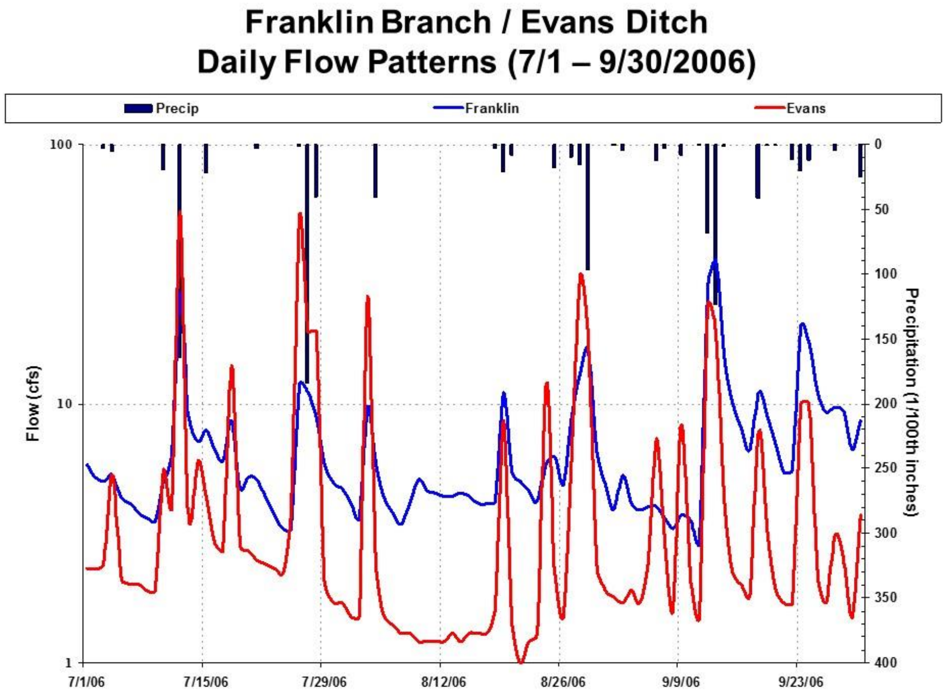


Existing Conditions Related to Flashiness. The Rouge River Watershed Management Plan describes an array of water quality concerns in the upper mainstem. Poor macroinvertebrate communities have been observed at several sites in the drainage through monitoring by both the Friends of the Rouge and MDEQ (ARC 2012, Goodwin 2009). The Rouge River Plan noted that the Pebble subwatershed is becoming increasingly developed and that unmitigated stormwater inputs could continue to degrade the stream as a result of higher peak flows and decreased base flow. In addition, Pebble Creek is tributary to a section of the Main Rouge River, which has degraded stream habitat due to excessive flow instability and accompanying bank erosion.

Although streamflow records for Pebble Creek are not available, several locations monitored by USGS in the upper Main Rouge watershed (one at Birmingham, one at Southfield, one on Franklin Branch, & one on Evans Ditch) can be used to develop flow estimates for this subwatershed (Table J-1). Figure J-1 depicts daily average flows for these sites. Estimated R-B Index values in Pebble Creek currently exceed 0.5 based on these estimates.

Table J-1. Hydrologic statistics for upper Rouge watershed

Location	Area *(mi.^{2})*	Gage ID	Flow *(inches)*			Metric Comparison	
			2-year Peak	*Annual Average*	*FDC $_{1\text{-}day}$*	*T_{Qmean}*	*R-B Flashiness*
Main Rouge at Farmington	33.3	04166000	0.473	9.2	0.313	*29.8%*	*0.391*
Franklin Branch	17.0	04166040	0.632	13.2	0.284	*33.3%*	*0.374*
Main Rouge at Southfield	87.9	04166100	0.558	11.0	0.409	*27.0%*	*0.467*
Evans Ditch	9.49	04166200	1.923	12.8	0.701	*20.0%*	*0.859*
Upper Rouge at Farmington	17.5	04166300	0.676	11.9	0.409	*26.6%*	*0.418*



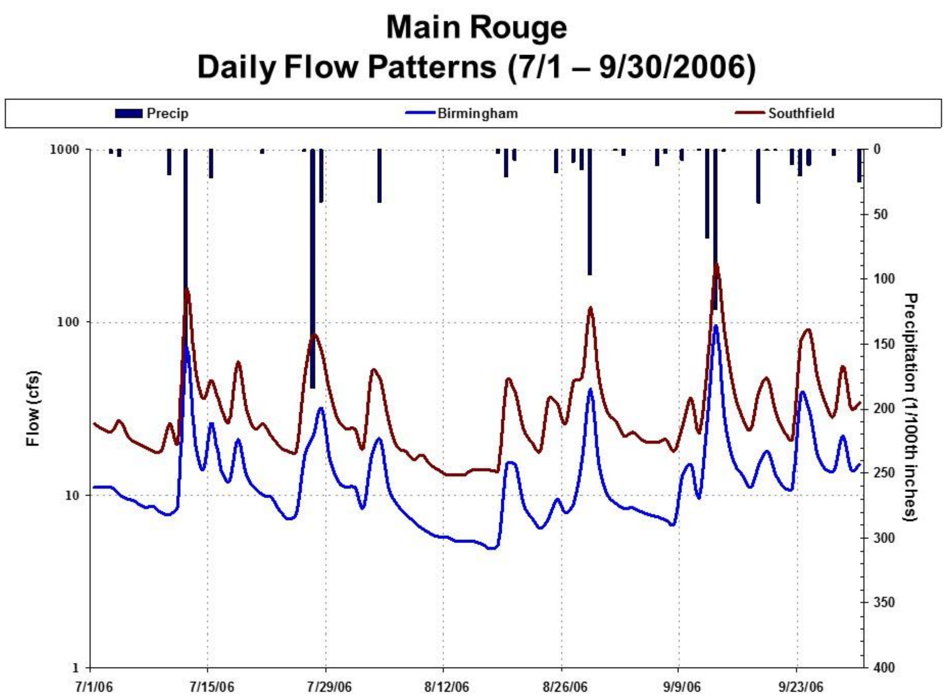


Figure J-1. Daily average upper Main Rouge watershed streamflow patterns *(7/1–9/30/2006)*

Soils and Sand Ridges. The soils in the Pebble Creek HUC-12 watershed range from sands that allow rapid infiltration to tight clays, which allow almost no infiltration. Storm water BMPs must be chosen that are effective given the variation of site-specific geology across the watershed. A significant part of the watershed contains silt loam or smaller particles. Heavier soils such as these have low permeability and do not lend themselves to percolating rain into the ground, then later slow release to the stream. Instead, they function as relatively impermeable surfaces, which shunt surface water over contours into the lowest point -- the stream (ARC, 2012).

Soils within the Pebble Creek HUC-12 watershed are categorized into hydrologic soil groups (Figure J-2), which provides a description of their runoff-producing or infiltration characteristics (Note: topography and vegetative cover are not considered in the hydrologic soil group classifications). Group A soils are well-drained sandy or gravelly materials with a high infiltration rate and low runoff potential. Group D soils, on the other hand, are soils having a very slow infiltration rate and thus a high runoff potential and are generally characterized as having a clay pan or clay lay near the surface. High water tables are also characteristic of these types of soils. Soils classified as Group B or C have characteristics intermediate of those soils in Groups A and D.

Most of the watershed was covered by waters of former glacial lakes. Sands and clays laid down in glacial lakes make up the surface deposits in portions of the Pebble Creek HUC-12 watershed. Other areas in the watershed are principally moraine deposits of retreating glaciers. The areas include sand ridges (Figure J-3); characteristics that allow fairly rapid infiltration of stormwater.

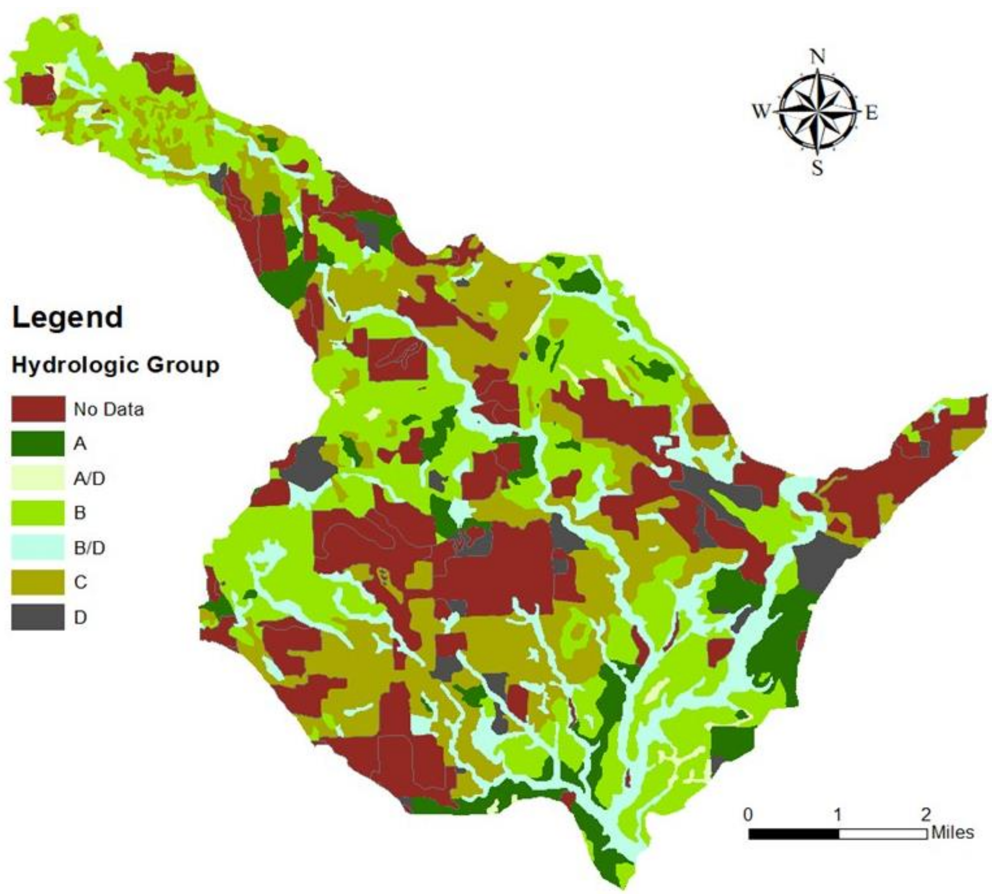
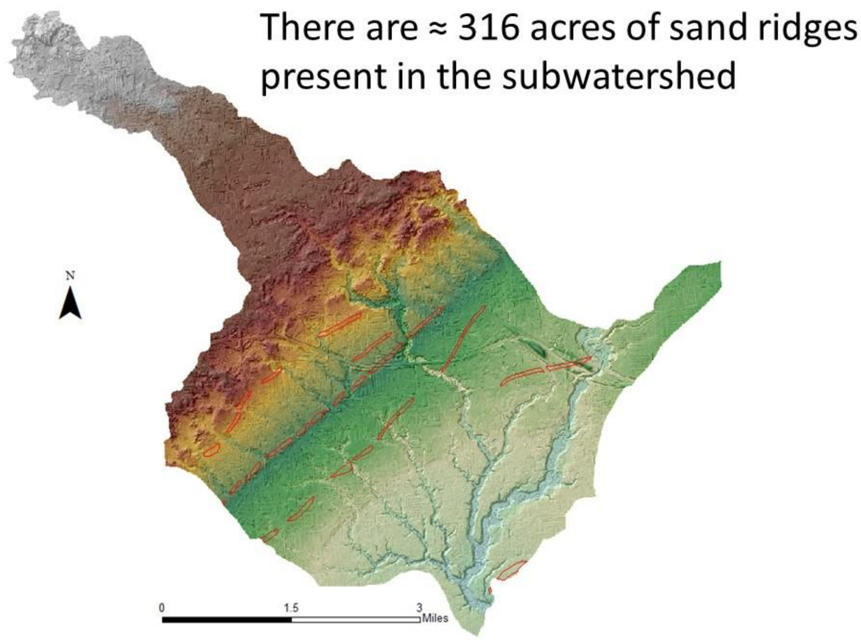
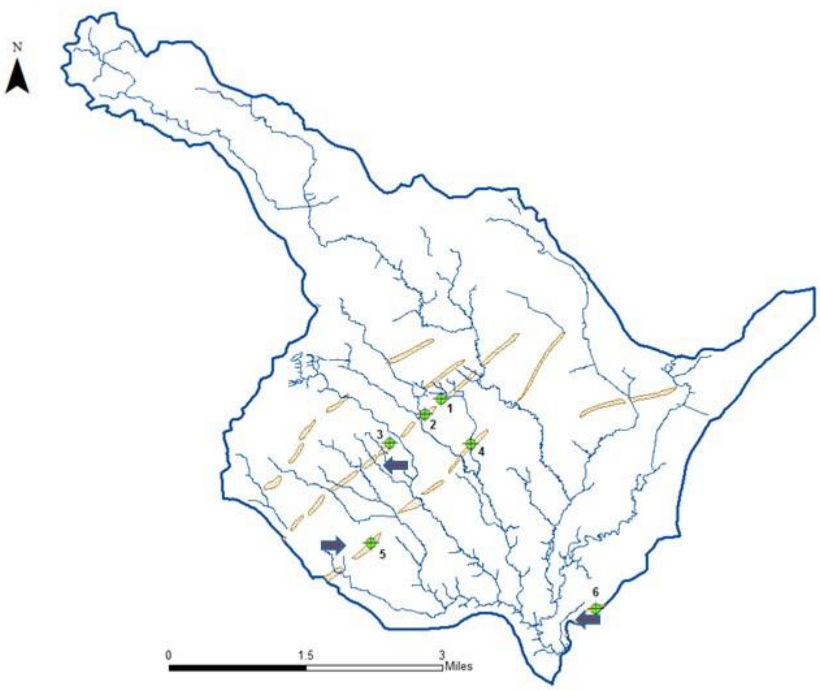


