August 28, 2015

Lisa R. Cox
Municipal Stormwater Coordinator
Oregon Department of Environmental Quality
811 SW 6th Avenue
Portland OR 97204

Subject: Hydromodification Assessement

Dear Ms. Cox:

The City of Milwaukie was issued an updated NPDES MS4 Discharge Permit (permit number 101348) on March 16, 2012. This letter is intended to serve as the submittal documentation for the hydromodification assessment report required under Schedule A.5. The hydromodification report, prepared by Brown and Caldwell is attached and certified below.

The undersigned hereby submits this Hydromodification Assessment in accordance with NPDES Permit Number 101348. I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person, or persons, who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Please contact me with any questions.

Respectfully,

Bradley S. Albert
Civil Engineer

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Hydromodification Assessment

Prepared for
City of Milwaukie
August 2015

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

BC	Brown and Caldwell
CCSD #1	Clackamas County Service District #1
CIP	capital improvement project
City	City of Milwaukie
DEQ	Oregon Department of Environmental Quality
DTD	Clackamas County Department of Transportation and Development
EPA	U.S. Environmental Protection Agency
GIS	geographic information system
HCA	habitat conservation area
IJC	Johnson Creek Inter-jurisdictional Committee
JCWC	Johnson Creek Watershed Council
KMS	Kellogg-Mt. Scott Watershed
LID	low-impact development
MMC	Milwaukie Municipal Code
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
Portland SWMM	*City of Portland, 2014 Stormwater Management Manual*
PW Standards	*Milwaukie Public Works Standards*
SMP	City of Milwaukie 2014 Stormwater Master Plan
TMDL	total maximum daily load
UIC	underground injection control
WAP	Watershed Action Plan
WES	Clackamas County Water Environment Services
WPCF	water pollution control facility
WQR	water quality resource

Section 1

Introduction and Key Findings

Brown and Caldwell (BC) completed a hydromodification assessment for the City of Milwaukie, Oregon (City). This study has been conducted in accordance with the City's National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) Permit.

Hydromodification of stream channels is caused by both natural and man-made factors. This study is focused on hydromodification impacts associated with urbanization and MS4 discharges. As a highly urbanized area, past development in the city has impacted stream conditions through the channelization and piping of natural channels, resulting in few remaining open-channel areas in the city.

Because the city is located at the downstream end of both the Johnson Creek and Kellogg Creek watersheds, extensive previous studies have been completed to document hydromodification concerns and action plans for those watersheds in conjunction with the multiple entities and jurisdictions that discharge to those creeks. This hydromodification assessment includes a review of those existing planning documents, a geographic information system (GIS) desktop evaluation of watershed conditions, and targeted field assessments to identify hydromodification indicators on Minthorn Creek (a tributary to Mt. Scott Creek and Kellogg Creek) and Spring Creek (a tributary to Johnson Creek). Contributing drainage area to Minthorn Creek and Spring Creek is almost entirely from area within Milwaukie city limits.

Based on these evaluations, the hydromodification assessment revealed the following findings:

- Current land use and future development patterns in the city indicate limited potential for future flow increases.
- Larger regional planning efforts have previously documented hydromodification concerns and resulting programmatic and capital projects for Johnson and Kellogg creeks and their larger watershed areas.
- Observed stream channels that remain in the city show only minor signs of hydromodification.
- Capital improvement projects (CIPs) at the local and regional levels have been identified to address hydromodification impacts by improving stream channels and managing flows.

In light of these findings, it is recommended that the City continue investment in programs and projects to address hydromodification. The following recommendations are expanded on in Section 8:

- implement key local CIPs, such as projects 1-1, 5-1, and 6-2 (see Table 7-1), to increase flood storage and mitigate peak flows
- support regional projects and programs focused on restoration and enhancement in the Johnson and Kellogg creek watersheds
- modify the City's stormwater design standards to specifically prioritize infiltration and low-impact development (LID) approaches for flow control and infiltration systems
- evaluate the use of LID practices during any future decommissioning of underground injection control (UIC) systems to limit additional stormwater contributions to surface systems

The conclusions and recommendations outlined in this hydromodification assessment may be used to inform City decisions related to land use and development policy, maintenance, design standards, and the selection of CIPs.

Section 2

Hydromodification Background

The city of Milwaukie is located in the greater Portland metro area, adjacent to the Willamette River. The City manages stormwater services for a service area of approximately 4.9 square miles.

As a highly urbanized area, stormwater discharges from the city have the potential to impact stream conditions through hydromodification. Increasing impervious area typically alters runoff conditions and increases flow to the stream channel, increasing stream energy. Increased stream energy can alter stream channels through flooding, bank erosion, bed incision, sediment production, and other impacts.

The City's NPDES MS4 permit requires the City to complete and submit a hydromodification assessment. The assessment must evaluate stream channels in the city to determine whether increased stream flows due to urbanization have impacted the stream channels and whether future development patterns are likely to contribute to additional impacts. The assessment must then identify strategies to address the hydromodification impacts.

2.1 What is Hydromodification?

The U.S. Environmental Protection Agency (EPA) (1993) broadly defines hydromodification as the "alteration of the hydrologic characteristics of coastal and non-coastal waters, which in turn could cause degradation of water resources." This definition covers a range of changes to hydrologic characteristics, which are generally associated with changes in land use, construction or removal of dams, or other man-made or natural channel modifications. This study is focused on the aspects of hydromodification that are addressed by the NPDES MS4 permit and associated with urbanization: erosion; sedimentation; and alteration of stormwater flow, volume, and duration that may cause or contribute to water quality degradation.

While the concept of hydromodification is new to the NPDES MS4 permits in Oregon, the concept is not new in scientific literature, which suggests that the frequency and duration of *geomorphically significant flows* are the primary factors that control channel stability or instability. Geomorphically significant flows range from a lower threshold of flow where bed material begins to move to an upper limit where flood flows are no longer contained in the channel (Dunne and Leopold, 1978). Smaller, more frequent flow events tend to move the most sediment over time, dictating channel dimensions.

When watersheds develop, the overall increase of flow and volume that occurs with increasing impervious surface translates to an increase in stream energy. This increase in stream energy can cause bank erosion, bed incision, sediment production, and other channel alterations. Small storm events tend to result in the greatest change in runoff patterns when development occurs (Hollis, 1975).

Figure 2-1 shows the percent change in stormwater runoff from storm events when a watershed moves from 20 percent to 30 percent impervious coverage. During frequent events, such as the 1-year storm, pervious areas provide opportunity for infiltration and more significant differences in runoff are observed as impervious surfaces are added to the watershed.

For large storm events greater than the 10-year storm, the increasing impervious coverage does not significantly increase runoff. Large storm events typically occur during saturated soil conditions, effectively turning the whole watershed into an impervious surface. Efforts to reduce hydromodification and manage the geomorphically significant flows must pay particular attention to small storm events.

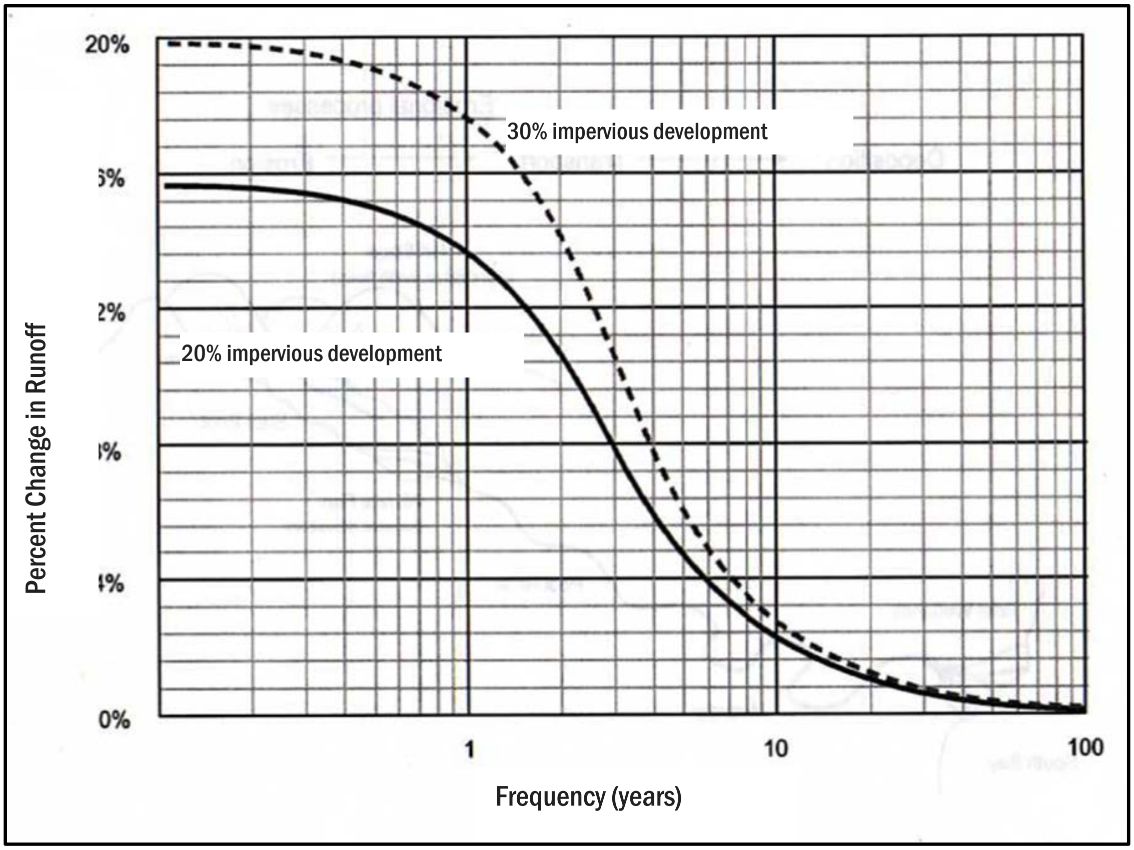

Figure 2-1. Effects of imperviousness and storm frequency on runoff

Source: Hollis, 1975

To control flooding, traditional flow control standards have required detention facilities that reduce peak flows to pre-development levels. These standards do not address the increase in runoff volume or the duration of peak flows. Figure 2-2 shows how the traditional flow control standards may have significant impacts on stream channel conditions. Development and urbanization increase peak flows above pre-development conditions (compare the “Development” line to “Predevelopment” line in Figure 2-2). When detention facilities are installed to reduce peak flows to pre-development levels (see “With Detention” line in Figure 2-2), the result is an increase in the duration of controlled peak flows. Those controlled peaks are often in the range of flows that impact channel shape. Hydromodification control strategies must focus on volume control to reduce the duration and frequency of geomorphically significant flows.

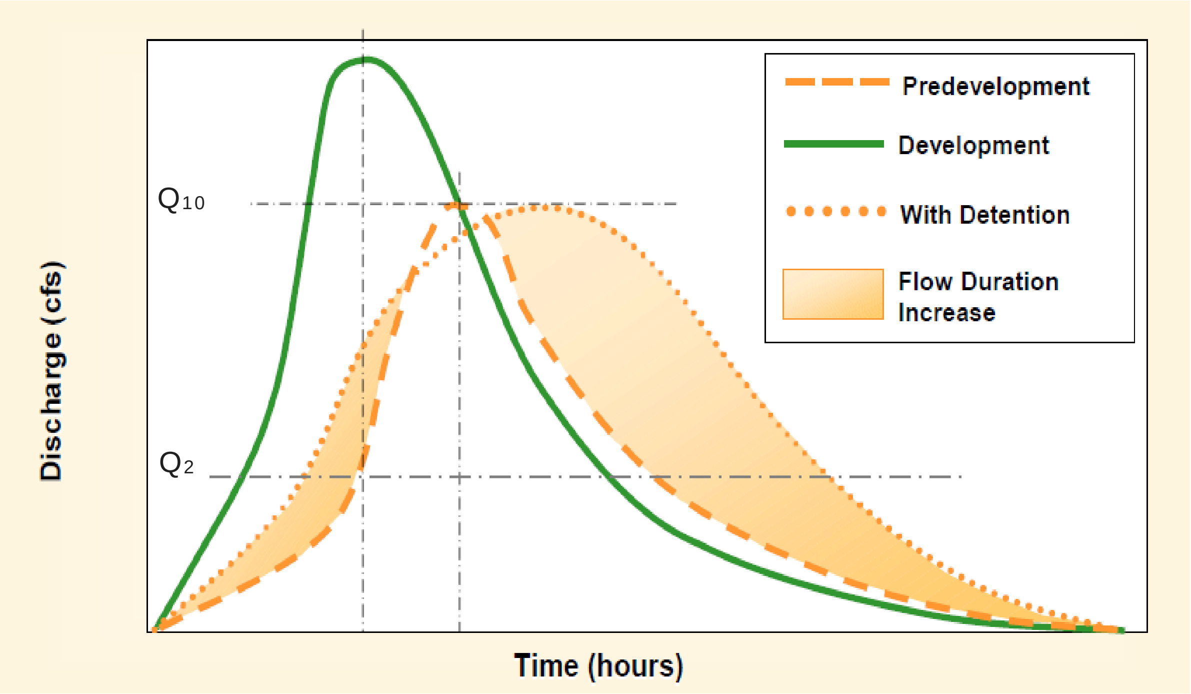

Figure 2-2. Schematic showing how peak flow matching can increase energy in creek systems

2.2 Regulatory Requirements

As a surface water management agency, the City must comply with the federal Clean Water Act and the associated NPDES program. The City is a co-permittee on the Clackamas County NPDES MS4 Phase I Permit 101348, which was issued by the Oregon Department of Environmental Quality (DEQ) on March 16, 2012.

Regionally, addressing hydromodification is considered to be the current best science in surface water management related to flows. The current regulatory emphasis on hydromodification acknowledges that changes in stream channels are due in part to changes in stormwater runoff patterns, peak flow, and volume.

The City's NPDES MS4 permit, Schedule A.5 requires the development of the hydromodification assessment. The specific permit language is written as follows:

5. *The co-permittee must conduct an initial hydromodification assessment and submit a report by July 1, 2015 that examines the hydromodification impacts related to the co-permittee's MS4 discharges, including erosion, sedimentation, and alteration to stormwater flow, volume and duration that may cause or contribute to water quality degradation. The report shall describe existing efforts and proposed actions the co-permittee has identified to address the following objectives:*
    a. *Collect and maintain information that will inform future stormwater management decisions related to hydromodification based on local conditions and needs;*
    b. *Identify or develop strategies to address hydromodification information or data gaps related to water bodies within the co-permittee's jurisdiction;*
    c. *Identify strategies and priorities for preventing or reducing hydromodification impacts related to the co-permittee's MS4 discharges; and,*
    d. *Identify or develop effective tools to reduce hydromodification.*

This report is intended to address the NPDES MS4 permit requirements for the hydromodification assessment.

2.3 Strategies to Address Hydromodification

This section describes potential strategies that jurisdictions might use to address hydromodification. Upland strategies manage flows from the contributing watershed. In-stream strategies adjust stream or creek conditions to accommodate higher flows and prevent ongoing channel alteration. Section 8 provides recommendations about which of these approaches, or combination of approaches, is recommended in the city.

2.3.1 Upland Strategies

Urbanization adds impervious surface, which reduces opportunities for stormwater runoff to infiltrate into the soil layer. As shown in Figure 2-1 in Section 2.1, this results in higher runoff rates and volumes. Typical upland strategies to combat this increase in stormwater flow rates and durations include the installation of stormwater management facilities to manage flows from the contributing watershed and/or site planning adjustments to reduce the impervious area in the watershed. Additional details are included below.

Infiltration. Infiltration reduces the overall volume of stormwater flowing into local waterways during storm events, better mimicking the pre-developed conditions.

Infiltration systems include green infrastructure (i.e., rain gardens, planters, swales), drywells, and infiltration trenches, and infiltrating storage tanks or vaults. Infiltration systems can be located throughout a watershed to infiltrate stormwater near the source or placed at the downstream end of a collection and conveyance system to infiltrate runoff before discharge to a natural channel. Below-ground infiltration systems, such as drywells, infiltrating storage tanks, or vaults, must be designed to comply with regulations governing UIC systems.

DEQ’s NPDES MS4 Phase I stormwater permits require Oregon communities to prioritize LID and other green infrastructure approaches to better mimic natural conditions.

Detention. Flow detention is a runoff management strategy that can be applied to new development areas, redevelopment areas, and regionally as a basin-wide control. Detention systems include ponds, storage wetlands, or underground tanks or vaults designed to capture runoff and release it at a lower rate.

Detention facilities can be designed based on a traditional peak flow matching standard or a flow-duration matching standard. As discussed in Section 2.1, a traditional peak flow matching standard can result in excess stream energy during the range of geomorphically significant flows. Flow-duration matching is the statewide standard in the state of Washington, and several Oregon jurisdictions have adopted a flow-duration matching standard as a way to address hydromodification.

Sizing detention facilities to match peak flow and flow duration can have a number of challenges. One challenge is that it requires use of more sophisticated modeling approaches than traditional approaches. Many jurisdictions that adopt a flow-duration standard also develop tools to aid developers and engineers with implementation. Another challenge is the difficulty in determining the appropriate range of geomorphically significant flows. Often the geomorphically significant flows are quite variable and stream-specific. Jurisdictions may either directly analyze their stream channels through a complicated monitoring approach or rely on literature values and regional assumptions that may over- or under-predict the necessary level of protection.

Site Planning. LID site planning principles emphasize design features that minimize impervious surfaces and reduce the effective impervious area that is directly connected to the MS4. These site planning principles may be applied to new development or redevelopment activities in an effort to replicate pre-development hydrology. Typical site planning principles include clustering development to reduce road and driveway surfaces, narrowing streets, using porous pavements, and disconnecting residential downspouts to provide increased stormwater dispersion and infiltration opportunities. By applying these principles, impervious surfaces in developed areas are reduced, which reduces the need for other flow management strategies.

2.3.2 In-Stream Strategies

When upland strategies are not effective or the preferred method for reducing stream energy in the natural system, in-stream strategies may be required to accommodate higher flows and prevent ongoing channel alteration. Additional details are included below.

Stream Stability Projects. Stream stability projects include a variety of in-stream channel improvements to modify the stream channel to accommodate larger stream flows, while still providing desired habitat, riparian, and water quality features. Stream stability and restoration projects can be effective in addressing hydromodification in areas where the upstream development patterns are established and the stream corridor has adequate buffer areas to allow for the creation of a larger channel and floodplain. Existing culverts and other man-made structures may need to be upsized to accommodate higher flows and/or provide fish passage.

Stream stability and restoration projects typically require permits from natural resource agencies. These projects must be designed to account for both upstream and downstream impacts and are typically most effective when designed to address specific problems within a larger watershed context.

Riparian Zone and Floodplain Restoration. Near-channel restoration is a strategy to reconnect a stream channel to the natural floodplain. Stream channels in equilibrium will naturally overtop stream banks during high flow events. When the channel flows out of bank, stream energy is reduced. Urbanized systems often have limited riparian areas because of development encroachment. This reduces the natural floodplain area available, so excess stream energy is focused in the channel, which leads to bank erosion and bed incision. Maintaining stream buffers, restoring riparian planting, and reconnecting stream channels to floodplain areas are all strategies to reduce stream energy during peak flows.

Piped Bypass Systems. When channel conditions cannot be modified to accommodate a changed flow regime, a piped bypass system could be considered to re-route stormwater flows away from the stream channel and toward reaches that can handle increased flows. To be effective at addressing hydromodification concerns, bypass systems should be designed to bypass excess stormwater flows during the full range of geomorphically significant flows.

Piped bypass systems may be an effective solution to address specific problems in areas that are adjacent to large rivers that can accept increased local flows (Willamette River, Clackamas River, etc.). However, these projects sometimes require property acquisition or a series of easements to install the bypass systems, which can be politically challenging and/or cost-prohibitive.

Section 3

Methodology and Approach

This report is intended to address the NPDES MS4 permit requirements for the hydromodification assessment. This assessment is based on a GIS desktop assessment, targeted field assessment, and review of existing planning documents to develop strategies and approaches to address hydromodification. The results of this study indicate that the City should continue to implement key programs and projects to address hydromodification impacts.

This hydromodification assessment includes the following elements:

- a *literature review* of existing reports and studies that evaluate stream conditions in the city (Section 4)
- a *GIS assessment* of watershed conditions to evaluate drainage patterns, natural features, and the extent of urbanization and future development potential (Section 4)
- a *field assessment* of known problem areas and other locations to identify hydromodification indicators (Section 5)
- a *review of existing planning documents* to determine whether current land use policy and development standards are adequate to protect against further impacts (Section 6)
- an *evaluation of planned projects* to identify projects that will restore impacted channels or help manage stormwater runoff to better mimic historical conditions (Section 7)

3.1 Existing Assessments

The two major streams in the city of Milwaukie are Johnson Creek and Kellogg Creek. Johnson and Kellogg creeks compose the northern and southern boundaries of the city, respectively. Both systems drain major watersheds with significant regional interest. As such, other agencies have previously conducted extensive studies and evaluations for those systems. In 2015, the Johnson Creek Watershed Council (JCWC) organized the first annual Johnson Creek Science Symposium, which is indicative of the level of study currently focused on Johnson Creek. Rather than duplicating efforts, this assessment refers to the work done by others for the larger Johnson and Kellogg creek watersheds. The field assessments in this report are focused on evaluating smaller tributaries in the city to advance existing information. Relevant hydromodification information from the existing assessments is summarized in Section 4.

3.2 Method of Assessment

The overall goal of this hydromodification assessment is to conduct a qualitative evaluation of stream channel conditions and to determine locations where past development patterns and controls (or lack of controls) have resulted in significant stream channel impacts. The assessment also looks at channel conditions to identify areas that are naturally resistant to erosion and incision and areas where minor increases in flows have the potential to cause significant impacts. Figure 3-1 illustrates the relationship between natural stream channel condition and urbanization patterns in causing or resisting hydromodification impacts.