Figure J-2. Pebble Creek HUC-12 soil map



Id	Location	Lat	Long
1	Farmington Recreation Center PC Main Ridge	42.48980930170	-83.32919570700
2	Farmington Recreation Center PC Main Ridge	42.48750417490	-83.33289402580
3	Private PC Main Ridge	42.48312688520	-83.34063983070
4	Private PC third ridge	42.48260762860	-83.32310855770
5	Lanigan Elementary School PC third ridge	42.46727338870	-83.34533980250
6	Beech Woods Park PC	42.45575902770	-83.29746138140



SITE 3

0-.5 feet - SM- dark brown, compact topsoils/fill, regraded silt, clay, gravel, and sand, slightly compact, dry
.5- 2.5 feet - SW- tan, slightly compact, well graded medium sand with trace gravel, silt and clay, dry
2.5- 3.5 feet - CL/ML/SW - gray lodgement till, dry, stiff
EOB - 3.5 feet

SITE 5

0-.25 sandy topsoil
.25 - 1.75 - SP - tan, Medium sand, poorly graded, dry, loose
1.75 - 2.25 ft - SW - iron stained, medium to coarse sand, with moderate silt and clay, trace slightly angular gravel, slightly compact, slightly cohesive
2.25 - 2.5 ft - SM/CL - gray, cohesive, moderate compaction, clayey, silt, sand
2.5 - 2.75 - SP - tan, Medium sand, poorly graded, dry, loose
2.75 - 3.5 - SM - tan, Medium sand, well graded, some silt/clay, wet, loose
3.5 - 4 - GW - tan to gray, coarse to Fine sand, with moderate fine to medium gravel, well graded, saturated, loose
4 - 4.5 SM - iron stained, fine sand, poorly graded, with silt, saturated, slightly cohesive
4.5 EOB - CH - clean, cohesive, plastic, clay, gray lake deposit

Site 6

0 - 3 - SP - tan, Medium sand, poorly graded, dry, loose
3 - 3.5 - SP - iron stained, Medium sand, poorly graded, dry, loose
3.5 - 4 - SP - tan, medium sand, poorly graded, dry, loose, trace silt
4 - 5 - SP - gray, medium sand, poorly graded, dry, wet, trace silt
5 - 6.25 - 3 - SP - gray, medium sand, poorly graded, saturated, loose, trace silt
EOB @ 6.25 due to saturation collapse

Figure J-3. Pebble Creek HUC-12 sand ridges

Areas of Opportunity and Priorities. The SEMCOG land cover data provides a starting point to describe opportunities (Table A-7). An important aspect is identifying potential impervious surface types that could be managed for stormwater using green infrastructure. Within the Pebble Creek subwatershed, pavement (roads, parking lots, driveways, sidewalks, etc.) represents over half of all impervious surface types (Table J-2).

Table J-2. Pebble Creek impervious cover estimates by surface type

Catchment ID		Area *(acres)*	Total Impervious Area *(acres)*	Percent of Total Impervious Area			Tree Canopy *(percent)*
				Building	*Road*	*Other Pavement*	
A	**00** -- *Upper Pebble*	2,959	1,163	*28%*	*50%*	*22%*	34%
B	**10** -- *Middle Pebble*	1,159	316	*23%*	*49%*	*27%*	46%
	11 -- *Pernick*	2,318	873	*22%*	*46%*	*32%*	36%
C	**20** -- *Ravines (east)*	1,652	507	*25%*	*59%*	*16%*	38%
D	**30** -- *Ravines (middle)*	1,160	364	*23%*	*58%*	*19%*	39%
E	**40** -- *Ravines (upper west)*	1,448	422	*25%*	*65%*	*9%*	43%
F	**50** -- *Ravines (lower west)*	909	293	*25%*	*57%*	*18%*	42%
G	**60** -- *Main Rouge (Telegraph)*	2,300	776	*24%*	*54%*	*22%*	41%
H	**70** -- *Main Rouge (Gage)*	666	133	*30%*	*59%*	*11%*	59%
TOTAL		14,571	4,847	*25%*	*53%*	*22%*	40%

Recommendations. Substantial restoration efforts already have been implemented to address flooding and water quality problems in the Pebble Creek subwatershed. To complement ongoing and planned activities, several recommendations are offered based on an analysis of existing conditions related to flashiness and priorities identified using land use/land cover information. These recommendations follow key components of SEMCOG's *Green Infrastructure Vision*.

Roadways

Green infrastructure, both natural and constructed, can be strategically used along roadway corridors to provide recreational, social, and aesthetic amenities to surrounding communities in addition to providing local and regional environmental benefits. Within the Pebble Creek subwatershed, roadway types include freeways (e.g., I-696, M-10), arterial (e.g., Telegraph Road, Northwestern Highway) and collector roads, local and residential streets, and alleys. Open spaces within the road rights-of-way represent potential opportunities to increase green infrastructure, depending on the array of site-specific factors.

Open spaces within the road rights-of-way represent potential opportunities to increase green infrastructure, depending on the array of site-specific factors. In addition to the *Low Impact Development Manual for Michigan* (SEMCOG 2008), the *Green Streets Guide: A Compilation of Road Projects Using Green Infrastructure* (SEMCOG 2013) provides information on suitable practices for use in road rights-of-way. Recommended potential BMPs include bioretention, permeable pavement, bioswales, and native plant grow zones.

Institutional Properties

Green infrastructure on institutional properties offers several benefits including a public display of the types of practices suitable for implementation in the local community. Based on SEMCOG's analysis of parcel-level information, more than 700 acres of the Pebble HUC-12 watershed are publicly owned or institutional property (Figure J-4). School districts can benefit from green infrastructure implementation through construction of schoolyard habitats and native plant grow zones. In addition to the educational value, green infrastructure on school properties can work to reduce long-term maintenance costs by improving drainage and replacing high-maintenance turf with lower-maintenance trees, shrubs, and ornamental grasses.

Of the different types of impervious surfaces on publicly owned properties, pavement represents the largest proportion. Recommended potential BMPs include bioretention, infiltration trenches, pervious pavement, planter boxes, level spreaders, and vegetated swales. The *Low Impact Development Manual for Michigan* (SEMCOG 2008) also describes the range of design options available to accommodate site-specific situations. Potential opportunities are highlighted in Table J-3, which details the land cover breakdown by jursidiction.

Stakeholder Opportunities

In 2015, SEMCOG, in partnership with Michigan Sea Grant, hosted a series of green infrastructure workshops for local communities and counties focusing on integrating green infrastructure into local programs. The first workshop demonstrated how to prioritize green infrastructure implementation and discussed partnership opportunities for collaborative projects. Local stakeholders identified priority opportunity locations in the Pebble Creek HUC-12 watershed, shown in Figure J-5.

Table J-3. Pebble Creek publicly owned property by jurisdiction

Jurisdiction	**Area** *(acres)*	**Impervious Surface Types** *(acres)*		**Pervious Area** *(acres)*	
		Building	***Pavement*** *(parking, driving surfaces, sidewalks)*	***Open***	***Tree Canopy***
City of Farmington Hills	61	4	*19*	*21*	*17*
City of Southfield	256	*3*	*25*	*67*	*161*
Oakland County	127	*1*	*16*	*82*	*28*
State of Michigan	3	*0*	*1*	*1*	*1*
School Property	283	*19*	*88*	*133*	*44*
TOTAL	**729**	***27***	***148***	***304***	***250***

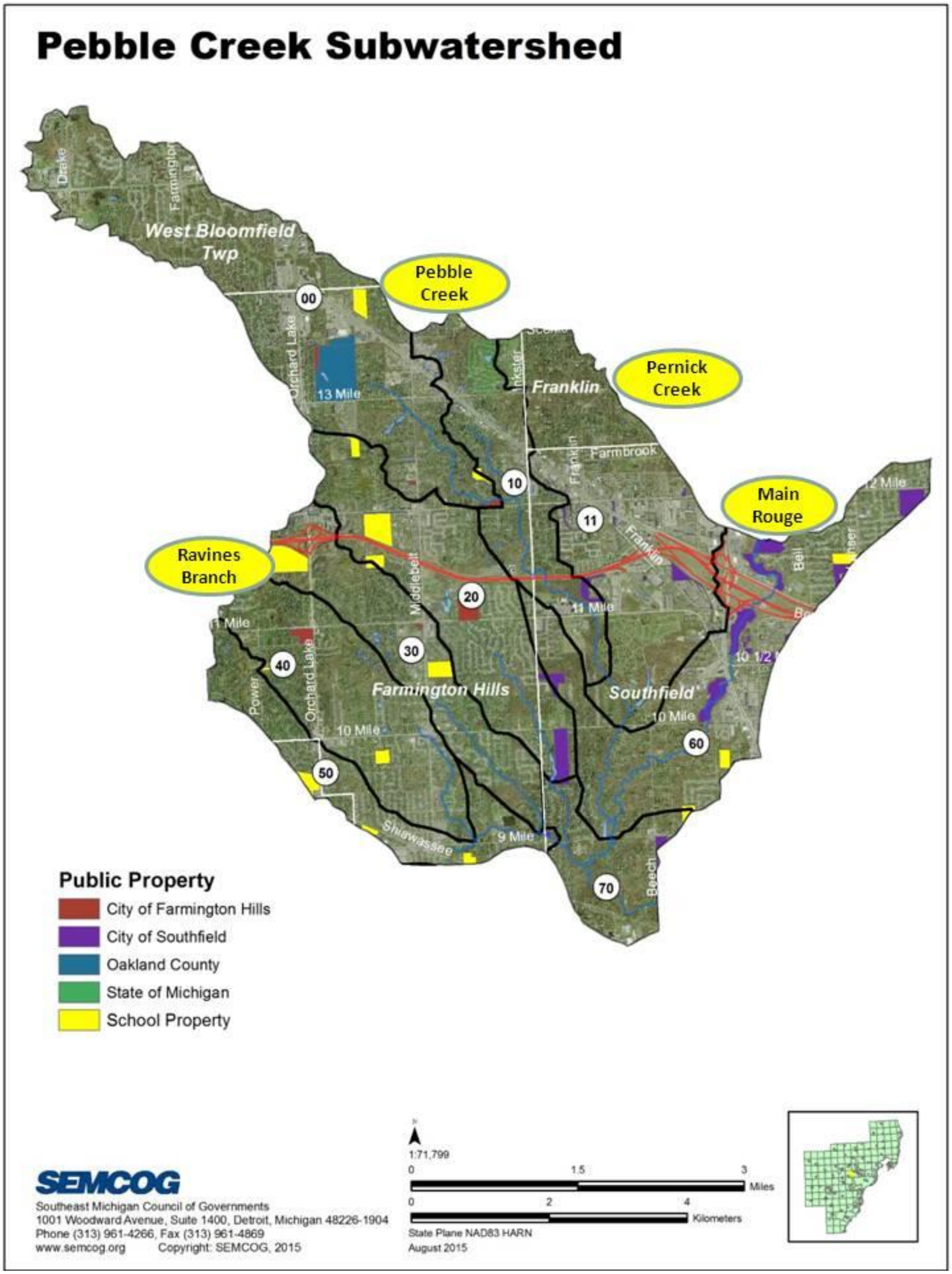


Figure J-4. Green Infrastructure Vision -- Pebble HUC-12 watershed public parcels