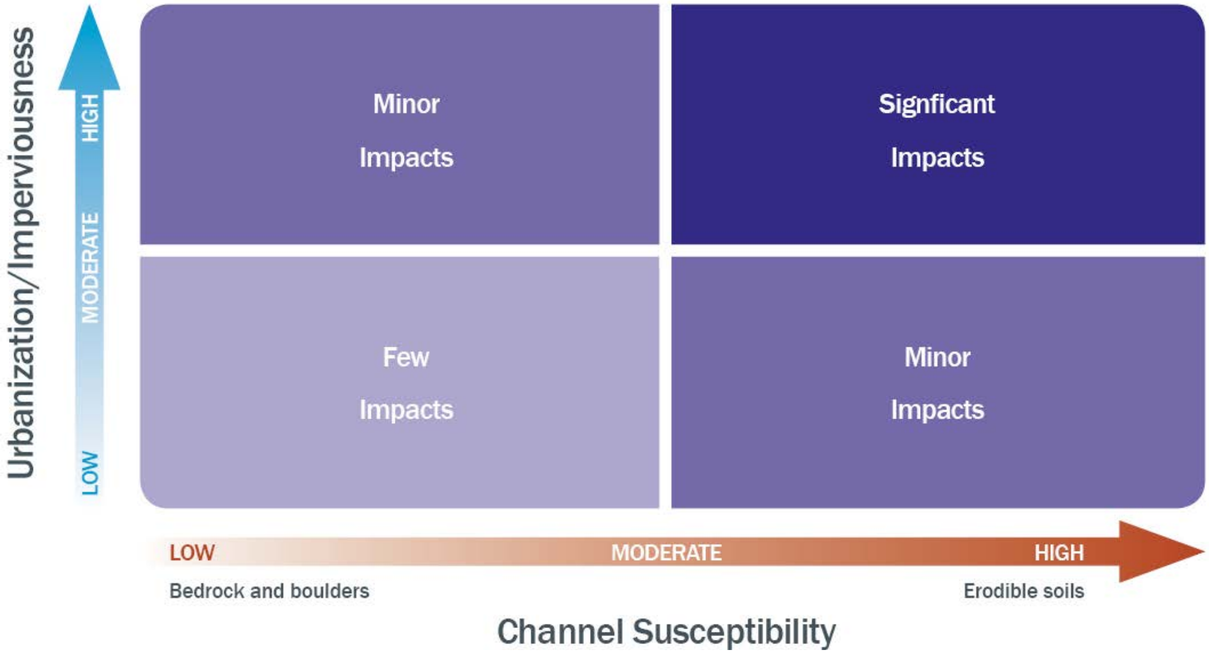

Figure 3-1. Relationship of urbanization and stream channel conditions on hydromodification potential

3.3 Other Methods Considered

DEQ's NPDES MS4 Phase I permit evaluation report acknowledges that the sources and issues related to hydromodification vary among jurisdictions. The combination of geology, topography, hydrology, land use planning, stream channel configurations, and drainage system layout may collectively contribute to hydromodification. However, the same combination of factors, coupled with policies, design standards, and CIPs, may serve to reduce the potential impacts.

Methods to assess and evaluate each stream segment and each hydromodification factor individually would require significant cost and resources. Methods of data collection and analysis that were initially considered for this hydromodification assessment included detailed stream surveys, cross-section mapping, and hydrologic/hydraulic modeling to inform shear stress analysis. Each of these methodologies would have required extensive additional data collection and analysis without significantly advancing the City's understanding of conditions or enhancing recommendations. Instead, this hydromodification assessment relies on existing local knowledge and targeted field assessments. This assessment could provide the background for more extensive data collection efforts in the future, if necessary.

3.4 Future Use of This Assessment

This hydromodification assessment may be used to inform City decisions related to land use and development policies, stormwater design standards, and CIPs. Where CIPs are identified to address hydromodification, they should be incorporated into the City's larger project prioritization and funding strategy. In the past, DEQ has indicated that the results of this assessment may be considered in developing future NPDES MS4 Permit language and post-construction stormwater performance standards.

Section 4

Literature Review and Desktop Assessment

This section includes an evaluation of existing literature and GIS data to form the background for the hydromodification assessment. The goal of the literature review is to document relevant hydromodification information from existing reports and studies, particularly for the Johnson and Kellogg creek systems. The goals of the GIS-based desktop assessment are to evaluate relevant data to understand drainage patterns and locations of natural features and to evaluate how current and future development patterns may contribute to hydromodification.

Source documents for this assessment include the following:

- *Stormwater Master Plan, City of Milwaukie, Oregon* (January 2014) (SMP)
- Johnson Creek Watershed Council, *2015–2025 Action Plan*
- *Johnson Creek State of the Watershed Report*, May 2012
- Watershed Action Plan: Kellogg-Mt. Scott Watershed, Clackamas County Water Environment Services (WES), June 2009 (KMS WAP)

GIS data layers provided by the City were used to evaluate development patterns and create the maps included in Appendix A.

As described in the following sections, past development has significantly impacted natural systems through channelization and piping of natural drainageways to support development. Other than the Willamette River bordering the city to the west, areas of natural open channels are limited to small portions of Johnson and Kellogg creeks as prior to their discharge into the Willamette River, and portions of the Minthorn Creek and Spring Creek tributaries.

While ongoing urbanization has caused hydromodification to the evaluated stream channels, there appears to be little potential for future flow increases. The city is essentially built out and unlikely to expand its service boundary; future development is likely to include small infill redevelopment projects with incremental increases in impervious surface. The City's existing design standards require flow mitigation to offset the incremental increase in flows. Additional information regarding design standards is included in Section 6.

4.1 Watershed Summary

The City's NPDES MS4 service area covers more than 3,100 acres. The city is located adjacent to the Willamette River in Clackamas County. Drainage basins in the city include portions of the Johnson and Kellogg creek watersheds, as well as areas of the Mt. Scott Creek watershed (which is a tributary to Kellogg Creek). Approximately one third of the city is topographically isolated from the major drainages and water bodies and is identified as a drywell basin because stormwater currently is infiltrated into the ground through the use of UICs or drywells. Stormwater from this basin does not directly discharge to stream channels.

Figure 4-1 shows an overview of drainage basins in the city.

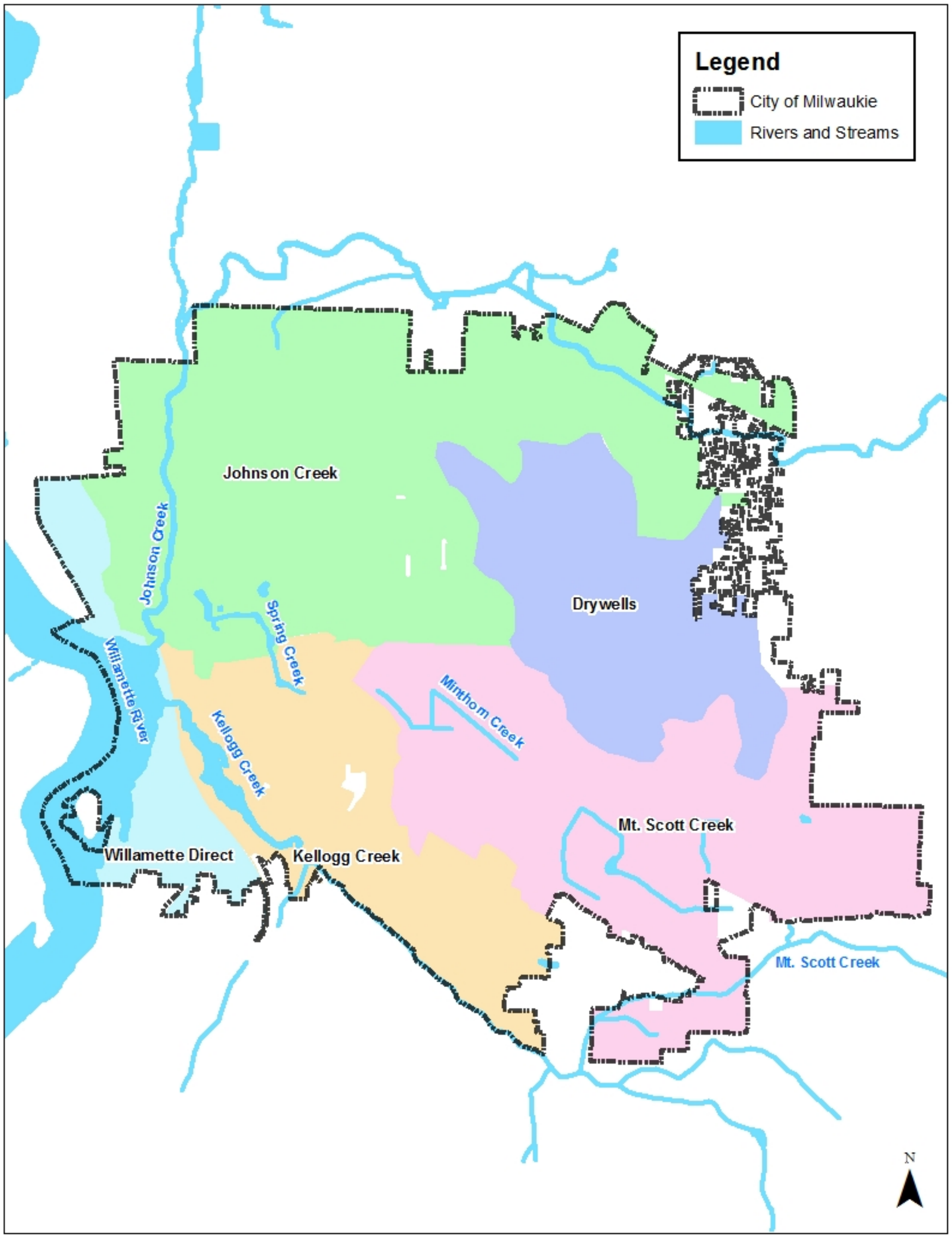

Figure 4-1. Overview of city basins

Source: Milwaukie GIS

Milwaukie is located at the downstream portion of two major watersheds: Johnson Creek and Kellogg Creek. A small area on the west side of the city discharges directly to the Willamette River via sheet flow or short pipe segments. The drainage areas for both Johnson and Kellogg creeks extend far beyond the city's MS4 service area and east into unincorporated Clackamas County (see Table 4-1). Hydromodification impacts to the major receiving waters will be influenced by Milwaukie's projects and policies, but are driven largely by factors upstream of the City's influence.

The City's land use policies and stormwater management programs are likely to have greater impact on tributaries to Johnson and Kellogg creeks, where the drainage areas are smaller and are composed primarily of the city's urbanized area. Tributaries in Milwaukie include Spring Creek, which is a tributary to Johnson Creek, and Minthorn Creek, which is a tributary to Mt. Scott Creek and part of the larger Kellogg Creek watershed.

Table 4-1. City Watersheds

Basin	Total area (acres)	Area within Milwaukie (acres)	Percentage within Milwaukie
Johnson Creek	34,500	1,125	3%
Kellogg Creek/Mt. Scott Creek	10,300	1,290	12%
Willamette River direct	-	185	100%
No outlet/UIC basin	-	460	100%

Source: Milwaukie GIS

Other than the short segments of Johnson Creek and Kellogg Creek and associated tributaries, the city has very few open-channel streams. Most natural drainage features, particularly for Minthorn and Spring creeks, have previously been channelized or piped to support development. With this level of hydromodification, the first priority for the city should be to focus surface water efforts on maintaining and enhancing the existing natural stream channels rather than trying to restore the piped/channelized stream channels to their natural condition and function. Opportunities to restore connections between natural systems, such as replacing culverts with bridges or reconnecting channels to wetland storage areas, may also have a positive impact on areas with limited natural systems.

Topography in the city is largely influenced by Johnson and Kellogg creeks, with elevations ranging from 30 to 200 feet. Soils in the city tributary to Johnson and Kellogg creeks generally have moderate to poor surface water infiltration characteristics. As mentioned previously, approximately one third of the city discharges to UICs or drywells, and areas within this basin experience relatively good infiltration. Because of the use of UICs, stormwater infrastructure is relatively limited in this basin.

The city includes several major commercial and industrial corridors, including Highway 99E on the west side of the city and Highway 224, which is also called the Milwaukie Expressway. These areas have the heaviest concentration of impervious surfaces, though residential areas in the city are nearly fully built out as well. Per the 2014 SMP, only about 5 percent of the city area is identified as vacant.