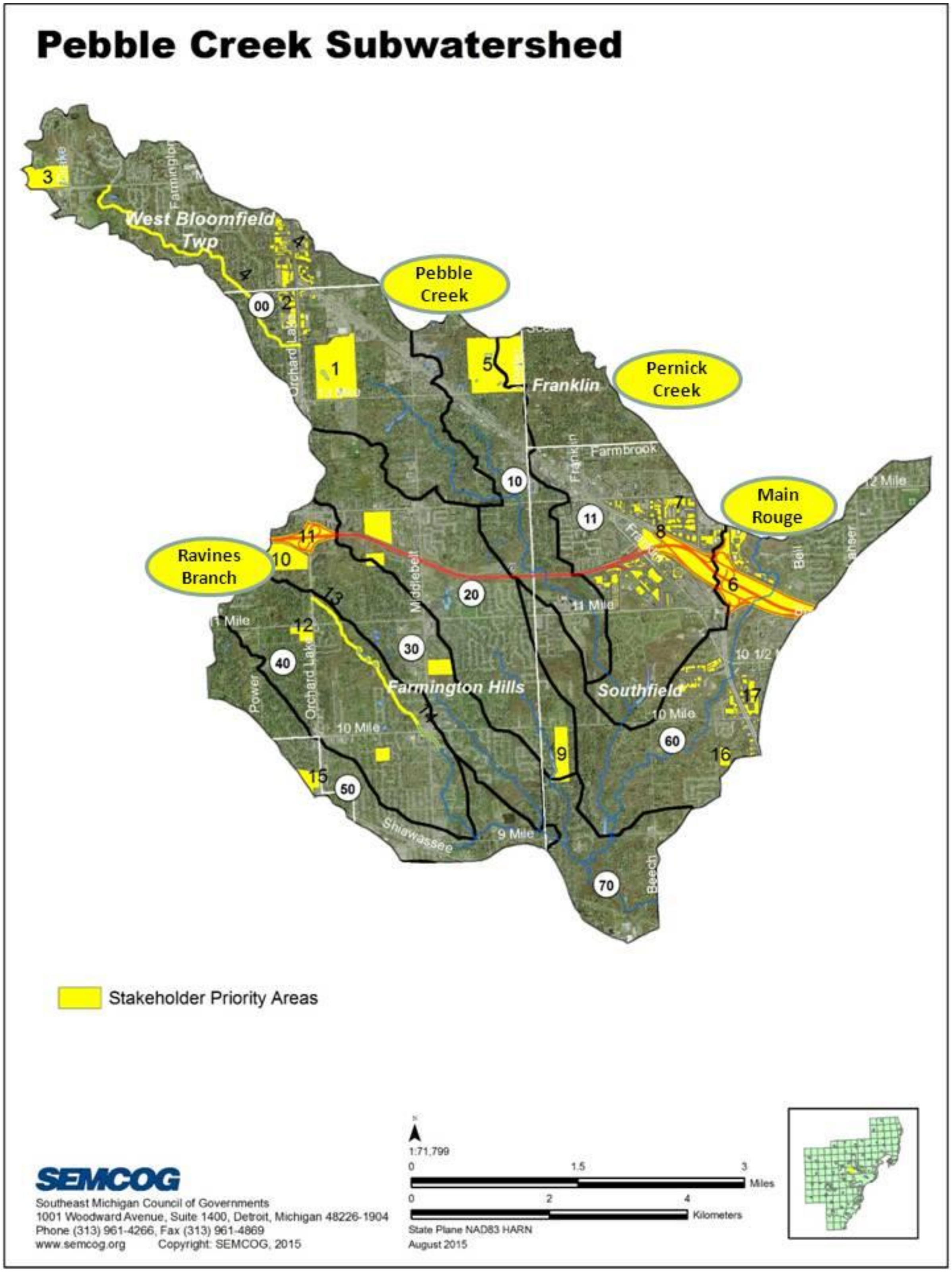


Figure J-5. Stakeholder opportunities -- Pebble Creek HUC-12 watershed

Parking Lots

Publicly and privately owned parking lots comprise a significant portion of all impervious surfaces in the Pebble subwatershed. Recommended potential BMPs to be implemented on parking lots include bioretention, infiltration trenches, pervious pavement, street planters, and increasing tree canopy. In benchmarking the amount of green infrastructure needed in southeast Michigan, SEMCOG evaluated land cover information from 2010 aerial imagery. This analysis included a compilation of impervious cover type across the Pebble Creek HUC-12 watershed. The SEMCOG impervious cover estimates are based on evaluation of parcel-scale data including transportation corridors, parking lot locations, and building footprints. SEMCOG's building data layer represents the digital footprint of each building in southeast Michigan, as of April 2015.

Parking lots were digitized by DEQ staff using a six-inch resolution 2015 aerial image of Oakland County. After digitizing was complete, aerial photographs were reviewed to attribute the shapefile to include the parking lots surface condition and its potential to include green infrastructure (Figure J-6). Surface conditions were evaluated to determine which lots were likely to be resurfaced soon. This would provide an opportunity for stakeholders to contact the lot owners to discuss the inclusion of green infrastructure practices. Surface condition criteria for evaluating parking lots include:

- **GOOD**: less than 20 percent of the paved surface has cracks
- **MODERATE**: between 20 and 50 percent of the surface has cracks or appears moderately worn
- **POOR**: greater than 50 percent of the surface has cracks or appears severely worn

Potential for green infrastructure was based on if there were existing structure in the lot that could potentially be used for green infrastructure. An aerial photo was also evaluated to determine if there were natural areas adjacent to the lot where stormwater could potentially be diverted. As noted, these evaluations were determined through aerial photograph review and field verification of conditions are required. The potential for green stormwater infrastructure (GSI) categories include:

- **GSI+DR**: potential for GSI structures plus opportunity exists to divert runoff to adjacent land
- **DR**: opportunity exists to divert runoff to adjacent land
- **GSI**: potential for GSI structures in lot could be used for GSI
- **GSI MIN**: minimal GSI potential and no opportunity to divert runoff to adjacent land

As the soil / sand ridge data was compiled and field inventory data evaluated, opportunities were noted where a green infrastructure could be implemented in several parking lots that could take advantage of areas with high infiltration capacity. Specifically, portions of 30 parking lots intersect with sand ridges. These areas are shown in Figure J-7.

Finally, parking lot attribute data compiled during the field inventory process helps guide targeting of projects in critical areas, which will reduce stormwater runoff volume in the Pebble Creek HUC-12 watershed. A summary of this information is presented in Table J-4 through Table J-16. (*Note:* Parking lots located in critical areas are listed in the first tables with those in poor condition shaded in light red; implementation opportunities in poor conditions lots are shaded in light green). Similarly, individual parking lot stormwater runoff volume estimates are provided in Table J-17 through Table J-29 for the two-year, five-year, ten-year, 25-year, 50-year, and 100-year, 24-hour storms.

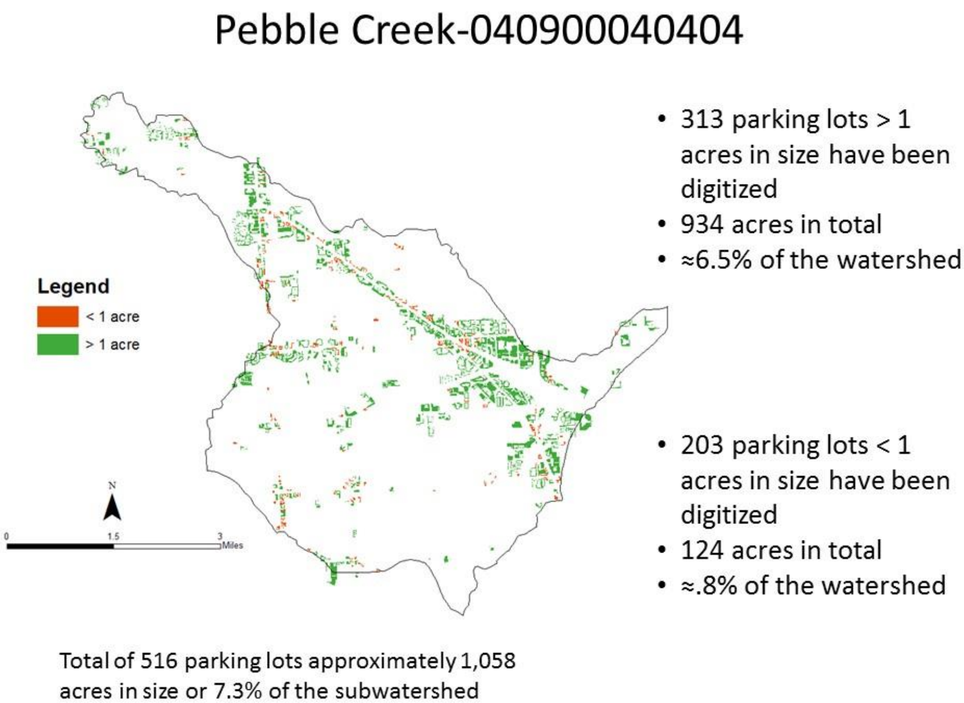


Figure J-6. Pebble Creek parking lots included in field inventory

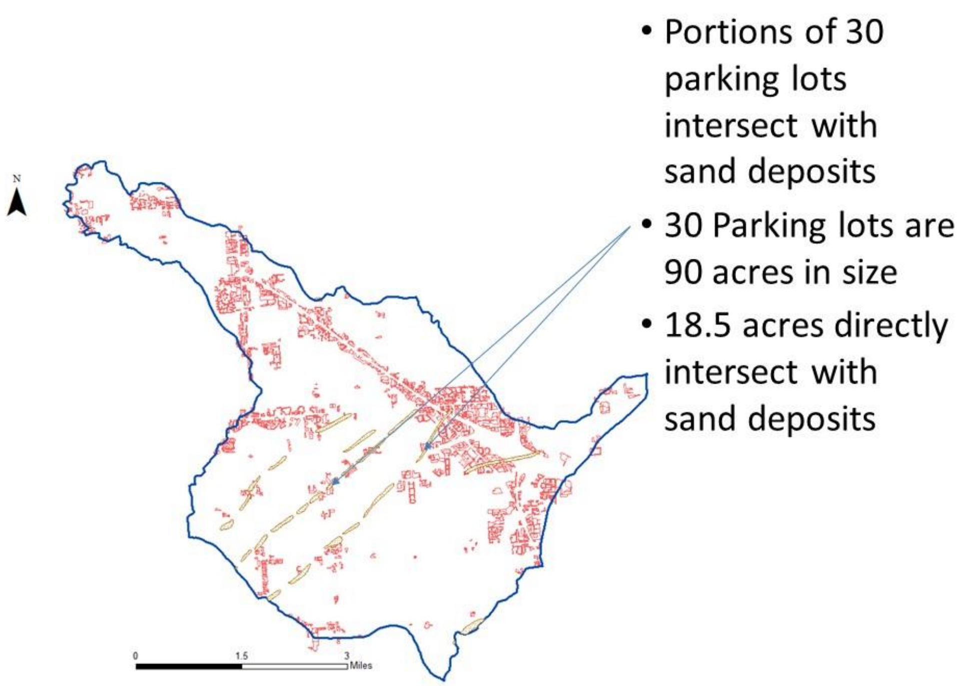


Figure J-7. Pebble Creek parking lots relative to sand ridges

Table J-4. Pebble Creek parking lots *(critical areas 00.a, 00.b, 00.c)*

Catchment	Critical Area	Size *(acres)*	Parking Lot ID	Condition			GSI Opportunity			
				GOOD	*MODERATE*	*POOR*	*GSI+DR*	*DR*	*GSI*	*MIN*
00	00.a	0.9	438			●●	●●			
		4.3	55			●●		D		
		2.5	3			●●			G	
		2.4	2			●●			G	
		4.1	1			●●				---
		0.4	439			●●				---
		3.2	46	○			●●			
		14.0	691		◗			D		
		2.2	50		◗				G	
		1.8	51		◗				G	
		2.1	54	○					G	
		0.4	52	○						---
	00.b	1.4	57			●●	●●			
		1.4	56			●●				---
		1.1	305			●●				---
		0.8	306			●●				---
		0.9	62		◗					---
		0.9	59		◗					---
		2.9	60	○						---
		0.9	58	○						---
		0.9	61	○						---
	00.c	3.6	43			●●		D		
		2.0	47			●●		D		
		2.7	40		◗		●●			
		1.7	49		◗		●●			
		1.3	38		◗		●●			
		8.2	45	○			●●			
		5.4	33	○			●●			
		5.1	44	○			●●			
		2.7	34		◗			D		
		2.0	42		◗			D		
		1.9	48		◗			D		
		0.7	41		◗			D		
		2.9	370		◗				G	
		1.5	36		◗					---
		4.9	35	○				D		
		0.6	37	○				D		
		0.6	39	○				D		

Notes: Condition

<20% ○ Less than 20 % of surface has cracks

20-50% ◗ 20 to 50% of surface has cracks or appears moderately worn

>50% ●● Greater than 50% of surface has cracks or appears severely worn

GSI Opportunity

●● Structures in lot could be used for GSI and potential to divert runoff to adjacent land

D Potential to divert lot runoff off to adjacent land

G Structures in lot could be used for green infrastructure

--- Minimal green infrastructure opportunity

Table J-5. Pebble Creek parking lots *(critical areas 00.d, 00.e, 00.f, 10.a)*

Catchment	Critical Area	Size *(acres)*	Parking Lot ID	Condition			GSI Opportunity			
				GOOD	*MODERATE*	*POOR*	*GSI+DR*	*DR*	*GSI*	*MIN*
00	00.d	1.0	245			●●	●●			
		0.4	665			●●			G	
		2.0	277			●●				---
		10.1	63		◗		●●			
		7.1	66		◗		●●			
		2.1	65		◗		●●			
		0.9	445		◗			D		
		1.8	67		◗					---
		1.0	278		◗					---
		0.9	235	○				D		
		1.3	236	○					G	
		1.0	64	○					G	
		0.8	237	○					G	
	00.e	3.1	104			●●			G	
	00.f	4.5	72			●●	●●			
		3.7	71			●●			G	
		3.6	432			●●			G	
		2.1	244			●●			G	
		0.6	418			●●			G	
		0.5	415			●●			G	
		0.6	232			●●				---
		0.3	417			●●				---
		2.8	75		◗		●●			
		1.8	73		◗		●●			
		1.1	74		◗		●●			
		1.6	70		◗				G	
		2.1	101		◗					---
		0.5	414		◗			D		
		0.3	416		◗					---
		5.9	76	○				D		
		1.9	78	○				D		
10	10.a	1.3	19			●●		D		
		0.6	466			●●			G	
		1.0	190		◗		●●			
		1.4	357		◗			D		
		0.8	707		◗			D		
		1.0	10		◗					---
		4.6	11	○				D		
		2.2	9	○				D		

Notes: Condition
- *<20%* ○ Less than 20 % of surface has cracks
- *20-50%* ◗ 20 to 50% of surface has cracks or appears moderately worn
- *>50%* ●● Greater than 50% of surface has cracks or appears severely worn

GSI Opportunity
- ●● Structures in lot could be used for GSI and potential to divert runoff to adjacent land
- D Potential to divert lot runoff off to adjacent land
- G Structures in lot could be used for green infrastructure
- --- Minimal green infrastructure opportunity

Table J-6. Pebble Creek parking lots *(critical areas 10.b, 11.a, 11.b)*

Catchment	Critical Area	Size *(acres)*	Parking Lot ID	Condition			GSI Opportunity			
				GOOD	*MODERATE*	*POOR*	*GSI+DR*	*DR*	*GSI*	*MIN*
10	**10.b**	3.9	226		◗		●●			
		3.8	623		◗			D		
		4.9	155	○					G	
		6.0	156			●●	●●			
		2.9	157			●●			G	
		1.4	158			●●			G	
11	**11.a**	3.1	521			●●	●●			
		1.5	220			●●	●●			
		3.3	291			●●		D		
		3.7	92			●●			G	
		2.5	95			●●			G	
		1.6	187			●●			G	
		1.5	288			●●			G	
		5.4	90			●●				---
		4.9	535			●●				---
		0.8	576			●●				---
		0.6	186			●●				---
		0.6	528			●●				---
		8.0	89		◗		●●			
		2.7	96	○			●●			
		4.4	185		◗			D		
		4.4	529		◗			D		
		1.2	219		◗			D		
		0.5	290		◗			D		
		0.2	527		◗			D		
		3.4	532		◗				G	
		1.4	289		◗				G	
		1.2	225		◗				G	
		0.8	526		◗				G	
		0.2	524		◗				G	
		1.4	188		◗					---
		1.0	184		◗					---
		0.3	525		◗					---
		1.0	520	○						---
		0.1	523	○						---
	11.b	1.0	666			●●	●●			
		0.8	699			●●	●●			
		6.9	462			●●		D		
		3.5	87			●●		D		
		3.4	98			●●		D		
		1.0	459			●●		D		
		3.9	151			●●			G	
		2.1	152			●●			G	

Notes: Condition

<20% ○ Less than 20 % of surface has cracks

20-50% ◗ 20 to 50% of surface has cracks or appears moderately worn

>50% ●● Greater than 50% of surface has cracks or appears severely worn

GSI Opportunity

●● Structures in lot could be used for GSI and potential to divert runoff to adjacent land

D Potential to divert lot runoff off to adjacent land

G Structures in lot could be used for green infrastructure

--- Minimal green infrastructure opportunity

Table J-7. Pebble Creek parking lots *(critical areas 11.b, 11.c)*

Catchment	Critical Area	Size *(acres)*	Parking Lot ID	Condition			GSI Opportunity			
				GOOD	*MODERATE*	*POOR*	*GSI+DR*	*DR*	*GSI*	*MIN*
11	**11.b**	1.3	458			●●			G	
		1.1	216			●●			G	
		1.1	457			●●			G	
		0.9	222			●●				---
		0.9	147			●●				---
		0.6	223			●●				---
		0.5	224			●●				---
		4.3	88		◗		●●			
		1.1	705		◗		●●			
		1.0	146		◗		●●			
		1.0	148		◗		●●			
		1.0	221		◗		●●			
		3.1	99	○			●●			
		1.9	150		◗			D		
		0.9	464		◗			D		
		1.0	217		◗					---
		0.8	94		◗					---
		0.8	149		◗					---
		0.6	575		◗					---
		0.8	93	○				D		
		0.2	706	○				D		
		0.7	218	○					G	
		0.7	574	○					G	
	11.c	9.3	84			●●	●●			
		5.5	131			●●	●●			
		0.3	696			●●	●●			
		1.9	85			●●		D		
		8.6	455			●●			G	
		3.4	124			●●			G	
		2.6	83			●●			G	
		1.8	508			●●			G	
		1.1	215			●●			G	
		7.4	79			●●				---
		2.5	514			●●				---
		5.9	86		◗		●●			
		2.7	506		◗		●●			
		1.0	130		◗		●●			
		3.5	452		◗				G	
		3.4	81		◗				G	
		2.6	214		◗				G	

Notes: Condition

<20% ○ Less than 20 % of surface has cracks

20-50% ◗ 20 to 50% of surface has cracks or appears moderately worn

>50% ●● Greater than 50% of surface has cracks or appears severely worn

GSI Opportunity

●● Structures in lot could be used for GSI and potential to divert runoff to adjacent land

D Potential to divert lot runoff off to adjacent land

G Structures in lot could be used for green infrastructure

--- Minimal green infrastructure opportunity

Table J-8. Pebble Creek parking lots *(critical areas 11.c, 60.a, 60.b, 60.c, 60.d)*

Catchment	Critical Area	Size *(acres)*	Parking Lot ID	Condition			GSI Opportunity			
				GOOD	*MODERATE*	*POOR*	*GSI+DR*	*DR*	*GSI*	*MIN*
11	**11.c**	2.3	82		◗				G	
		1.1	509		◗				G	
		0.8	512		◗				G	
		2.6	453		◗					---
		1.8	511		◗					---
		12.3	80	○					G	
		6.5	125	○					G	
		0.5	515	○					G	
60	**60.a**	2.4	123			●●	●●			
		3.4	120			●●		D		
		2.5	450			●●		D		
		0.9	499			●●				---
		2.3	121	○			●●			
		7.5	119		◗			D		
		1.4	122		◗				G	
	60.b	7.4	117			●●		D		
		5.6	212			●●		D		
		3.2	213		◗					---
	60.c	1.8	198			●●	●●			
		4.0	197			●●		D		
		0.5	620			●●		D		
		18.5	116			●●			G	
		5.6	323			●●				---
		2.5	300		◗		●●			
		2.3	343		◗		●●			
		3.2	345		◗			D		
	60.d	0.6	333			●●	●●			
		0.3	639			●●		D		
		3.3	106			●●			G	
		2.5	105			●●			G	
		0.9	319			●●				---
		0.9	275			●●				---
		0.8	637			●●				---
		0.4	638			●●				---
		5.8	108		◗		●●			
		2.7	174		◗		●●			
		2.3	172		◗		●●			
		1.1	248	○			●●			
		2.3	332		◗			D		
		1.0	246		◗			D		

Notes: Condition

<20% ○ Less than 20 % of surface has cracks

20-50% ◗ 20 to 50% of surface has cracks or appears moderately worn

>50% ●● Greater than 50% of surface has cracks or appears severely worn

GSI Opportunity

●● Structures in lot could be used for GSI and potential to divert runoff to adjacent land

D Potential to divert lot runoff off to adjacent land

G Structures in lot could be used for green infrastructure

--- Minimal green infrastructure opportunity

Table J-9. Pebble parking lots *(critical areas 60.d, 60.e; non-critical areas in catchment group 00)*

Catchment	Critical Area	Size *(acres)*	Parking Lot ID	Condition			GSI Opportunity			
				GOOD	*MODERATE*	*POOR*	*GSI+DR*	*DR*	*GSI*	*MIN*
60	**60.d**	9.1	107		◗				G	
		3.5	173		◗				G	
		0.4	276		◗				G	
		0.4	318		◗				G	
		1.2	272		◗					---
		0.7	273		◗					---
		0.4	640		◗					---
		0.2	274		◗					---
	60.e	3.3	115			●●	●●			
		3.1	112			●●	●●			
		2.2	176			●●	●●			
		0.5	349			●●		D		
		0.4	348			●●		D		
		0.3	346			●●		D		
		0.3	347			●●			G	
		6.8	109		◗		●●			
		4.7	110		◗		●●			
		3.2	175		◗			D		
		2.6	111		◗			D		
		1.2	262		◗				G	
		0.9	261		◗					---
		0.9	260	○					G	
		0.7	259	○					G	
00		1.5	352			●●	●●			
		1.5	250			●●	●●			
		1.4	436			●●	●●			
		1.4	492			●●	●●			
		1.2	374			●●	●●			
		4.9	475			●●		D		
		4.4	354			●●		D		
		3.1	362			●●		D		
		2.1	379			●●		D		
		2.0	437			●●		D		
		1.9	378			●●		D		
		1.6	474			●●		D		
		1.4	233			●●		D		
		1.1	25			●●		D		
		0.6	443			●●		D		
		0.4	351			●●		D		
		0.2	473			●●		D		

Notes: Condition

<20% ○ Less than 20 % of surface has cracks

20-50% ◗ 20 to 50% of surface has cracks or appears moderately worn

>50% ●● Greater than 50% of surface has cracks or appears severely worn

GSI Opportunity

●● Structures in lot could be used for GSI and potential to divert runoff to adjacent land

D Potential to divert lot runoff off to adjacent land

G Structures in lot could be used for green infrastructure

--- Minimal green infrastructure opportunity

Table J-10. Pebble Creek parking lots *(non-critical areas in catchment groups 00)*

Catchment	Critical Area	Size *(acres)*	Parking Lot ID	Condition			GSI Opportunity			
				GOOD	*MODERATE*	*POOR*	*GSI+DR*	*DR*	*GSI*	*MIN*
00		1.9	419			●●			G	
		1.1	231			●●			G	
		1.1	303			●●			G	
		0.9	358			●●			G	
		0.6	375			●●			G	
		0.5	377			●●			G	
		4.7	472			●●				---
		7.8	356		◗		●●			
		2.2	239		◗		●●			
		1.9	372		◗		●●			
		1.6	21		◗		●●			
		1.1	302		◗		●●			
		1.1	376		◗		●●			
		1.1	144		◗		●●			
		1.0	238		◗		●●			
		0.6	441		◗		●●			
		0.5	353		◗		●●			
		0.4	480		◗		●●			
		1.5	5	○			●●			
		1.3	6	○			●●			
		0.6	26	○			●●			
		3.3	20		◗			D		
		1.6	355		◗			D		
		1.4	252		◗			D		
		1.4	137		◗			D		
		1.1	23		◗			D		
		1.1	27		◗			D		
		1.0	447		◗			D		
		0.9	249		◗			D		
		0.9	440		◗			D		
		0.7	498		◗			D		
		0.2	444		◗			D		
		3.7	4		◗				G	
		2.9	7		◗				G	
		2.7	32		◗				G	
		2.1	143		◗				G	
		1.3	68		◗				G	
		1.1	69		◗				G	
		0.8	229		◗				G	
		0.2	442		◗				G	

Notes: Condition

<20% ○ Less than 20 % of surface has cracks

20-50% ◗ 20 to 50% of surface has cracks or appears moderately worn

>50% ●● Greater than 50% of surface has cracks or appears severely worn

GSI Opportunity

●● Structures in lot could be used for GSI and potential to divert runoff to adjacent land

D Potential to divert lot runoff off to adjacent land

G Structures in lot could be used for green infrastructure

--- Minimal green infrastructure opportunity

Table J-11. Pebble Creek parking lots *(non-critical areas in catchment groups 00, 10)*

Catchment	Critical Area	Size *(acres)*	Parking Lot ID	Condition			GSI Opportunity			
				GOOD	*MODERATE*	*POOR*	*GSI+DR*	*DR*	*GSI*	*MIN*
00		3.6	53		◗					---
		3.0	28		◗					---
		1.2	22		◗					---
		1.1	77		◗					---
		1.0	8		◗					---
		1.0	230		◗					---
		0.5	31		◗					---
		1.6	24	○				D		
		1.1	371	○				D		
		0.9	183	○				D		
		0.8	304	○				D		
		0.8	29	○				D		
		0.3	301	○				D		
		1.1	350	○					G	
		0.7	251	○						---
		0.6	30	○						---
		0.4	307	○						---
10		7.8	159			●●	●●			
		4.1	91			●●	●●			
		2.7	97			●●	●●			
		2.5	408			●●	●●			
		1.5	189			●●	●●			
		1.4	580			●●	●●			
		1.3	409			●●	●●			
		2.0	581			●●		D		
		1.3	468			●●		D		
		1.0	103			●●		D		
		0.9	181			●●		D		
		0.5	496			●●		D		
		3.7	563		◗		●●			
		1.4	191		◗		●●			
		3.5	177	○			●●			
		0.9	708		◗			D		
		0.4	192		◗			D		
		0.4	410		◗			D		
		0.8	577		◗				G	
		0.3	497		◗				G	
		0.2	413		◗					---
		1.1	102	○				D		
		0.4	465	○					G	

Notes: Condition

<20% ○ Less than 20 % of surface has cracks

20-50% ◗ 20 to 50% of surface has cracks or appears moderately worn

>50% ●● Greater than 50% of surface has cracks or appears severely worn

GSI Opportunity

●● Structures in lot could be used for GSI and potential to divert runoff to adjacent land

D Potential to divert lot runoff off to adjacent land

G Structures in lot could be used for green infrastructure

--- Minimal green infrastructure opportunity

Table J-12. Pebble Creek parking lots *(non-critical areas in catchment groups 10, 11, 20)*