This watershed summary is supported by the following maps, located in Appendix A:

- Figure A-1. Soils and Topography
- Figure A-2. Zoning and Vacant Lands Coverage
- Figure A-3. Hydromodification Data Compilation

4.2 Development Patterns

As part of the desktop assessment, an evaluation of land use and Metro-designated vacant lands was conducted to assess the current level of urbanization and impervious surface in the city and evaluate whether future development is likely to contribute significantly to additional hydromodification in the stream channels.

The city is highly urbanized with little potential for future development. Most commercial and residential development occurred from 1950 to 1990. Consequently, many developments occurred without stormwater management facilities that would provide treatment or detention of stormwater runoff.

In addition to physical changes to the natural stream system, such as the channelization and piping of the stream channels, urbanization significantly increased the overall impervious surface in the city's basins. The 2014 SMP estimated current impervious surface coverage in the city to be between 35 and 75 percent, depending on land use. The KMS WAP estimated impervious coverage in the Lower Kellogg Creek subbasin, which includes large portions of Milwaukie, at 35–50 percent. As described in Section 2, the conversion of open space and vacant property to a developed land use results in an increase in impervious surface and leads to increased stormwater runoff, particularly for the range of geomorphically significant flows.

During the desktop analysis, Metro-designated vacant lands were reviewed with aerial imagery as shown in Figure A-3 in Appendix A. Vacant lands are generally limited to the corridor along Railroad Avenue and areas near the Willamette River, which are protected from development by sensitive-lands zoning. Most vacant lands with future development potential appear to be single lots or tracts that could be subdivided into additional residential dwelling units or redeveloped to a higher impervious surface coverage.

Per the City's public works standards, development projects are currently required to implement stormwater management controls that restrict peak flows and provide water quality treatment. These controls attempt to address some of the impacts associated with the increased peak flows, but do not currently address volume or duration of flow. However, a majority of future development is likely to be single-lot redevelopment or lot partitions that are typically excluded from implementation of the standards. In general, these small projects are not expected to significantly increase in-channel flow volumes because so much of the watershed is already urbanized and covered with impervious surface.

Additional information regarding the City's stormwater management design standards is included in Section 6.

4.3 Previous Watershed Evaluations

The literature review included evaluating previously completed studies to identify relevant hydromodification data and action plans already completed for watersheds in the city. Both Johnson and Kellogg creeks are regionally significant watersheds and numerous studies have been conducted by local agencies, watershed councils, students, and nonprofit groups.

The following sections document relevant information for Johnson and Kellogg creeks, as identified in existing published documents.

4.3.1 Johnson Creek

Johnson Creek flows 26 miles from its headwaters near Boring, Oregon, to its confluence with the Willamette River in the northern portion of Milwaukie, passing through forests, farms, golf courses, parks and natural areas, industrial stretches, trails, and residential communities. Johnson Creek is home to a number of threatened and native fish and wildlife, including steelhead and cutthroat trout, Coho and Chinook salmon, red-legged frogs, painted turtles, salamanders, pileated woodpeckers, and great blue herons (JCWC Action Plan, 2015).

The JCWC is a large nonprofit organization with a mission to promote restoration and stewardship of the watershed. The JCWC works in coordination with the Johnson Creek Inter-jurisdictional

Committee (IJC), which includes representatives from the City of Portland, City of Gresham, City of Milwaukie, City of Damascus, Multnomah County, Clackamas County, Metro, East Multnomah Soil and Water Conservation District, Clackamas County Soil and Water Conservation District, DEQ, Oregon Department of Agriculture, and U.S. Geological Survey.

The JCWC publishes a regular *State of the Watershed* report and an Action Plan to guide future protection efforts. Johnson Creek is of such great regional interest that the JCWC hosted the first annual Johnson Creek Science Symposium in May 2015, with nearly 30 presentations and posters about scientific research in the Johnson Creek watershed.

The JCWC 2015–2025 Action Plan documents projects and programs for overall watershed health, many of which address hydromodification. In 2011, private landowners, the City of Milwaukie, and the JCWC collaborated to construct engineered log jams and a riffle at the confluence of Johnson Creek with the Willamette River. One hundred and fifty logs were installed to provide cover and shelter for salmon and trout and to allow year-round fish passage over an exposed sewer pipe. Since then, Council volunteers have replanted the 6-acre site with native forest species, removed garbage, and pulled weeds. An interpretive overlook was constructed on the south bluff in Milwaukie Riverfront Park, with signs describing the ecological benefits of log jams and streamside forests and the site's history.

The JCWC also has active projects to reduce impervious surfaces in the watershed, remove fish barriers, and remove man-made pond features. These activities address hydromodification by restoring more natural flow patterns and altered stream channels to a more natural state.

The JCWC also promotes land use policies, outreach programs, public involvement activities, and information sharing with the mission to promote restoration and stewardship of the watershed. Continuing to support the JCWC efforts and participating on the IJC is a major opportunity for the City to address hydromodification in Johnson Creek.

4.3.2 Kellogg Creek and Mt. Scott Creek

The Kellogg Creek watershed is a highly developed urban watershed that is more than 35 percent impervious. The KMS watershed includes eight major subbasins. Drainage areas in the city are part of the Lower Kellogg Creek subbasin and the Mt. Scott Creek subbasin. Land use includes commercial and industrial corridors, along with older residential development west of Interstate 205 and primarily newer residential developments east of Interstate 205.

Clackamas County is the lead agency in managing the KMS watershed, as Clackamas County Service District #1 (CCSD #1) covers over 80 percent of the watershed. Milwaukie covers only 12 percent of the total watershed area.

Adult salmon, steelhead, and cutthroat trout have been documented in Kellogg and Mt. Scott creeks (WES, 2009). A dam constructed under the Highway 99 Bridge at the confluence with the Willamette River has created a potential impediment for upstream migrating salmonids. There is a partial fish passage ladder at the dam and occasional evidence of migrating fish upstream of the dam. The City is part of a regional effort to evaluate the full removal of the existing dam structure and associated Kellogg Lake (see Section 7).

In 2009, Clackamas County WES completed an extensive study of the KMS watershed, to prioritize surface water management program activities and future investments for watershed management. The KMS WAP identified key stressors in the watershed, including loss of tree canopy, reduced infiltration and increased water pollutants from increasing impervious surface, and floodplain development. The KMS WAP identified numerous stress responses in the watershed. Those applicable to this hydromodification assessment are:

- increased flow volume and duration during storm events
- channel instability including bank erosion and channel widening
- flooding affecting infrastructure
- reduction in quality of aquatic habitat through fine sediment accumulation and loss of in-stream structure, such as deep pool habitat and large woody debris

The KMS WAP acknowledges that returning the watershed to its natural hydrologic flow regime is likely not feasible because of the extent of development. However, there is still an opportunity for the Kellogg Creek watershed to serve as functioning aquatic habitat if managed appropriately. The WAP includes the following recommended actions to reduce hydromodification impacts and maintain hydrologic equilibrium throughout the watershed:

- Update stormwater design standards to promote LID techniques for new development and redevelopment areas; implement hydrologic control of runoff from small and large storm events for new development, as well as redevelopment when feasible.
- Ensure that the replacement of structures (e.g., road culverts and bridges) at upstream locations does not change the high flow conditions downstream (or appropriately mitigate for such impacts) and address the potential for channel migration during structure replacement.
- Maintain and, where possible, improve the riparian buffer conditions around stream channels.
- Maintain and, where possible, increase the upland tree canopy in the watershed.
- Evaluate and prioritize opportunities to retrofit older detention ponds to provide flow control and water quality treatment for smaller storm events.
- Track stream channel conditions and bank stability in at-risk areas for erosion and instability in the mainstem and upper tributaries; compare periodically to lower-risk areas.
- Implement strong erosion prevention and sediment control practices in areas at high risk for erosion based on steep slopes and erodible soils, including conducting frequent high-priority site inspections and periodically reviewing site inspection data to continually improve process.
- Continue to track flooding complaints and issues related to WES infrastructure. Evaluate opportunities to assist the Clackamas County Department of Transportation and Development (DTD) in addressing other flooding issues as appropriate in support of overall watershed health.
- Where feasible, provide additional off-channel flood storage and enhanced wetlands with connections to streams.
- Where feasible, improve in-stream habitat using designs appropriate for the current flow regime.
- Investigate use of water rights and active water withdrawals in areas where low summer flow is a concern, such as in Upper Kellogg Creek.

The KMS WAP also includes numerous recommendations to focus on water quality issues and aquatic habitat/biological communities. From all the recommendations, project and program priorities were developed into a long-term implementation plan.

The City of Milwaukie is currently implementing a number of these recommended actions through its existing stormwater design standards, its 2014 SMP and CIP, and its Willamette River TMDL [Total Maximum Daily Load] Implementation Plan for temperature. More details about the CIPs that are relevant to Milwaukie are included in Section 7.

Section 5

Field Assessment

BC and City staff conducted the field assessment in August 2015. The field assessment focused on Spring and Minthorn creeks, using ***hydromodification indicators*** to identify locations where past events have already caused alteration to the stream channel. The data gathered in this field assessment are intended to supplement the assessments already completed for Johnson and Kellogg creeks to form a complete hydromodification evaluation for the City.

The results of the field assessment showed the following hydromodification indicators on the small tributaries in the city:

- heavily modified open-channel areas
- man-made structures that alter channel flow
- minor bed incision in localized areas
- limited riparian areas

These observations indicate that past urbanization has altered the natural flow patterns and open-channel alignment. These changes have also reduced vegetated buffers and floodplain areas, resulting in an increase in stream energy, which can cause flooding, bank erosion, and bed incision. However, most observed locations of bank erosion or bed incision are minor and the majority of observed stream channels look to be stable, although significantly altered.

The field assessment did not identify significant hydromodification impacts on Spring or Minthorn creek. The City could improve existing tributary function by removing man-made structures and targeting restoration projects to enhance riparian corridors. However, greater benefit may come from larger regional projects to address conditions on Johnson and Kellogg creeks.

5.1 Field Methodology

Alissa Maxwell, P.E. and Angela Wieland, P.E., of BC, and Rob Livingston from the City of Milwaukie, conducted the field assessment on August 4, 2015.

The field assessment is qualitative in nature, and was focused on documenting existing channel conditions. Field observations were focused on Spring and Minthorn creeks, as the larger systems have conditions previously established through prior study.

Upstream segments of Spring Creek are located on private property, behind residential homes, which limits access. Therefore, observation locations were limited to the portions of the stream channel at public road crossings, parks, and properties where owners were willing to allow staff to access the stream channel. Minthorn Creek is accessible from the industrial areas and roadways adjacent to Highway 224. Prior to the field assessment, the City identified locations where the natural channel would be accessible. Table 5-1 lists the specific locations of field observations. Field observation locations are also mapped on Figure A-3 in Appendix A.

The field assessment was used to document hydromodification indicators, by taking photographs at each site (see Appendix B) and completing Stream Channel Observation Forms for the observed reaches of Spring and Minthorn creeks (see Appendix C).