Catchment	Critical Area	Size *(acres)*	Parking Lot ID	Condition			GSI Opportunity			
				GOOD	*MODERATE*	*POOR*	*GSI+DR*	*DR*	*GSI*	*MIN*
10		0.4	411	○					G	
		0.3	412	○					G	
11		20.9	134			●●	●●			
		2.2	135			●●	●●			
		1.1	254			●●	●●			
		3.8	461			●●		D		
		3.4	502			●●		D		
		1.9	255			●●		D		
		1.7	227			●●		D		
		1.2	257			●●		D		
		1.0	234			●●		D		
		0.9	180			●●		D		
		0.7	241			●●		D		
		0.6	582			●●		D		
		3.1	505			●●				---
		3.1	256			●●				---
		5.6	153		◗		●●			
		6.3	16	○			●●			
		3.9	12	○			●●			
		3.0	13	○			●●			
		1.6	14	○			●●			
		0.6	243	○			●●			
		7.2	17		◗			D		
		5.6	113		◗			D		
		5.4	154		◗			D		
		3.7	18		◗			D		
		1.1	501		◗			D		
		0.9	242		◗			D		
		0.5	698		◗			D		
		0.2	314		◗			D		
		1.7	228		◗				G	
		0.7	258		◗				G	
		9.0	15	○				D		
20		6.0	132			●●	●●			
		4.5	165			●●	●●			
		2.5	606			●●	●●			
		1.5	199			●●	●●			
		1.5	204			●●	●●			
		1.2	145			●●	●●			
		0.5	586			●●	●●			

Notes: Condition

<20% ○ Less than 20 % of surface has cracks

20-50% ◗ 20 to 50% of surface has cracks or appears moderately worn

>50% ●● Greater than 50% of surface has cracks or appears severely worn

GSI Opportunity

●● Structures in lot could be used for GSI and potential to divert runoff to adjacent land

D Potential to divert lot runoff off to adjacent land

G Structures in lot could be used for green infrastructure

--- Minimal green infrastructure opportunity

Table J-13. Pebble Creek parking lots *(non-critical areas in catchment groups 20, 30)*

Catchment	Critical Area	Size *(acres)*	Parking Lot ID	Condition			GSI Opportunity			
				GOOD	*MODERATE*	*POOR*	*GSI+DR*	*DR*	*GSI*	*MIN*
20		7.8	594			●●		D		
		3.8	163			●●		D		
		2.6	483			●●		D		
		2.0	482			●●		D		
		1.0	491			●●		D		
		4.5	136			●●			G	
		1.2	584			●●			G	
		1.0	477			●●			G	
		0.3	478			●●			G	
		1.0	299			●●				---
		0.9	467			●●				---
		0.8	292			●●				---
		6.3	100		◗		●●			
		2.7	164		◗		●●			
		0.6	479	○			●●			
		0.3	641	○			●●			
		1.9	253		◗			D		
		0.7	485		◗			D		
		0.5	484		◗			D		
		0.5	583		◗			D		
		1.0	293		◗				G	
		0.5	489		◗				G	
		0.4	703		◗				G	
		0.9	476		◗					---
		1.2	138	○					G	
30		1.2	205			●●	●●			
		1.2	201			●●	●●			
		0.6	614			●●	●●			
		4.4	615			●●		D		
		4.3	202			●●		D		
		2.7	211			●●		D		
		2.4	618			●●		D		
		1.9	310			●●		D		
		0.8	206			●●		D		
		0.5	486			●●		D		
		0.3	634			●●		D		
		1.0	633			●●			G	
		3.9	133			●●				---
		1.7	170			●●				---
		1.1	207			●●				---

Notes: Condition

- *<20%* ○ Less than 20 % of surface has cracks
- *20-50%* ◗ 20 to 50% of surface has cracks or appears moderately worn
- *>50%* ●● Greater than 50% of surface has cracks or appears severely worn

GSI Opportunity

- ●● Structures in lot could be used for GSI and potential to divert runoff to adjacent land
- D Potential to divert lot runoff off to adjacent land
- G Structures in lot could be used for green infrastructure
- --- Minimal green infrastructure opportunity

Table J-14. Pebble Creek parking lots *(non-critical areas in catchment groups 30, 40)*

Catchment	Critical Area	Size *(acres)*	Parking Lot ID	Condition			GSI Opportunity			
				GOOD	*MODERATE*	*POOR*	*GSI+DR*	*DR*	*GSI*	*MIN*
30		1.0	142			●●				---
		0.8	330			●●				---
		0.7	208			●●				---
		0.7	609			●●				---
		0.5	487			●●				---
		6.1	210		◗		●●			
		4.2	209		◗		●●			
		1.3	200		◗		●●			
		1.2	309		◗		●●			
		3.7	166	○			●●			
		1.0	141	○			●●			
		2.6	203		◗			D		
		1.8	171		◗			D		
		0.7	312		◗			D		
		0.7	490		◗			D		
		0.6	311		◗			D		
		5.3	240		◗				G	
		1.3	140		◗				G	
		1.3	139		◗				G	
		0.6	589		◗				G	
		0.5	667		◗					---
		0.3	488	○					G	
40		1.0	643			●●	●●			
		1.5	327			●●		D		
		0.8	178			●●		D		
		0.7	285			●●		D		
		0.5	266			●●		D		
		0.3	337			●●		D		
		1.5	263			●●			G	
		1.1	287			●●			G	
		1.4	267			●●				---
		1.2	339			●●				---
		0.6	329			●●				---
		0.5	331			●●				---
		0.5	336			●●				---
		0.3	338			●●				---
		3.2	194		◗		●●			
		1.7	280		◗		●●			
		1.1	265		◗			D		
		1.0	646		◗			D		

Notes: Condition

<20% ○ Less than 20 % of surface has cracks

20-50% ◗ 20 to 50% of surface has cracks or appears moderately worn

>50% ●● Greater than 50% of surface has cracks or appears severely worn

GSI Opportunity

●● Structures in lot could be used for GSI and potential to divert runoff to adjacent land

D Potential to divert lot runoff off to adjacent land

G Structures in lot could be used for green infrastructure

--- Minimal green infrastructure opportunity

Table J-15. Pebble Creek parking lots *(non-critical areas in catchment groups 40, 50)*

Catchment	Critical Area	Size *(acres)*	Parking Lot ID	Condition			GSI Opportunity			
				GOOD	*MODERATE*	*POOR*	*GSI+DR*	*DR*	*GSI*	*MIN*
40		0.9	281		◗			D		
		0.6	645		◗			D		
		0.6	340		◗			D		
		0.5	341		◗			D		
		1.2	279		◗				G	
		1.2	193		◗				G	
		0.7	328		◗				G	
		1.2	264		◗					---
		0.7	270		◗					---
		0.6	636		◗					---
		0.3	647		◗					---
		1.9	179	○				D		
		0.3	342	○				D		
		0.2	635	○				D		
		0.6	268	○					G	
		0.5	644	○					G	
		1.1	269	○						---
		0.6	286	○						---
		0.5	610	○						---
50		1.3	297			●●	●●			
		2.5	161			●●		D		
		1.4	294			●●		D		
		1.1	168			●●		D		
		1.0	653			●●		D		
		0.7	663			●●		D		
		0.6	298			●●		D		
		0.4	326			●●		D		
		0.2	659			●●		D		
		14.9	167			●●			G	
		1.0	169			●●			G	
		0.9	284			●●			G	
		0.5	655			●●			G	
		0.3	660			●●			G	
		1.7	661			●●				---
		1.6	657			●●				---
		1.6	296			●●				---
		1.0	295			●●				---
		0.8	649			●●				---
		0.8	282			●●				---
		0.6	651			●●				---

Notes: Condition

- *<20%* ○ Less than 20 % of surface has cracks
- *20-50%* ◗ 20 to 50% of surface has cracks or appears moderately worn
- *>50%* ●● Greater than 50% of surface has cracks or appears severely worn

GSI Opportunity

- ●● Structures in lot could be used for GSI and potential to divert runoff to adjacent land
- D Potential to divert lot runoff off to adjacent land
- G Structures in lot could be used for green infrastructure
- --- Minimal green infrastructure opportunity

Table J-16. Pebble Creek parking lots *(non-critical areas in catchment groups 50, 60, 70)*

Catchment	Critical Area	Size *(acres)*	Parking Lot ID	Condition			GSI Opportunity			
				GOOD	*MODERATE*	*POOR*	*GSI+DR*	*DR*	*GSI*	*MIN*
50		1.6	162		◗			D		
		1.0	325		◗			D		
		0.5	650		◗			D		
		0.2	664		◗				G	
		0.6	658		◗					---
		0.4	283		◗					---
		0.4	652		◗					---
		0.3	654		◗					---
60		6.5	335			●●	●●			
		4.9	128			●●	●●			
		3.3	118			●●	●●			
		1.1	195			●●	●●			
		0.7	516			●●	●●			
		0.6	517			●●	●●			
		0.5	317			●●	●●			
		2.9	500			●●		D		
		2.2	247			●●		D		
		0.9	518			●●		D		
		0.9	334			●●		D		
		0.6	324			●●		D		
		5.5	114			●●			G	
		2.5	129			●●				---
		2.7	344		◗		●●			
		2.2	196		◗		●●			
		1.9	182		◗		●●			
		1.3	126		◗		●●			
		2.8	322		◗			D		
		0.8	315		◗			D		
		0.4	316		◗			D		
		1.7	127	○				D		
		0.3	321	○				D		
		0.3	313	○						---
		0.3	320	○						---
70		1.4	271			●●		D		
		2.7	160		◗			D		
		0.3	656		◗				G	

Notes: Condition

<20% ○ Less than 20 % of surface has cracks
20-50% ◗ 20 to 50% of surface has cracks or appears moderately worn
>50% ●● Greater than 50% of surface has cracks or appears severely worn

GSI Opportunity

●● Structures in lot could be used for GSI and potential to divert runoff to adjacent land
D Potential to divert lot runoff off to adjacent land
G Structures in lot could be used for green infrastructure
--- Minimal green infrastructure opportunity

Table J-17. Parking lot stormwater runoff volume estimates *(critical areas 00.a, 00.b, 00.c)*

Catchment	Critical Area	Size *(acres)*	Parking Lot ID	Stormwater Volume *(ft3/day)*					
				2-year, 24-hour	*5-year, 24-hour*	*10-year, 24-hour*	*25-year, 24-hour*	*50-year, 24-hour*	*100-year, 24-hour*
00	00.a	0.9	438	6,248	7,817	9,037	10,550	11,775	13,001
		4.3	55	29,979	37,504	43,360	50,618	56,495	62,378
		2.5	3	17,153	21,460	24,810	28,963	32,326	35,692
		2.4	2	17,125	21,424	24,769	28,915	32,272	35,632
		4.1	1	28,396	35,524	41,071	47,946	53,512	59,084
		0.4	439	2,753	3,445	3,982	4,649	5,189	5,729
		3.2	46	22,428	28,058	32,439	37,869	42,265	46,666
		14.0	691	97,726	122,260	141,349	165,009	184,167	203,343
		2.2	50	15,264	19,096	22,077	25,773	28,765	31,760
		1.8	51	12,714	15,906	18,390	21,468	23,960	26,455
		2.1	54	14,976	18,736	21,661	25,287	28,223	31,162
		0.4	52	2,802	3,506	4,053	4,731	5,281	5,830
	00.b	1.4	57	10,120	12,661	14,638	17,088	19,072	21,058
		1.4	56	9,927	12,419	14,358	16,762	18,708	20,656
		1.1	305	7,366	9,215	10,653	12,437	13,881	15,326
		0.8	306	5,817	7,277	8,413	9,822	10,962	12,103
		0.9	62	6,333	7,922	9,159	10,693	11,934	13,177
		0.9	59	6,176	7,727	8,933	10,428	11,639	12,851
		2.9	60	20,091	25,135	29,060	33,924	37,863	41,805
		0.9	58	6,640	8,307	9,604	11,212	12,513	13,816
		0.9	61	6,341	7,933	9,171	10,706	11,949	13,193
	00.c	3.6	43	24,990	31,263	36,144	42,195	47,093	51,997
		2.0	47	14,029	17,551	20,291	23,687	26,437	29,190
		2.7	40	19,009	23,781	27,494	32,096	35,822	39,552
		1.7	49	11,643	14,566	16,840	19,659	21,942	24,226
		1.3	38	9,048	11,319	13,086	15,277	17,051	18,826
		8.2	45	57,370	71,772	82,978	96,868	108,115	119,372
		5.4	33	37,917	47,436	54,842	64,022	71,455	78,895
		5.1	44	35,745	44,719	51,701	60,356	67,363	74,377
		2.7	34	18,997	23,766	27,477	32,076	35,800	39,528
		2.0	42	14,209	17,776	20,551	23,991	26,777	29,565
		1.9	48	13,492	16,880	19,515	22,782	25,427	28,074
		0.7	41	5,202	6,508	7,525	8,784	9,804	10,825
		2.9	370	20,563	25,725	29,741	34,720	38,751	42,786
		1.5	36	10,345	12,942	14,963	17,468	19,496	21,526
		4.9	35	34,542	43,213	49,960	58,323	65,094	71,872
		0.6	37	4,329	5,415	6,261	7,309	8,158	9,007
		0.6	39	3,985	4,985	5,764	6,729	7,510	8,292

Table J-18. Parking lot stormwater runoff volume estimates *(critical areas 00.d, 00.e, 00.f, 10.a)*

Catchment	Critical Area	Size *(acres)*	Parking Lot ID	Stormwater Volume *(ft3/day)*					
00	00.d	1.0	245	6,725	8,413	9,726	11,354	12,673	13,992
		0.4	665	2,635	3,296	3,811	4,448	4,965	5,482
		2.0	277	13,853	17,330	20,036	23,390	26,106	28,824
		10.1	63	70,480	88,174	101,941	119,004	132,821	146,651
		7.1	66	49,898	62,424	72,171	84,251	94,033	103,824
		2.1	65	14,625	18,297	21,154	24,694	27,561	30,431
		0.9	445	6,597	8,253	9,542	11,139	12,432	13,727
		1.8	67	12,743	15,942	18,431	21,516	24,014	26,514
		1.0	278	6,745	8,438	9,756	11,388	12,711	14,034
		0.9	235	6,608	8,267	9,558	11,158	12,453	13,750
		1.3	236	8,957	11,205	12,955	15,123	16,879	18,637
		1.0	64	6,701	8,384	9,693	11,315	12,629	13,944
		0.8	237	5,434	6,798	7,860	9,175	10,241	11,307
	00.e	3.1	104	21,541	26,948	31,156	36,371	40,594	44,820
	00.f	4.5	72	31,617	39,555	45,730	53,385	59,583	65,788
		3.7	71	25,274	31,619	36,555	42,674	47,629	52,588
		3.6	432	14,429	18,051	20,869	24,362	27,191	30,022
		2.1	244	3,990	4,992	5,771	6,737	7,519	8,302
		0.6	418	3,578	4,476	5,174	6,041	6,742	7,444
		0.5	415	4,044	5,060	5,850	6,829	7,622	8,415
		0.6	232	2,201	2,754	3,183	3,716	4,148	4,580
		0.3	417	19,308	24,155	27,927	32,602	36,387	40,175
		2.8	75	12,566	15,720	18,175	21,217	23,680	26,146
		1.8	73	8,043	10,062	11,633	13,580	15,157	16,735
		1.1	74	3,514	4,396	5,083	5,933	6,622	7,312
		1.6	70	1,956	2,447	2,829	3,303	3,686	4,070
		2.1	101	41,291	51,657	59,723	69,720	77,814	85,917
		0.5	414	26,109	32,664	37,764	44,085	49,203	54,327
		0.3	416	11,082	13,864	16,029	18,712	20,884	23,059
		5.9	76	14,816	18,535	21,429	25,016	27,921	30,828
		1.9	78	12,977	16,235	18,770	21,912	24,456	27,002
10	10.a	1.3	19	8,981	11,235	12,989	15,164	16,924	18,687
		0.6	466	4,367	5,463	6,316	7,374	8,230	9,087
		1.0	190	7,251	9,071	10,488	12,243	13,664	15,087
		1.4	357	9,729	12,172	14,072	16,428	18,335	20,244
		0.8	707	5,695	7,125	8,237	9,616	10,733	11,850
		1.0	10	7,313	9,149	10,578	12,349	13,782	15,217
		4.6	11	32,381	40,510	46,836	54,675	61,023	67,377
		2.2	9	15,474	19,359	22,382	26,128	29,162	32,198

Table J-19. Parking lot stormwater runoff volume estimates *(critical areas 10.b, 11.a, 11.b)*

Catchment	Critical Area	Size *(acres)*	Parking Lot ID	Stormwater Volume *(ft3/day)*					
				2-year, 24-hour	*5-year, 24-hour*	*10-year, 24-hour*	*25-year, 24-hour*	*50-year, 24-hour*	*100-year, 24-hour*
10	10.b	3.9	226	26,943	33,707	38,970	45,493	50,775	56,062
		3.8	623	26,668	33,362	38,571	45,028	50,256	55,488
		4.9	155	34,261	42,863	49,555	57,850	64,566	71,289
		6.0	156	41,994	52,537	60,740	70,907	79,139	87,380
		2.9	157	20,105	25,153	29,080	33,948	37,889	41,834
		1.4	158	9,688	12,121	14,013	16,359	18,258	20,159
11	11.a	3.1	521	21,342	26,700	30,869	36,036	40,220	44,408
		1.5	220	10,591	13,249	15,318	17,882	19,958	22,037
		3.3	291	23,078	28,872	33,380	38,968	43,492	48,020
		3.7	92	26,092	32,642	37,738	44,055	49,170	54,290
		2.5	95	17,553	21,960	25,389	29,638	33,079	36,524
		1.6	187	10,996	13,756	15,904	18,566	20,721	22,879
		1.5	288	10,823	13,540	15,654	18,274	20,396	22,520
		5.4	90	38,054	47,607	55,040	64,254	71,714	79,181
		4.9	535	34,301	42,912	49,612	57,917	64,641	71,372
		0.8	576	5,842	7,308	8,450	9,864	11,009	12,155
		0.6	186	4,310	5,392	6,233	7,277	8,122	8,967
		0.6	528	4,294	5,372	6,211	7,251	8,093	8,935
		8.0	89	55,730	69,720	80,606	94,098	105,024	115,959
		2.7	96	19,050	23,833	27,554	32,166	35,901	39,639
		4.4	185	31,046	38,840	44,904	52,421	58,507	64,599
		4.4	529	30,898	38,655	44,690	52,171	58,228	64,291
		1.2	219	8,717	10,906	12,608	14,719	16,428	18,138
		0.5	290	3,172	3,969	4,588	5,356	5,978	6,601
		0.2	527	1,289	1,612	1,864	2,176	2,429	2,682
		3.4	532	24,103	30,154	34,862	40,698	45,423	50,152
		1.4	289	9,833	12,302	14,222	16,603	18,531	20,460
		1.2	225	8,518	10,656	12,320	14,383	16,052	17,724
		0.8	526	5,519	6,905	7,983	9,319	10,401	11,484
		0.2	524	1,267	1,586	1,833	2,140	2,388	2,637
		1.4	188	9,806	12,268	14,184	16,558	18,480	20,404
		1.0	184	6,747	8,441	9,759	11,393	12,716	14,040
		0.3	525	2,294	2,870	3,318	3,873	4,323	4,773
		1.0	520	6,688	8,367	9,673	11,292	12,603	13,916
		0.1	523	700	875	1,012	1,181	1,318	1,456
	11.b	1.0	666	7,140	8,933	10,327	12,056	13,456	14,857
		0.8	699	5,432	6,796	7,857	9,173	10,237	11,303
		6.9	462	48,198	60,298	69,713	81,382	90,831	100,289
		3.5	87	24,406	30,533	35,300	41,209	45,993	50,782
		3.4	98	23,640	29,574	34,192	39,915	44,550	49,188
		1.0	459	7,325	9,164	10,595	12,369	13,805	15,242
		3.9	151	27,174	33,996	39,304	45,883	51,210	56,542
		2.1	152	14,671	18,354	21,220	24,771	27,648	30,526

Table J-20. Parking lot stormwater runoff volume estimates *(critical areas 11.b, 11.c)*

Catchment	Critical Area	Size *(acres)*	Parking Lot ID	Stormwater Volume *(ft3/day)*					
				2-year, 24-hour	*5-year, 24-hour*	*10-year, 24-hour*	*25-year, 24-hour*	*50-year, 24-hour*	*100-year, 24-hour*
11	11.b	1.3	458	8,833	11,050	12,775	14,914	16,645	18,378
		1.1	216	7,886	9,866	11,406	13,315	14,861	16,409
		1.1	457	7,658	9,580	11,076	12,930	14,432	15,934
		0.9	222	6,465	8,088	9,351	10,916	12,183	13,452
		0.9	147	6,398	8,004	9,253	10,802	12,056	13,312
		0.6	223	4,484	5,610	6,486	7,572	8,451	9,331
		0.5	224	3,576	4,474	5,173	6,038	6,740	7,441
		4.3	88	29,990	37,518	43,376	50,637	56,516	62,401
		1.1	705	7,448	9,318	10,773	12,576	14,036	15,498
		1.0	146	7,316	9,152	10,581	12,352	13,786	15,222
		1.0	148	7,215	9,027	10,436	12,183	13,597	15,013
		1.0	221	7,155	8,951	10,349	12,081	13,484	14,888
		3.1	99	21,426	26,805	30,991	36,178	40,378	44,583
		1.9	150	13,502	16,892	19,529	22,798	25,445	28,095
		0.9	464	6,252	7,822	9,043	10,557	11,783	13,010
		1.0	217	6,832	8,547	9,881	11,535	12,875	14,215
		0.8	94	5,571	6,969	8,058	9,406	10,499	11,592
		0.8	149	5,525	6,911	7,991	9,328	10,411	11,495
		0.6	575	4,265	5,335	6,169	7,201	8,037	8,874
		0.8	93	5,377	6,727	7,777	9,079	10,133	11,188
		0.2	706	1,595	1,995	2,307	2,693	3,006	3,319
		0.7	218	4,802	6,007	6,945	8,108	9,049	9,992
		0.7	574	4,758	5,953	6,882	8,034	8,967	9,901
	11.c	9.3	84	64,994	81,310	94,006	109,741	122,483	135,236
		5.5	131	38,422	48,068	55,573	64,875	72,407	79,947
		0.3	696	2,123	2,656	3,071	3,585	4,001	4,418
		1.9	85	13,531	16,927	19,570	22,846	25,499	28,154
		8.6	455	60,001	75,063	86,783	101,310	113,072	124,846
		3.4	124	24,107	30,158	34,867	40,704	45,429	50,160
		2.6	83	18,467	23,104	26,711	31,182	34,802	38,426
		1.8	508	12,452	15,578	18,010	21,025	23,466	25,909
		1.1	215	7,842	9,811	11,343	13,241	14,779	16,317
		7.4	79	51,725	64,710	74,813	87,336	97,476	107,626
		2.5	514	17,690	22,131	25,587	29,870	33,338	36,809
		5.9	86	41,112	51,433	59,464	69,418	77,477	85,545
		2.7	506	18,972	23,735	27,440	32,033	35,753	39,475
		1.0	130	7,087	8,866	10,250	11,966	13,355	14,746
		3.5	452	24,211	30,289	35,018	40,880	45,626	50,377
		3.4	81	23,591	29,513	34,121	39,833	44,457	49,087
		2.6	214	18,073	22,610	26,141	30,516	34,059	37,606

Table J-21. Parking lot runoff volume estimates *(critical areas 11.c, 60.a, 60.b, 60.c, 60.d)*

Catchment	Critical Area	Size *(acres)*	Parking Lot ID	Stormwater Volume *(ft3/day)*					
				2-year, 24-hour	*5-year, 24-hour*	*10-year, 24-hour*	*25-year, 24-hour*	*50-year, 24-hour*	*100-year, 24-hour*
11	**11.c**	2.3	82	16,375	20,486	23,685	27,649	30,859	34,072
		1.1	509	7,649	9,569	11,063	12,915	14,415	15,916
		0.8	512	5,663	7,085	8,191	9,562	10,672	11,783
		2.6	453	18,137	22,690	26,233	30,624	34,180	37,739
		1.8	511	12,723	15,917	18,402	21,483	23,977	26,473
		12.3	80	86,326	107,998	124,860	145,760	162,683	179,623
		6.5	125	45,229	56,584	65,419	76,369	85,235	94,111
		0.5	515	3,151	3,942	4,558	5,321	5,939	6,557
60	**60.a**	2.4	123	16,448	20,577	23,790	27,772	30,997	34,224
		3.4	120	23,881	29,876	34,541	40,323	45,004	49,690
		2.5	450	17,288	21,628	25,005	29,190	32,579	35,972
		0.9	499	6,514	8,150	9,422	10,999	12,276	13,555
		2.3	121	16,328	20,427	23,617	27,570	30,771	33,975
		7.5	119	52,562	65,757	76,024	88,749	99,053	109,367
		1.4	122	10,115	12,654	14,630	17,079	19,062	21,047
	60.b	7.4	117	51,570	64,517	74,590	87,076	97,185	107,305
		5.6	212	39,226	49,073	56,735	66,232	73,921	81,619
		3.2	213	22,108	27,658	31,976	37,329	41,663	46,001
	60.c	1.8	198	12,665	15,844	18,318	21,384	23,867	26,352
		4.0	197	28,127	35,189	40,683	47,493	53,007	58,526
		0.5	620	3,197	4,000	4,625	5,399	6,025	6,653
		18.5	116	129,197	161,631	186,867	218,146	243,474	268,826
		5.6	323	38,995	48,784	56,401	65,842	73,487	81,139
		2.5	300	17,690	22,131	25,587	29,870	33,338	36,809
		2.3	343	16,087	20,125	23,268	27,162	30,316	33,472
		3.2	345	22,278	27,870	32,222	37,615	41,983	46,354
	60.d	0.6	333	4,038	5,052	5,840	6,818	7,610	8,402
		0.3	639	2,094	2,619	3,028	3,535	3,946	4,356
		3.3	106	22,869	28,610	33,077	38,614	43,097	47,585
		2.5	105	17,788	22,254	25,728	30,035	33,522	37,012
		0.9	319	6,227	7,791	9,007	10,515	11,735	12,957
		0.9	275	6,170	7,719	8,924	10,417	11,627	12,838
		0.8	637	5,557	6,952	8,038	9,383	10,473	11,563
		0.4	638	2,853	3,569	4,127	4,817	5,377	5,937
		5.8	108	40,639	50,842	58,780	68,619	76,586	84,560
		2.7	174	18,660	23,344	26,989	31,507	35,165	38,827
		2.3	172	16,124	20,171	23,321	27,225	30,385	33,549
		1.1	248	7,626	9,541	11,030	12,877	14,372	15,868
		2.3	332	16,105	20,148	23,294	27,193	30,350	33,511
		1.0	246	7,236	9,053	10,466	12,218	13,637	15,057

Table J-22. Parking lot runoff volumes *(critical areas 60.d, 60.e; non-critical areas in group 00)*