Table 5-1. Field Observation Locations

Site number	Water body	Location	Description
001	Spring Creek	Private property at 11123 SE 30th Avenue	• Downstream of culvert under 30th Avenue • Upstream end of open-channel system for Spring Creek • Upstream of man-made ponds on private property
002	Spring Creek	Private properties at 2725 SE Washington Street and corner of SE 27th Avenue	• Corner of Washington and SE 27th Avenue is an old mill site with man-made controls still impacting channel
003	Spring Creek	East side of Spring Creek Apartments, between SE Monroe Street and SE Harrison Street	• Open-channel segment in riparian corridor
004	Spring Creek	Downstream of SE Harrison Street and Portland Waldorf School	• Creek is integrated into urban landscaping
005	Minthorn Creek	SE Mallard Way	• Upstream of open channel is drainage ditch behind Blount International
006 and 007	Minthorn Creek	Between SE Mallard Way and Industrial Way	• Channel through industrial business park
008	Minthorn Creek	Between Industrial Way and Highway 224	• Southern branch of Minthorn Creek through industrial business park
009	Minthorn Creek	At SE Harmony Road, behind Harmony Park Apartments	• Channel through private property with heavy vegetative cover
010	Minthorn Creek	Railroad Avenue and SE Harmony Road	• Downstream end of Minthorn channel • Channel is a drainage ditch along the south side of the railroad • In-stream and macroinvertebrate monitoring site

5.2 Stream Channel Characterization

Table 5-2 lists the hydromodification indicators observed in the city. The table includes both general observations and specific problem locations that show the impacts of hydromodification. The table was developed based on field observation and review of existing documents. The hydromodification indicators documented in Table 5-2 correspond to the Stream Channel Observation Forms included in Appendix C. These indicators are intended to be representative, not comprehensive, in nature.

Table 5-2. City Hydromodification Indicators

Indicators	Current conditions based on available data	
	Spring Creek	Minthorn Creek
Flooding	• None observed or reported.	• None observed or reported.
Degradation/ bed incision	• Creek system is controlled by man-made structures. • Control weir at old mill site (site 002) has eroded, causing concentrated location for stream energy. Channel is actively eroding and incising to reach equilibrium between existing pond and downstream system. Incision looks isolated to small location.	• None observed or reported.
Bank erosion/widening	• None observed.	• None observed or reported.
Riparian vegetation	• Stream channel is located on private property with varying degrees of vegetative cover. Man-made ponds generally do not have quality riparian vegetation. • Sites 002 and 003 showed good riparian cover.	• Channel is located in industrial area with varying degrees of vegetative cover.
Aggradation/ sediment loads *(evidence of increasing sediment loads without capacity to transport)*	• Minor evidence of sedimentation in flat reach downstream of SE Washington Street (site 002), which looks to be sediment from localized incision upstream of SE Washington Street at the old mill site.	• None observed or reported.
Other observed problems or unique features	• Man-made features on private properties include concrete pools, weir structures, and bed controls. • Creek is integrated into urban landscaping, including man-made waterfalls and ponds.	• Channel is primarily constructed open-channel conveyance system to serve industrial business park along Highway 224. • Channel has been constructed as a landscaping feature through industrial park, including pond areas, footbridges, and other landscape features.

The field observations indicate that Spring and Minthorn creeks are small drainage channels. Spring Creek has been historically altered to create in-channel ponds, weirs, small waterfalls, and other landscaping features. One site adjacent to SE Washington Street was previously a small mill. The old mill site has a large concrete detention pond and concrete-lined open channels on site. There is one location of active stream incision, where the concrete-lined channel ends and flow (quickly) discharges to a soil-lined channel, but the impacts are concentrated to a very small channel reach and do not seem to be significantly impacting upstream or downstream channel conditions.

Minthorn Creek is an open-channel conveyance system, likely established as a landscaping feature during the development of the industrial business park north of Highway 224. The system includes a large pond and several footbridges for pedestrian access to buildings. Downstream of the business park, the channel becomes a narrow, shallow channel through private property that includes a drainage ditch along the south side of the railroad at Harmony Road.

Compared to regional conditions, the observed channels in the city show only minor evidence of bank erosion and localized bed incision. Reduced riparian cover and evidence of invasive species were observed in some reaches. The City could improve existing tributary function by removing man-made structures and targeting restoration projects to enhance riparian corridors. However, as mentioned above, greater benefit may come from larger regional projects to address conditions on Johnson and Kellogg creeks.

Section 6

Design Standards and Land Use Policy

This evaluation of the City's stormwater design standards and land use policies was used to determine if existing policies are likely to provide adequate protection against ongoing hydromodification as development occurs in the city. The primary source documents for this evaluation were:

- *Milwaukie Public Works Standards* (PW Standards), last revised February 4, 2015
- Milwaukie Municipal Code (MMC)
- *City of Portland, 2014 Stormwater Management Manual* (Portland SWMM)

Review of these documents showed that the City has existing policies focused on stream protection and flow mitigation. Specifically, the City has existing policies to:

- require detention of stormwater runoff to mitigate peak flows from new development or redevelopment to match pre-development rates
- require stormwater treatment facilities to offset pollutant discharge associated with new development or redevelopment activities, specifically vegetative facilities in conjunction with Portland's 2014 SWMM
- require drywells and UICs to meet DEQ's UIC guidelines, in conjunction with implementation of the City's water pollution control facility (WPCF) permit for UICs
- require stream channel buffers and setbacks to protect existing natural corridors

Minor adjustments to the PW Standards would enhance the existing policies. Based on this evaluation, it is recommended that the City update the PW Standards to specify a development (impervious area) threshold that will require installation of stormwater management facilities, prioritize the use of infiltration and/or LID in flow control facilities, and expand references to the Portland SWMM for detention and infiltration systems. These changes would provide better mitigation for increased runoff from future development. Emphasizing green infrastructure design approaches would also give the City flexibility in retrofitting existing areas.

Current land use policies include requirements for stream buffers that should provide for riparian area protection when the land use restrictions are enforced. However, much of the city was developed prior to the establishment of buffer zones, and existing developments do not have the required setback from the stream channels. Historical development limits the City's opportunities to enhance stream channel function and restore riparian areas and buffers.

6.1 Stormwater Design Standards

The City's stormwater design standards for new development and redevelopment are outlined in the PW Standards, Section 2. Key aspects of the PW Standards include the following policies and design requirements:

- **Thresholds**: Section 2.0040 of the PW Standards indicates that all developments will be required to provide onsite detention, unless the developer can demonstrate by hydraulic analysis that the proposed development will not significantly increase stormwater runoff volumes or peak discharge. Section 2.0050 of the PW Standards implies that all development (with the exception of specific conditions) is required to provide water quality treatment in conjunction with the Portland SWMM. These standards seem to be consistent with the City's NPDES MS4 Permit, which requires stormwater management in conjunction with a threshold for new development and redevelopment of 1,000 square feet of new or replaced impervious surface. However, the City may benefit from providing or specifying the specific impervious area threshold in the PW Standards, and eliminating the subjective language regarding significant stormwater increases in Section 2.0040.
- **Infiltration:** In Milwaukie, soil conditions allow for infiltration of stormwater in many areas. When conditions allow, infiltration facilities reduce runoff volumes and help to reduce the flashiness of peak flows. PW Standards Section 2.0045 has detailed guidelines for testing infiltration rates and designing UIC facilities, as the use of UICs or drywells is common in eastern portions of the city. However, the standards for flow control do not prioritize infiltration as an acceptable alternative to detention.

  In addition, the 2014 SMP, which references the groundwater protectiveness demonstration completed for the City in 2013, identifies a number of existing UICs that are at risk and may need to be decommissioned for compliance with the City's WPCF permit. If decommissioned, the City should consider the use of surface infiltration and green infrastructure as an alternative to installing a piped stormwater system that could result in increased flows to local streams.
- **Flow control:** PW Standards Section 2.0013 requires detention facilities to provide storage up to the 25-year storm event. Post-development flows from the 2-, 5-, 10-, and 25-year events shall be reduced to pre-development levels for the same storms. The current standards do not require volume reduction or duration matching.

  As described in Section 2, protection from hydromodification is achieved by controlling peak flow rates and the duration of flow from development. The flow control requirements in PW Standards Section 2.0013 are aimed at reducing a range of post-development peak flows, but do not require volume reduction or duration matching. These standards are not considered full mitigation in terms of addressing hydromodification impacts from geomorphically significant flows. However, based on projected development patterns in the city, it is not anticipated that the City would need to adopt a flow duration matching standard to address future increases in geomorphically significant flows. In Milwaukie, soil conditions allow for infiltration of stormwater in many areas. Reducing flow volumes through infiltration can be beneficial for multiple reasons including management of geomorphically significant flows, increasing groundwater recharge, and improving water temperature issues. Therefore, the PW Standards could be amended to simply prioritize use of infiltration (without a stringent flow duration matching standard) in order to reduce volumes and durations in conjunction with existing peak flow matching standards.
- **Facility design guidelines:** PW Standards Section 2.0044 prioritizes the use of surface storage ponds over underground storage, but does not include design guidelines for either type of system. PW Standards Section 2.0013 refers to the current Portland SWMM for water quality facility design, which includes some limited guidance for designing orifice and weir control

structures for detention systems, but an equivalent design manual is not referenced for detention facility design.

It is recommended that the City consider refining the PW Standards to adopt the Portland SWMM for both water quality and detention facilities. Adopting the Portland SWMM for all stormwater facility design would also allow the City to prioritize infiltration as a primary method for reducing flow volumes and durations because the Portland SWMM prioritizes LID/infiltration.

6.2 Land Use and Zoning Code

The MMC includes land use requirements that have the potential to impact stream channels, by either contributing to or mitigating hydromodification. The City's land use policies do seek to protect stream channels by requiring stormwater peak flow control, designating vegetated buffers around stream channels, and promoting landscaping and natural surfaces.

The zoning code in MMC, Chapter 17.20.020 requires projects to comply with the PW Standards as described in Section 6.1 above.

The MMC designates several overlay zones that aim to protect stream channels. The City designates water quality resources (WQRs), which include protected water features and associated vegetated corridors, and habitat conservation areas (HCAs), which include significant Goal 5 wetlands, riparian areas, and fish and wildlife habitat. Vegetated corridors around water features range from 15 feet for secondary protected features with flat adjacent slopes to 200 feet for primary protected features with steep adjacent slopes.

The City does allow specific development activities, such as restoration and maintenance activities, within WQRs and HCAs. Other limited uses such as utilities, walkways, and bike paths and existing road expansion are allowed to encroach in the buffer, provided that the projects mitigate impacts by creating additional vegetated areas in the same corridor.

Planting requirements for the WQR and HCA are focused on reestablishing a forested canopy and enhancing vegetation in riparian areas. A vegetated canopy provides opportunity for rainfall interception and evapotranspiration, reducing runoff to stream channels. The field observations documented in Section 5 of this hydromodification assessment show that encroachment from development prevents the canopy from being established on many private properties.

Section 7

Review of Planned Projects

This section documents previously identified CIPs that have the potential to address hydromodification impacts. The City has previously identified CIPs related to the stormwater infrastructure and natural systems in its January 2014 SMP. The identified projects are focused primarily on improving capacity of the stormwater conveyance system, though some projects have the potential to address hydromodification impacts by increasing upland flow control or restoring a more natural flow regime.

7.1 Stormwater Master Plan

The primary source document for existing data regarding the City's stormwater and surface water infrastructure is the SMP. The SMP includes a comprehensive inventory of stormwater infrastructure and hydrologic and hydraulic model results developed to help evaluate existing and projected stormwater flows in the system. While the SMP did not include a comprehensive evaluation of in-stream flow conditions, the modeling provided estimates of contributing flows to the stream systems during various storm events.

The SMP identifies CIPs to address flood control, water quality, and UIC decommissioning needs. The SMP was developed as an integrated plan so that projects address multiple objectives. Therefore, many of the projects address hydromodification impacts through upland flow control, in-stream channel maintenance, and upland erosion/sedimentation control measures. Upland flow control is proposed in the form of rain gardens and other LID stormwater management systems and the retrofit of existing detention ponds to promote infiltration and reduce flow to stream channels.

The SMP includes a project priority list and implementation schedule that was developed in conjunction with a staffing analysis and utility rate study. Projects were prioritized in accordance with City goals and objectives, and a general schedule for implementation was developed based on project priorities and anticipated funding. With adoption of the SMP in August 2013, the City Council approved a proactive rate structure that would promote implementation of the CIPs in a 10-year time frame.

Table 7-1 documents the CIPs from the SMP that have direct or indirect hydromodification benefits for tributary streams within the city. Project locations are also shown on Figure A-3 (Appendix A).

Table 7-1. Stormwater Capital Improvement Projects with Potential Hydromodification Benefits

Watershed	Project number	Project name	Description	Potential hydromodification benefits
Johnson Creek	1-1	Willow Detention Pond Retrofit	Enhance treatment capability of existing pond through vegetation enhancement and promoting infiltration.	Provides upland flow control and opportunities for infiltration
Johnson Creek	1-2	Stanley-Willow UIC Decommissioning	Re-route drainage from decommissioned UICs to existing Ball-Mitchell stormwater facility. Add vegetation to pond bottom to enhance treatment and promote infiltration.	Provides opportunity to mitigate increased flow from decommissioned UICs
Johnson Creek	5-1	Meek Street	Large, multi-phase project to increase system capacity, and provide additional detention and infiltration.	Provides upland flow control and opportunities for infiltration
Johnson Creek (via Spring Creek)	6-2	Washington Green Streets	Extension of existing green street features in conjunction with pipe replacement.	Provides upland flow control and opportunities for infiltration
Mt. Scott Creek (via Minthorn Creek)	13-1	UIC Decommissioning on Lloyd Street	Re-route drainage from decommissioned UICs on Lloyd Street to rain gardens.	Provides opportunity to mitigate increased flow from decommissioned UICs
Mt. Scott Creek (via Minthorn Creek)	13-2	Linwood Avenue	Planning-level study to evaluate opportunity for flood mitigation and water quality in conjunction with CIPs 13-1 and 13-3 (pipe replacement).	Provides upland flow control and opportunities for infiltration
Mt Scott Creek (via Minthorn Creek)	13-4	Railroad Avenue Channel	Targeted maintenance including sediment removal, removal of non-native vegetation, and replanting.	Increases channel capacity and retention capability
Johnson Creek	G2	36th Avenue and King Street (UIC retrofit)	Installation of a rain garden to minimize flow to the existing UIC with reported flooding. This project is an alternative to direct piping of stormwater to Johnson Creek.	Provides opportunity to mitigate increased flow from a limited functioning UIC
Drywell	G3	55th Avenue between King Street and Monroe Street	Installation of a soakage trench to minimize flow to existing UICs with reported flooding. This project is an alternative to direct piping of stormwater to a surface water body.	Provides opportunity to mitigate increased flow from limited functioning UICs

7.2 Regional Projects

Outside the CIPs identified in the SMP, other agencies and watershed groups have initiated regional programs and projects that have the potential to address hydromodification in the city's stream channels. The following sections document the potential regional projects and programs that are identified in the JCWC 2015–2025 Action Plan and the KMS WAP.

JCWC Action Plan

The JCWC's Action Plan includes general priorities that will guide project and program decisions over the next 10 years. The Action Plan includes a listing of priority actions under the following categories: build community, open migration, cooler streams, cleaner water, habitat conservation, and information hub. The priority actions with the potential for direct hydromodification benefits include:

- **Open migration:**
    - **Barrier removal:** Coordinate with partners and private landowners to remove 18 highest-priority fish passage barriers, opening salmon access to 9 miles of habitat.

  - **Aquatic habitat:** Support partner efforts to enhance aquatic habitat and floodplains.
- **Cooler streams:**
  - **In-line ponds:** Analyze which ponds could make the greatest difference in salmonid-bearing tributaries; conduct landowner outreach.
  - **Preserve existing riparian forests:** Increase JCWC conservation efforts and support partner acquisition and policies.
- **Cleaner water:**
  - Identify portions of the watershed that are high priority for private property projects to address stormwater impacts, in partnership with jurisdictions, conservation districts, and Depave.
  - Reach out to commercial, private, industrial, church, and school property owners to promote voluntary pollution and storm flow reduction projects. Share information about relevant incentive and technical assistance programs.
  - Construct demonstration projects on commercial, industrial, church, or school properties.
- **Habitat conservation:** Use the Johnson Creek acquisition strategy to guide support for partners' conservation efforts.

While these priority actions provide only a general framework, it is clear that the JCWC and associated agencies continue to make the restoration of Johnson Creek a high priority. The City of Milwaukie should continue to support regional efforts in Johnson Creek by continuing involvement in the IJC.

Kellogg-Mt. Scott Watershed Action Plan

The KMS WAP includes a more detailed hydromodification assessment with recommended programs and projects. The WAP was developed in 2009 but, because of funding and other resource shortages, many of the priority projects still need to be completed. An overview of the recommendations was included in Section 4 of this hydromodification assessment. Table 7-2 below includes a list of specific priority projects that could have a potential hydromodification benefit to stream systems in the city of Milwaukie.

Of particular interest is project KMS-9: Kellogg for Coho Initiative. The project would address fish passage concerns at the dam located under Highway 99E in Milwaukie. The general project description includes replacing the Kellogg Lake Bridge, removing the Kellogg Lake dam and associated fish ladder, and restoring the Kellogg Creek stream channel. The KMS WAP identified the City as the lead agency on the project. In 2010 the project received a Metropolitan Transportation Improvement Program grant of $1 million to conduct an engineering and environmental assessment of the dam removal. The City has since continued to coordinate with agencies and stakeholders to determine how the project could incorporate water quality trading and/or mitigation banking.

At the time of this assessment, the project has been put on hold because of changing project goals and funding constraints. The Milwaukie City Council still considers this project as a goal. The KMS WAP also includes a number of watershed-wide priorities, which are identified with project numbers starting with "D." These include programs to retrofit existing stormwater facilities (project D-2), install additional water quality treatment facilities (projects D-12 and D-13), and additional fish passage barrier removal (project D-18). These upland and upstream projects could also have hydromodification benefits in the city by improving upstream flow controls and restoring a more natural flow regime in the channel.

The City of Milwaukie should continue to support regional efforts in the Kellogg Creek watershed.

Table 7-2. KMS WAP Projects with Potential Hydromodification Benefits to Milwaukie

Project identifier	Project name	Source document	Description	Lead agency	Potential hydromodification benefits
KMS-3	Dean Creek Wetlands	KMS WAP	Enhance Dean Creek wetlands and stream channel	WES	Improved hydrologic conditions; restored water quality and aquatic habitat; improved riparian buffer
KMS-4	Mount Scott in Three Creeks	KMS WAP	Enhance Mt. Scott Creek to increase floodplain storage and hydraulic connectivity; enhance aquatic habitat in the Three Creeks area	WES	Reduced stream energy due to increased storage and hydraulic connectivity Project area is at the southeast edge of the city
KMS-5	Flood-prone Culverts	KMS WAP	Evaluate flood-prone culverts and options for reducing impacts; modify selected culverts	WES	Restored channel hydraulics, reduced stream energy, and reduced potential for channel erosion at structures
KMS-6	Willing-seller Program	KMS WAP	Purchase property from willing sellers in areas of the Kellogg and Mt. Scott watersheds where the purchase would improve watershed health	WES	Increased riparian buffer and improved floodplain storage
KMS-9	Kellogg-for-Coho Initiative	KMS WAP	Replace the Kellogg Lake Bridge, remove the Kellogg Lake dam and associated fish ladder, and restore the Kellogg Creek stream channel in the City of Milwaukie	City of Milwaukie	Improved stream connectivity; removes a man-made structure; restores more natural stream channel at downstream end of the Kellogg Creek
D-2	SW Detention Retrofit	KMS WAP	Evaluate and prioritize retrofit of existing stormwater detention facilities	WES	Upland flow control
D-4	Channel Morphology Monitoring	KMS WAP	Conduct cross-section monitoring to evaluate changing channel morphology conditions in a variety of watershed locations	WES	Data gathering to inform future decision making
D-5	Improve Riparian Buffer	KMS WAP	Work with private landowners and parties to target riparian planting in priority reaches	WES	Enhanced riparian buffer and canopy; reduced stream bank erosion potential
D-7	Update Erosion Control Protocol	KMS WAP	Update Clackamas County's erosion prevention and sediment control protocol	WES	Reduced sediment contribution to stream channel
D-12 and D-13	Water Quality Retrofit Programs	KMS WAP	Retrofit existing impervious surface with water quality treatment facilities D-12 is for streets and D-13 is for institutional, commercial, and residential areas	Clackamas County DTD and WES	Upland flow control
D-18	Improve Fish Passage	KMS WAP	Replace fish passage barriers with structures that better support natural channel hydraulics	Clackamas County DTD	Restore natural flow regime and channel hydraulics

Section 8

Strategies and Recommendations

The hydromodification assessment presented in Sections 4 through 7 identifies the hydromodification impacts and potential strategies to offset or mitigate those impacts. Observed stream channels in the city display hydromodification impacts associated with past development activities. Such activities included the channelization and piping of natural stream channels, encroachment into riparian areas, and construction of culverts and other structures. As such, observed hydromodification indicators include minor areas of channel incision and bed/bank erosion and stream channel aggradation. While future development activity in the city is expected to be limited as the city is mostly built out, small-scale redevelopment projects will continue to occur over time. Reducing runoff volumes and enhancing groundwater recharge for summer flows would be beneficial and protective of stream systems as the city redevelops.

The results of this study show that the City should continue to implement key programs and projects to address hydromodification impacts. The results of this hydromodification assessment could be used to:

- inform the City's prioritization of CIPs and ongoing implementation schedule
- guide updates to existing stormwater design standards
- support operations and activities to maintain existing stream channels and structures

The following sections provide additional detail about the key programs and projects recommended for implementation.

Capital Improvement Projects

With little expected change to land use or development patterns, the City's best opportunity to address hydromodification is through projects that enhance existing stream channel conditions and/or mitigate peak flows from existing development. As outlined in Section 7 and Table 7-1, the City's SMP includes CIPs that have the potential to address hydromodification impacts. It is recommended that the City continue to prioritize and implement stormwater CIPs based on available funding. Because the observed hydromodification problems in the remaining open waterways are relatively minor, stormwater program priorities should focus on the most pressing issues of water quality, failing infrastructure, and conveyance capacity needs.

Regional Efforts

The City is located at the downstream end of both the Johnson Creek and Kellogg Creek watersheds. Regional action plans are in place to enhance and restore stream channels and improve upland controls. The City currently participates in the JCWC IJC and has coordinated with WES and other agencies on projects in the KMS watershed. The City should continue to support these partnerships and encourage regional cooperation on both upland and in-stream projects that will provide hydromodification benefits. Regional cooperation may come in the form of data collection and information sharing, staff involvement, and/or project cost shares, depending on the project, needs, and resources.