Catchment	Critical Area	Size *(acres)*	Parking Lot ID	Stormwater Volume *(ft3/day)*					
				2-year, 24-hour	*5-year, 24-hour*	*10-year, 24-hour*	*25-year, 24-hour*	*50-year, 24-hour*	*100-year, 24-hour*
60	60.d	9.1	107	63,766	79,774	92,230	107,668	120,169	132,682
		3.5	173	24,727	30,934	35,764	41,750	46,598	51,450
		0.4	276	3,142	3,931	4,544	5,305	5,921	6,537
		0.4	318	2,510	3,140	3,630	4,238	4,730	5,222
		1.2	272	8,642	10,811	12,499	14,591	16,286	17,981
		0.7	273	5,218	6,528	7,548	8,811	9,834	10,858
		0.4	640	3,074	3,845	4,446	5,190	5,792	6,395
		0.2	274	1,545	1,933	2,235	2,609	2,912	3,215
	60.e	3.3	115	22,839	28,573	33,034	38,564	43,041	47,523
		3.1	112	21,545	26,954	31,163	36,379	40,603	44,831
		2.2	176	15,648	19,577	22,633	26,422	29,489	32,560
		0.5	349	3,404	4,258	4,923	5,747	6,415	7,083
		0.4	348	2,774	3,470	4,012	4,683	5,227	5,771
		0.3	346	1,843	2,306	2,666	3,113	3,474	3,836
		0.3	347	2,304	2,882	3,332	3,890	4,342	4,794
		6.8	109	47,670	59,637	68,949	80,490	89,835	99,190
		4.7	110	33,110	41,423	47,890	55,906	62,397	68,894
		3.2	175	22,053	27,589	31,897	37,236	41,559	45,886
		2.6	111	17,951	22,457	25,964	30,310	33,829	37,351
		1.2	262	8,138	10,181	11,770	13,740	15,336	16,932
		0.9	261	6,626	8,289	9,583	11,187	12,486	13,786
		0.9	260	6,427	8,040	9,296	10,852	12,112	13,373
		0.7	259	4,939	6,179	7,144	8,340	9,308	10,277
00		1.5	352	10,794	13,504	15,612	18,226	20,342	22,460
		1.5	250	10,279	12,859	14,867	17,356	19,371	21,388
		1.4	436	10,100	12,636	14,609	17,054	19,034	21,016
		1.4	492	10,078	12,608	14,576	17,016	18,992	20,969
		1.2	374	8,516	10,654	12,317	14,379	16,049	17,720
		4.9	475	33,996	42,530	49,171	57,401	64,066	70,737
		4.4	354	30,950	38,720	44,766	52,259	58,327	64,400
		3.1	362	21,891	27,387	31,663	36,963	41,254	45,550
		2.1	379	14,857	18,586	21,488	25,085	27,998	30,913
		2.0	437	13,873	17,356	20,066	23,425	26,144	28,866
		1.9	378	13,428	16,799	19,422	22,673	25,306	27,940
		1.6	474	11,288	14,122	16,327	19,060	21,273	23,488
		1.4	233	9,820	12,286	14,204	16,581	18,507	20,434
		1.1	25	7,818	9,780	11,308	13,200	14,733	16,267
		0.6	443	4,070	5,092	5,887	6,872	7,670	8,469
		0.4	351	2,947	3,686	4,262	4,975	5,553	6,131
		0.2	473	1,709	2,138	2,472	2,886	3,221	3,556

Table J-23. Parking lot runoff volume estimates *(non-critical areas in catchment groups 00)*

Catchment	Critical Area	Size *(acres)*	Parking Lot ID	Stormwater Volume *(ft3/day)*					
				2-year, 24-hour	*5-year, 24-hour*	*10-year, 24-hour*	*25-year, 24-hour*	*50-year, 24-hour*	*100-year, 24-hour*
00		1.9	419	13,594	17,007	19,662	22,953	25,618	28,285
		1.1	231	7,974	9,976	11,533	13,464	15,027	16,592
		1.1	303	7,568	9,468	10,946	12,778	14,262	15,747
		0.9	358	6,495	8,126	9,395	10,967	12,241	13,515
		0.6	375	4,447	5,564	6,433	7,509	8,381	9,254
		0.5	377	3,520	4,404	5,091	5,943	6,633	7,324
		4.7	472	33,038	41,333	47,786	55,785	62,262	68,745
		7.8	356	54,277	67,903	78,505	91,646	102,286	112,937
		2.2	239	15,436	19,311	22,326	26,064	29,090	32,119
		1.9	372	13,572	16,980	19,631	22,917	25,577	28,241
		1.6	21	11,271	14,101	16,303	19,031	21,241	23,453
		1.1	302	7,658	9,581	11,077	12,931	14,432	15,935
		1.1	376	7,413	9,274	10,722	12,517	13,970	15,425
		1.1	144	7,353	9,199	10,636	12,416	13,858	15,301
		1.0	238	7,196	9,003	10,408	12,150	13,561	14,973
		0.6	441	4,215	5,273	6,097	7,117	7,943	8,770
		0.5	353	3,614	4,522	5,228	6,103	6,811	7,520
		0.4	480	2,978	3,726	4,308	5,029	5,613	6,197
		1.5	5	10,501	13,137	15,188	17,731	19,789	21,850
		1.3	6	8,956	11,204	12,953	15,122	16,877	18,635
		0.6	26	4,331	5,419	6,265	7,313	8,163	9,013
		3.3	20	22,954	28,716	33,199	38,757	43,256	47,760
		1.6	355	11,307	14,146	16,355	19,092	21,309	23,528
		1.4	252	9,675	12,103	13,993	16,335	18,232	20,130
		1.4	137	9,509	11,896	13,754	16,056	17,920	19,786
		1.1	23	7,882	9,861	11,401	13,309	14,855	16,401
		1.1	27	7,696	9,628	11,131	12,995	14,503	16,014
		1.0	447	6,984	8,737	10,102	11,793	13,162	14,532
		0.9	249	6,349	7,942	9,183	10,720	11,964	13,210
		0.9	440	6,151	7,695	8,896	10,385	11,591	12,798
		0.7	498	4,992	6,245	7,220	8,429	9,408	10,387
		0.2	444	1,643	2,055	2,376	2,774	3,096	3,419
		3.7	4	25,817	32,298	37,340	43,591	48,652	53,718
		2.9	7	20,134	25,189	29,122	33,996	37,943	41,894
		2.7	32	18,736	23,439	27,099	31,635	35,307	38,984
		2.1	143	14,412	18,030	20,845	24,334	27,160	29,988
		1.3	68	9,147	11,444	13,230	15,445	17,238	19,033
		1.1	69	7,441	9,309	10,763	12,564	14,023	15,483
		0.8	229	5,586	6,988	8,079	9,432	10,527	11,623
		0.2	442	1,328	1,661	1,920	2,242	2,502	2,762

Table J-24. Parking lot runoff volume estimates *(non-critical areas in catchment groups 00, 10)*

Catchment	Critical Area	Size *(acres)*	Parking Lot ID	Stormwater Volume *(ft3/day)*					
				2-year, 24-hour	*5-year, 24-hour*	*10-year, 24-hour*	*25-year, 24-hour*	*50-year, 24-hour*	*100-year, 24-hour*
00		3.6	53	25,155	31,470	36,384	42,474	47,406	52,342
		3.0	28	20,973	26,238	30,334	35,412	39,523	43,639
		1.2	22	8,676	10,855	12,549	14,650	16,351	18,054
		1.1	77	7,856	9,829	11,363	13,265	14,806	16,347
		1.0	8	7,266	9,090	10,509	12,268	13,692	15,118
		1.0	230	6,845	8,563	9,900	11,557	12,899	14,242
		0.5	31	3,574	4,471	5,170	6,035	6,736	7,437
		1.6	24	11,092	13,876	16,043	18,728	20,903	23,079
		1.1	371	7,380	9,233	10,674	12,461	13,908	15,356
		0.9	183	6,603	8,261	9,551	11,150	12,444	13,740
		0.8	304	5,659	7,080	8,185	9,555	10,665	11,775
		0.8	29	5,590	6,993	8,085	9,438	10,534	11,631
		0.3	301	2,287	2,861	3,308	3,861	4,309	4,758
		1.1	350	7,965	9,965	11,520	13,449	15,010	16,573
		0.7	251	4,666	5,837	6,748	7,878	8,793	9,708
		0.6	30	4,324	5,409	6,254	7,300	8,148	8,996
		0.4	307	3,044	3,808	4,402	5,139	5,736	6,333
10		7.8	159	54,587	68,291	78,954	92,170	102,871	113,583
		4.1	91	28,779	36,003	41,625	48,592	54,234	59,881
		2.7	97	19,122	23,923	27,658	32,288	36,036	39,789
		2.5	408	17,143	21,447	24,796	28,946	32,307	35,671
		1.5	189	10,597	13,257	15,327	17,893	19,970	22,050
		1.4	580	9,496	11,880	13,735	16,034	17,896	19,759
		1.3	409	9,180	11,485	13,278	15,501	17,301	19,102
		2.0	581	13,892	17,380	20,094	23,457	26,181	28,907
		1.3	468	8,989	11,245	13,001	15,177	16,939	18,703
		1.0	103	6,780	8,482	9,807	11,448	12,777	14,108
		0.9	181	6,035	7,550	8,729	10,190	11,373	12,557
		0.5	496	3,195	3,997	4,621	5,394	6,021	6,647
		3.7	563	25,690	32,139	37,157	43,377	48,413	53,454
		1.4	191	9,582	11,987	13,859	16,179	18,057	19,938
		3.5	177	24,812	31,041	35,887	41,894	46,758	51,627
		0.9	708	6,277	7,853	9,079	10,598	11,829	13,061
		0.4	192	2,955	3,696	4,274	4,989	5,568	6,148
		0.4	410	2,614	3,270	3,780	4,413	4,926	5,438
		0.8	577	5,367	6,714	7,762	9,062	10,114	11,167
		0.3	497	2,268	2,837	3,280	3,829	4,274	4,719
		0.2	413	1,500	1,876	2,169	2,532	2,826	3,120
		1.1	102	7,364	9,213	10,651	12,434	13,878	15,323
		0.4	465	2,981	3,730	4,312	5,034	5,619	6,204

Table J-25. Parking lot runoff volume estimates *(non-critical areas in catchment groups 10, 11, 20)*

Catchment	Critical Area	Size *(acres)*	Parking Lot ID	Stormwater Volume *(ft3/day)*					
				2-year, 24-hour	*5-year, 24-hour*	*10-year, 24-hour*	*25-year, 24-hour*	*50-year, 24-hour*	*100-year, 24-hour*
10		0.4	411	2,467	3,086	3,568	4,166	4,649	5,133
		0.3	412	1,858	2,325	2,687	3,137	3,502	3,866
11		20.9	134	146,531	183,317	211,939	247,415	276,141	304,894
		2.2	135	15,660	19,591	22,650	26,441	29,511	32,584
		1.1	254	7,858	9,831	11,366	13,268	14,809	16,351
		3.8	461	26,639	33,326	38,529	44,979	50,201	55,428
		3.4	502	23,998	30,023	34,710	40,520	45,225	49,934
		1.9	255	13,174	16,481	19,054	22,244	24,826	27,411
		1.7	227	11,910	14,900	17,226	20,110	22,445	24,782
		1.2	257	8,355	10,453	12,085	14,108	15,746	17,386
		1.0	234	6,799	8,506	9,834	11,480	12,812	14,146
		0.9	180	6,378	7,980	9,226	10,770	12,020	13,272
		0.7	241	4,607	5,764	6,664	7,780	8,683	9,587
		0.6	582	3,954	4,947	5,719	6,677	7,452	8,228
		3.1	505	21,857	27,344	31,614	36,905	41,190	45,479
		3.1	256	21,618	27,046	31,268	36,502	40,740	44,983
		5.6	153	39,063	48,870	56,500	65,958	73,616	81,281
		6.3	16	44,041	55,097	63,699	74,362	82,995	91,637
		3.9	12	26,931	33,692	38,953	45,473	50,752	56,037
		3.0	13	21,090	26,384	30,504	35,609	39,744	43,882
		1.6	14	11,051	13,825	15,984	18,659	20,826	22,994
		0.6	243	3,969	4,966	5,741	6,702	7,480	8,259
		7.2	17	50,526	63,210	73,079	85,312	95,217	105,131
		5.6	113	39,174	49,009	56,661	66,145	73,825	81,512
		5.4	154	38,005	47,546	54,969	64,170	71,621	79,078
		3.7	18	26,191	32,766	37,882	44,223	49,358	54,497
		1.1	501	7,475	9,351	10,811	12,621	14,086	15,553
		0.9	242	5,967	7,464	8,630	10,074	11,244	12,415
		0.5	698	3,191	3,992	4,616	5,388	6,014	6,640
		0.2	314	1,603	2,005	2,318	2,706	3,020	3,334
		1.7	228	11,643	14,565	16,839	19,658	21,941	24,225
		0.7	258	4,824	6,035	6,977	8,145	9,091	10,037
		9.0	15	62,970	78,779	91,079	106,324	118,669	131,025
20		6.0	132	41,888	52,404	60,586	70,727	78,939	87,159
		4.5	165	31,425	39,313	45,452	53,060	59,220	65,386
		2.5	606	17,782	22,246	25,719	30,024	33,510	37,000
		1.5	199	10,455	13,079	15,121	17,652	19,702	21,753
		1.5	204	10,177	12,732	14,720	17,184	19,179	21,176
		1.2	145	8,703	10,888	12,588	14,695	16,402	18,110
		0.5	586	3,783	4,733	5,472	6,388	7,129	7,872