Refine Design Standards

Enhancements to existing PW Standards are recommended to incorporate stormwater facility design guidelines that better mimic natural runoff patterns so that flow regimes are restored incrementally as redevelopment occurs. The following enhancements are recommended:

- Establish a specific threshold when projects are required to install stormwater management facilities, so that developers and project engineers are not left with the burden of proving that a project does not have a “significant” impact to stormwater runoff. It is recommended that the threshold be set at 500 square feet to be consistent with the Portland SWM or 1,000 square feet of impervious surface, consistent with the City’s NPDES MS4 permit.
- Modify PW Standards Section 2.0044 to prioritize the use of surface infiltration and LID facilities to meet flow control requirements to maximize volume reduction without requiring a stringent flow duration matching standard. This should be a specific requirement in conjunction with future UIC decommissioning, in order to avoid increased flow to surface waters.
- Refine the existing language in PW Standards Section 2.0013 to refer to the Portland SWMM for both water quality and detention facility design.

Section 9

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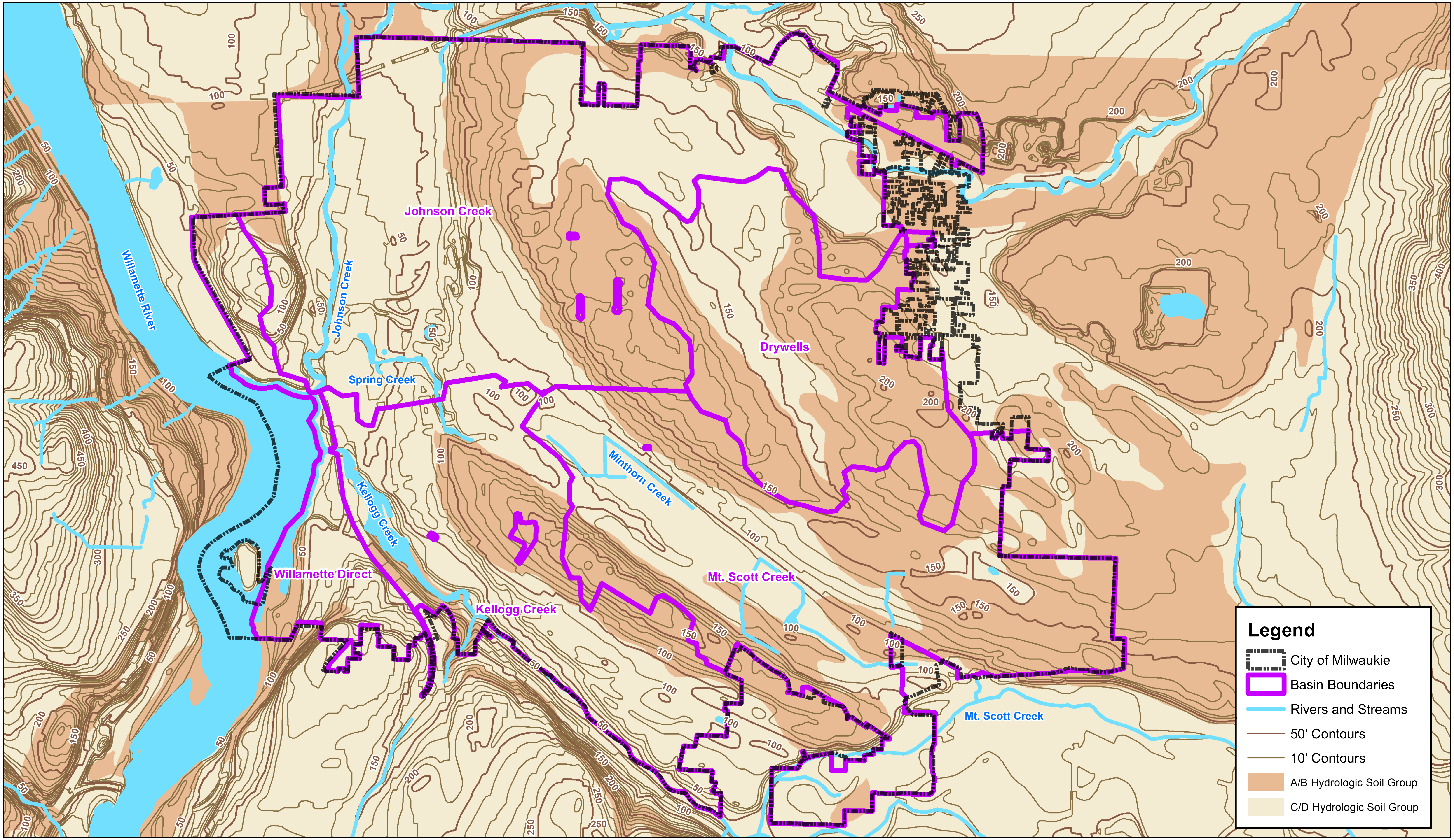
WES. Watershed Action Plan, Kellogg-Mt. Scott Watershed, June 2009, prepared by Brown and Caldwell, Ellis Ecological Services, and Waterways Consulting.

Limitations

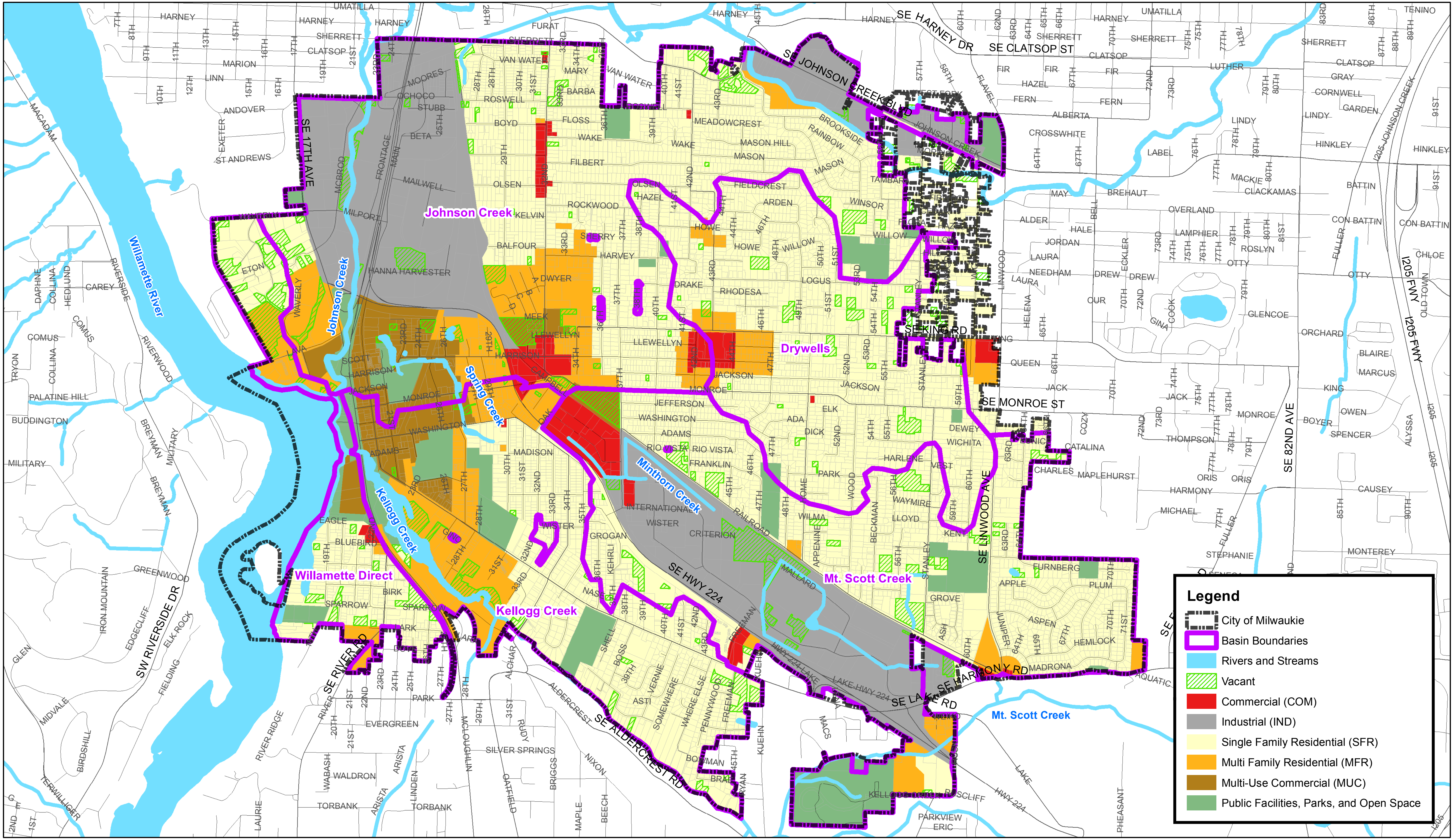
This document was prepared solely for the City of Milwaukie (City) in accordance with professional standards at the time the services were performed and in accordance with the contract between the City and Brown and Caldwell dated May 4, 2015. This document is governed by the specific scope of work authorized by the City; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by the City and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

Appendix A: Figures



City of Milwaukie
Hydromodification Assessment

A-1 Soils and Topography



Brown AND Caldwell

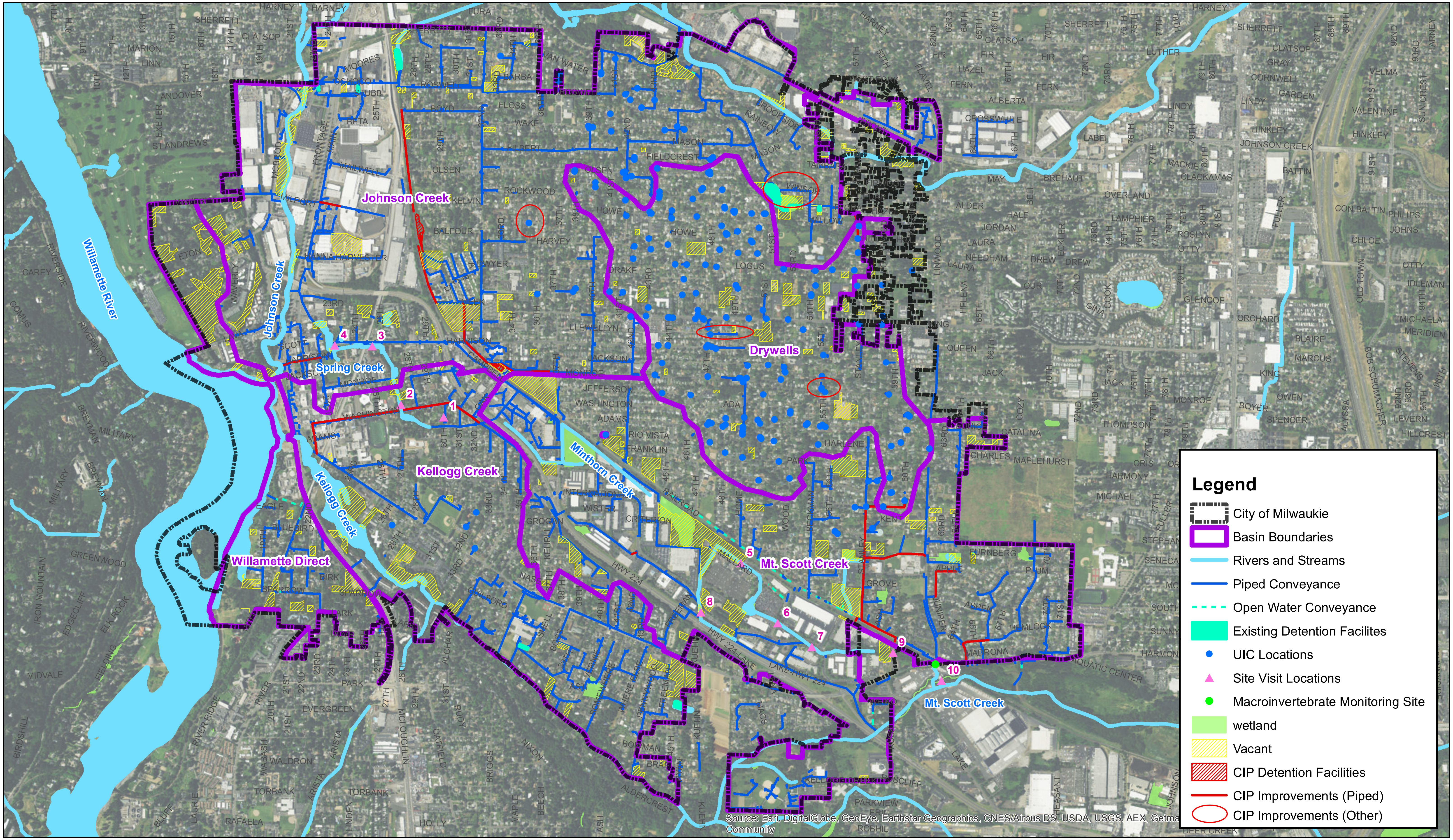
City of Milwaukie
Hydromodification Assessment