Table J-26. Parking lot runoff volume estimates *(non-critical areas in catchment groups 20, 30)*

Catchment	Critical Area	Size *(acres)*	Parking Lot ID	Stormwater Volume *(ft3/day)*					
				2-year, 24-hour	*5-year, 24-hour*	*10-year, 24-hour*	*25-year, 24-hour*	*50-year, 24-hour*	*100-year, 24-hour*
20		7.8	594	54,905	68,688	79,413	92,706	103,469	114,243
		3.8	163	26,776	33,499	38,729	45,212	50,461	55,715
		2.6	483	17,927	22,428	25,930	30,270	33,784	37,302
		2.0	482	13,911	17,403	20,120	23,488	26,215	28,944
		1.0	491	7,141	8,933	10,328	12,057	13,457	14,858
		4.5	136	31,826	39,816	46,033	53,738	59,977	66,222
		1.2	584	8,579	10,733	12,408	14,485	16,167	17,851
		1.0	477	6,964	8,712	10,073	11,759	13,124	14,490
		0.3	478	2,362	2,955	3,417	3,989	4,452	4,915
		1.0	299	6,945	8,688	10,045	11,726	13,087	14,450
		0.9	467	6,515	8,150	9,422	11,000	12,277	13,555
		0.8	292	5,833	7,297	8,436	9,848	10,992	12,136
		6.3	100	43,757	54,742	63,290	73,883	82,461	91,048
		2.7	164	18,699	23,393	27,046	31,573	35,239	38,908
		0.6	479	4,294	5,373	6,211	7,251	8,093	8,936
		0.3	641	2,156	2,697	3,118	3,640	4,063	4,486
		1.9	253	13,429	16,800	19,424	22,675	25,307	27,943
		0.7	485	5,186	6,488	7,501	8,756	9,773	10,790
		0.5	484	3,544	4,433	5,125	5,983	6,678	7,373
		0.5	583	3,207	4,011	4,638	5,414	6,043	6,672
		1.0	293	6,805	8,514	9,843	11,491	12,825	14,160
		0.5	489	3,398	4,251	4,915	5,737	6,404	7,070
		0.4	703	2,633	3,293	3,808	4,445	4,961	5,478
		0.9	476	6,379	7,980	9,226	10,770	12,020	13,272
		1.2	138	8,480	10,609	12,265	14,318	15,981	17,645
30		1.2	205	8,519	10,658	12,322	14,384	16,054	17,726
		1.2	201	8,386	10,491	12,129	14,160	15,803	17,449
		0.6	614	4,306	5,387	6,228	7,271	8,115	8,960
		4.4	615	30,726	38,439	44,441	51,880	57,903	63,932
		4.3	202	30,376	38,002	43,935	51,289	57,244	63,205
		2.7	211	18,617	23,291	26,927	31,434	35,084	38,737
		2.4	618	16,554	20,710	23,943	27,951	31,196	34,444
		1.9	310	13,033	16,305	18,850	22,006	24,561	27,118
		0.8	206	5,729	7,168	8,287	9,674	10,797	11,921
		0.5	486	3,169	3,964	4,583	5,350	5,972	6,593
		0.3	634	2,163	2,706	3,129	3,653	4,077	4,501
		1.0	633	7,253	9,074	10,491	12,247	13,669	15,092
		3.9	133	27,526	34,436	39,813	46,477	51,873	57,274
		1.7	170	12,084	15,117	17,478	20,403	22,772	25,143
		1.1	207	7,636	9,553	11,045	12,893	14,390	15,889

Table J-27. Parking lot runoff volume estimates *(non-critical areas in catchment groups 30, 40)*

Catchment	Critical Area	Size *(acres)*	Parking Lot ID	Stormwater Volume *(ft3/day)*					
				2-year, 24-hour	*5-year, 24-hour*	*10-year, 24-hour*	*25-year, 24-hour*	*50-year, 24-hour*	*100-year, 24-hour*
30		1.0	142	6,904	8,637	9,986	11,657	13,010	14,365
		0.8	330	5,841	7,307	8,448	9,862	11,007	12,153
		0.7	208	5,010	6,268	7,247	8,460	9,442	10,425
		0.7	609	4,680	5,855	6,769	7,902	8,819	9,738
		0.5	487	3,678	4,601	5,320	6,210	6,931	7,653
		6.1	210	42,468	53,129	61,424	71,706	80,031	88,365
		4.2	209	29,656	37,101	42,894	50,074	55,888	61,707
		1.3	200	9,274	11,602	13,413	15,658	17,476	19,296
		1.2	309	8,487	10,618	12,276	14,331	15,994	17,660
		3.7	166	25,922	32,429	37,493	43,769	48,850	53,937
		1.0	141	7,063	8,836	10,216	11,926	13,310	14,696
		2.6	203	18,477	23,115	26,725	31,198	34,820	38,446
		1.8	171	12,865	16,094	18,607	21,722	24,244	26,768
		0.7	312	5,131	6,418	7,421	8,663	9,669	10,675
		0.7	490	4,901	6,131	7,089	8,275	9,236	10,198
		0.6	311	4,206	5,262	6,083	7,101	7,926	8,751
		5.3	240	37,301	46,666	53,952	62,983	70,295	77,615
		1.3	140	8,814	11,026	12,748	14,882	16,610	18,339
		1.3	139	8,804	11,014	12,733	14,865	16,591	18,318
		0.6	589	4,013	5,020	5,804	6,775	7,562	8,349
		0.5	667	3,822	4,781	5,528	6,453	7,202	7,952
		0.3	488	2,057	2,573	2,974	3,472	3,876	4,279
40		1.0	643	7,274	9,100	10,521	12,282	13,708	15,136
		1.5	327	10,192	12,750	14,741	17,209	19,206	21,206
		0.8	178	5,825	7,287	8,425	9,835	10,977	12,120
		0.7	285	5,021	6,281	7,262	8,477	9,461	10,446
		0.5	266	3,601	4,505	5,208	6,080	6,786	7,493
		0.3	337	2,310	2,890	3,341	3,900	4,353	4,806
		1.5	263	10,761	13,463	15,565	18,171	20,280	22,392
		1.1	287	7,800	9,758	11,281	13,170	14,699	16,229
		1.4	267	10,137	12,681	14,661	17,115	19,103	21,092
		1.2	339	8,548	10,694	12,363	14,433	16,109	17,786
		0.6	329	4,071	5,093	5,888	6,874	7,672	8,471
		0.5	331	3,687	4,613	5,333	6,226	6,949	7,673
		0.5	336	3,152	3,944	4,559	5,323	5,941	6,559
		0.3	338	2,107	2,636	3,048	3,558	3,971	4,384
		3.2	194	22,060	27,598	31,907	37,248	41,572	45,901
		1.7	280	11,825	14,793	17,103	19,966	22,284	24,604
		1.1	265	7,351	9,196	10,632	12,412	13,853	15,295
		1.0	646	6,811	8,520	9,851	11,499	12,835	14,171

Table J-28. Parking lot runoff volume estimates *(non-critical areas in catchment groups 40, 50)*

Catchment	Critical Area	Size *(acres)*	Parking Lot ID	Stormwater Volume *(ft3/day)*					
				2-year, 24-hour	*5-year, 24-hour*	*10-year, 24-hour*	*25-year, 24-hour*	*50-year, 24-hour*	*100-year, 24-hour*
40		0.9	281	5,998	7,504	8,675	10,128	11,303	12,480
		0.6	645	4,277	5,351	6,186	7,222	8,060	8,899
		0.6	340	4,225	5,286	6,111	7,134	7,962	8,791
		0.5	341	3,358	4,201	4,857	5,670	6,329	6,987
		1.2	279	8,732	10,924	12,629	14,743	16,455	18,169
		1.2	193	8,467	10,593	12,247	14,297	15,957	17,618
		0.7	328	5,236	6,551	7,573	8,841	9,868	10,895
		1.2	264	8,559	10,708	12,380	14,452	16,130	17,809
		0.7	270	4,629	5,791	6,695	7,816	8,723	9,632
		0.6	636	4,086	5,112	5,910	6,900	7,701	8,502
		0.3	647	2,223	2,781	3,215	3,753	4,189	4,625
		1.9	179	13,529	16,925	19,568	22,843	25,495	28,150
		0.3	342	2,060	2,577	2,979	3,478	3,881	4,285
		0.2	635	1,078	1,349	1,560	1,821	2,032	2,244
		0.6	268	4,393	5,496	6,354	7,418	8,279	9,141
		0.5	644	3,427	4,288	4,957	5,787	6,459	7,132
		1.1	269	7,355	9,202	10,638	12,419	13,861	15,304
		0.6	286	3,852	4,819	5,572	6,505	7,260	8,016
		0.5	610	3,575	4,472	5,170	6,036	6,737	7,438
50		1.3	297	8,870	11,096	12,829	14,976	16,715	18,455
		2.5	161	17,226	21,551	24,916	29,086	32,463	35,843
		1.4	294	9,492	11,875	13,729	16,027	17,887	19,750
		1.1	168	7,940	9,933	11,484	13,406	14,962	16,520
		1.0	653	7,330	9,171	10,602	12,377	13,814	15,253
		0.7	663	4,736	5,925	6,851	7,997	8,926	9,855
		0.6	298	4,460	5,579	6,450	7,530	8,404	9,279
		0.4	326	3,126	3,911	4,522	5,279	5,891	6,505
		0.2	659	1,631	2,040	2,359	2,754	3,073	3,393
		14.9	167	103,976	130,079	150,389	175,562	195,945	216,348
		1.0	169	7,087	8,866	10,251	11,966	13,356	14,747
		0.9	284	6,415	8,025	9,278	10,831	12,089	13,347
		0.5	655	3,687	4,613	5,333	6,226	6,949	7,672
		0.3	660	1,855	2,321	2,683	3,132	3,496	3,860
		1.7	661	12,077	15,109	17,469	20,393	22,760	25,130
		1.6	657	11,473	14,353	16,595	19,372	21,621	23,873
		1.6	296	11,249	14,073	16,270	18,993	21,199	23,406
		1.0	295	7,170	8,970	10,371	12,106	13,512	14,919
		0.8	649	5,720	7,155	8,273	9,657	10,779	11,901
		0.8	282	5,331	6,669	7,710	9,001	10,046	11,092
		0.6	651	4,311	5,394	6,236	7,280	8,125	8,971

Table J-29. Parking lot runoff volume estimates *(non-critical areas in catchment groups 50, 60, 70)*

Catchment	Critical Area	Size *(acres)*	Parking Lot ID	Stormwater Volume *(ft3/day)*					
				2-year, 24-hour	*5-year, 24-hour*	*10-year, 24-hour*	*25-year, 24-hour*	*50-year, 24-hour*	*100-year, 24-hour*
50		1.6	162	11,368	14,222	16,443	19,195	21,424	23,654
		1.0	325	6,795	8,500	9,828	11,473	12,805	14,138
		0.5	650	3,321	4,155	4,803	5,608	6,259	6,910
		0.2	664	1,676	2,097	2,424	2,830	3,158	3,487
		0.6	658	3,940	4,930	5,699	6,653	7,426	8,199
		0.4	283	3,133	3,919	4,531	5,290	5,904	6,519
		0.4	652	2,633	3,294	3,809	4,446	4,963	5,479
		0.3	654	1,839	2,300	2,659	3,105	3,465	3,826
60		6.5	335	45,669	57,134	66,054	77,111	86,064	95,025
		4.9	128	34,358	42,983	49,694	58,013	64,748	71,490
		3.3	118	22,895	28,643	33,115	38,658	43,146	47,639
		1.1	195	7,706	9,641	11,146	13,012	14,522	16,034
		0.7	516	4,776	5,976	6,909	8,065	9,001	9,939
		0.6	517	4,303	5,383	6,223	7,265	8,109	8,953
		0.5	317	3,699	4,628	5,351	6,246	6,971	7,697
		2.9	500	19,958	24,968	28,866	33,698	37,611	41,527
		2.2	247	15,365	19,223	22,224	25,944	28,956	31,971
		0.9	518	6,536	8,177	9,454	11,036	12,317	13,600
		0.9	334	6,182	7,735	8,942	10,439	11,651	12,864
		0.6	324	4,482	5,607	6,483	7,568	8,447	9,326
		5.5	114	38,250	47,852	55,324	64,584	72,082	79,588
		2.5	129	17,400	21,768	25,166	29,379	32,790	36,204
		2.7	344	18,599	23,268	26,901	31,403	35,049	38,699
		2.2	196	15,082	18,868	21,815	25,466	28,423	31,382
		1.9	182	13,080	16,364	18,918	22,085	24,649	27,216
		1.3	126	9,190	11,497	13,292	15,516	17,318	19,121
		2.8	322	19,752	24,710	28,568	33,350	37,222	41,098
		0.8	315	5,323	6,660	7,700	8,989	10,032	11,077
		0.4	316	2,484	3,107	3,593	4,194	4,681	5,168
		1.7	127	11,981	14,989	17,329	20,230	22,579	24,930
		0.3	321	2,176	2,722	3,147	3,674	4,101	4,528
		0.3	313	2,402	3,005	3,474	4,055	4,526	4,997
		0.3	320	2,244	2,807	3,245	3,788	4,228	4,669
70		1.4	271	9,483	11,863	13,716	16,012	17,871	19,731
		2.7	160	18,843	23,573	27,254	31,816	35,510	39,207
		0.3	656	1,804	2,256	2,609	3,045	3,399	3,753