A-2 Zoning and Vacant Lands Coverage

0 750 1,500 3,000 Feet

1 inch = 1,500 feet

N



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

City of Milwaukie
Hydromodification Assessment

A-3 Hydromodification Data Compilation

Appendix B: Photo Log

Appendix B

Photo Log Documentation

Photographs and descriptions of the field investigation (by site) are provided on the following pages.

Waterbody:	**Spring Creek**
Reach description:	**Open channel segment on private property at 11123 SE 30th Avenue.**
Site locations:	**001**

Site location:	001
Photo number:	007
Description:	Immediately downstream of culvert under 30th Avenue. Observed gravel and cobble material.

Site location:	001
Photo number:	003
Description:	At culvert and splash pad.

Site location:	001
Photo number:	004
Description:	Looking downstream along private property. Armored banks and manmade impoundment to detain water onsite.

Site location:	001
Photo number:	005
Description:	Looking downstream along private property.

Waterbody:	**Spring Creek**
Reach description:	**Open channel segment on private properties at 2725 SE Washington Street and corner of SE Washington Street and SE 27th Avenue**
Site locations:	**002**

Site location: 002

Photo number: 012

Description: Looking downstream from 2725 SE Washington Street. Observed high sediment load and evidence of minor sediment accumulation.

Site location: 002

Photo number: 014

Description: Looking upstream toward SE Washington Ave. Widened channel with little flow. Established riparian vegetation.

Site location:	002
Photo number:	015
Description:	Steep western bank adjacent to St Johns Church and School. Leaning trees but limited evidence of bank sloughing.

Site location:	002
Photo number:	016
Description:	Mill site at corner of SE Washington Street and SE 27th Avenue, upstream of photos 012, 014 and 015. Concrete lined channel and fast moving flow discharges directly to natural channel system. Evidence of incision and bank erosion at pond outlet.

Site location:	002
Photo number:	017
Description:	Concrete impoundment at Mill site.

Waterbody:	**Spring Creek**
Reach description:	**Behind Spring Creek Apartments between SE Monroe Street and SE Harrison Street**
Site locations:	**003**

Site location:	003
Photo number:	020
Description:	Looking downstream, heavy riparian vegetation and widened channel, consistent characteristics as location 002.

Site location:	003
Photo number:	021
Description:	Hardened southern bank of channel, adjacent to apartments. Little evidence of bank erosion or incision. Significant invasive vegetation (ivy).

Waterbody:	**Spring Creek**
Reach description:	**Downstream open channel segment on SE Harrison Avenue and SE 25th Avenue.**
Site locations:	**004**

Site location: 004

Photo number: 023

Description: Looking upstream from 25th Avenue. Manmade waterfall on the St Johns campus.

Site location: 004

Photo number: 025

Description: Looking downstream from 25th Avenue. Manmade impoundment.

Waterbody:	Minthorn Creek
Reach description:	Upstream portion of creek along SE Mallard Way, behind Blount International.
Site locations:	005

Site location: 005

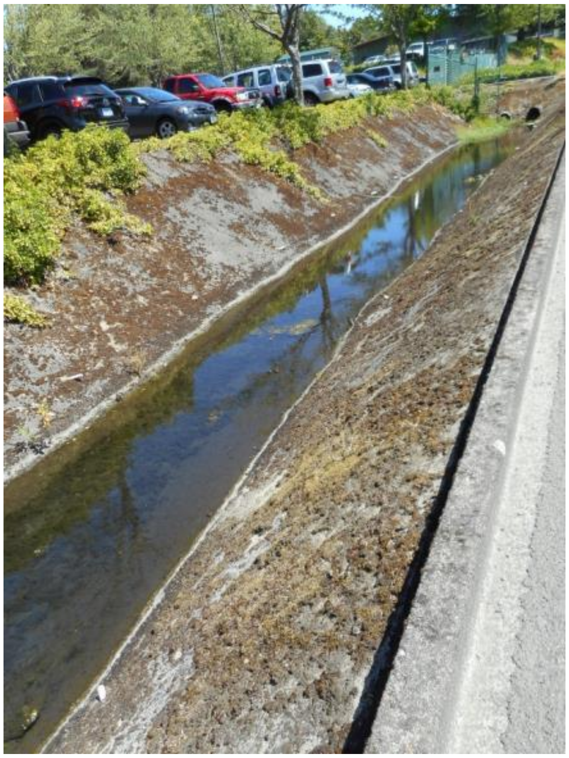
Photo number: 028

Description: Dense vegetative cover along channel adjacent to SE Mallard Way.

Site location: 005

Photo number: 030

Description: Looking downstream. Discharge to concrete lined sediment of channel. Significant invasive (ivy).



Site location:	005
Photo number:	032
Description:	Concrete lined portion of channel.

Site location:	005
Photo number:	034
Description:	Downstream from photo 032. Manmade impoundment.

Waterbody:	**Minthorn Creek**
Reach description:	**Upstream portion of creek along SE Mallard Way, downstream of site location 005.**
Site locations:	**006**

Site location:	006
Photo number:	036
Description:	Looking upstream, some vegetative canopy adjacent to creek and neighboring parking area.

Site location:	006
Photo number:	038
Description:	Looking downstream. Observed slow moving water and minor sediment accumulation.

Waterbody:	**Minthorn Creek**
Reach description:	**At International Way, downstream from site location 006**
Site locations:	**007**

Site location:	007
Photo number:	045
Description:	Looking upstream. Manmade channel adjacent to industrial/ commercial parking areas. Observed invasive (ivy).

Site location:	007
Photo number:	046
Description:	Limited flow and observed algal growth.

Site location: 007

Photo number: 042

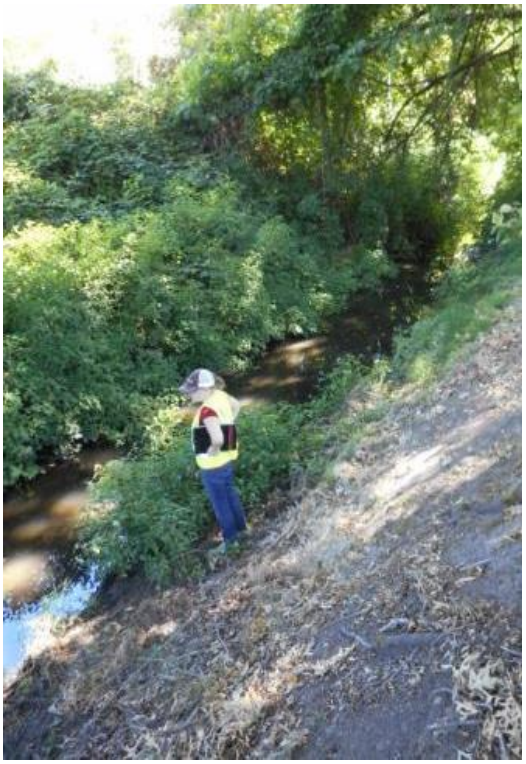
Description: Observed algal growth

Site location: 007

Photo number: 044

Description: Roof drain and parking lot runoff directly discharges to channel.

Waterbody:	**Minthorn Creek**
Reach description:	**Southern branch of Minthorn Creek**
Site locations:	**008**



Site location: 008

Photo number: 053

Description: Tree canopy and riparian vegetation. Significant invasive (blackberries, ivy).

Site location: 008

Photo number: 052

Description: Silty bed sediment and limited flow conditions.

Site location:	008
Photo number:	056
Description:	Silty bed sediment and limited flow conditions.

Waterbody:	**Minthorn Creek**
Reach description:	**At SE Harmony Road, behind Harmony Park Apartments**
Site locations:	**009**

Site location:	009
Photo number:	060
Description:	Dense vegetation and tree canopy. Limited observed flow.

Site location:	009
Photo number:	062
Description:	Dense vegetation and tree canopy. Limited observed flow.

Waterbody:	**Minthorn Creek**
Reach description:	**At Railroad Avenue, current instream and macroinvertebrate monitoring location**
Site locations:	**010**

Site location: 010

Photo number: 067

Description: Looking downstream from monitoring location.

Site location: 010

Photo number: 066

Description: Concrete splash block, silty bed conditions and bank armoring along alignment.

Appendix C: Stream Channel Observation Form

Channel Stability Observation Form

Water Body:	Spring Creek	**Date:**	8/4/15
Site/Location:	001	**Time:**	1^{00} pm
		Crew:	AM, AW, RL
Photos:		**Weather:**	Sunny + warm
Channel Size:	4-5' wide / 3-4' deep	**Observed problems:**	A. Flooding [✓ B. Degradation] C. Bank Erosion D. Lack of Vegetation E. Sediment Loads
Channel Pattern:	Meandering [✓ Straight] Braided [✓ Channelized/Altered]		

A. Flooding

Describe observed/known flooding problems:	N/A

B. Degradation/Bed Incision

Primary Bed Material:	Bedrock Boulders [✓ Cobbles] Gravel Sand [✓ Silt] Clay diverse combo
Degree of incision*	0-25% [✓ 26-50%] 51-75% 76-100% Historic incision, since stabilized.
Exposed Roots	None [✓ Mild] Moderate Severe
Head cutting or nick points	Describe: N/A – Upstream end of open channel system

C. Bank Erosion/Widening

Primary Bank Materials	Bedrock Boulders Gravel/Sand Silt/Clay
Bank Protection	None [✓ Left Bank] [✓ Right Bank] Cobbles armoring banks
Streambank Erosion	Left Bank: [✓ None] Fluvial Mass Wasting Right Bank: [✓ None] Fluvial Mass Wasting armoring
Streambank Instability (% each bank failing)	Left Bank: [✓ 0-25%] 26-50% 51-75% 76-100% Right Bank: [✓ 0-25%] 26-50% 51-75% 76-100%
Vegetation Impacts	Exposed Roots Leaning Trees J-shaped Trees N/A

D. Lack of Vegetation

Established riparian woody-vegetative cover	Left Bank: 0-25% [✓ 26-50%] 51-75% 76-100% open channel Right Bank: 0-25% [✓ 26-50%] 51-75% 76-100% Ponds downstream

E. Sediment Loads

Aggradation	☐ Fresh sediment deposition: channel bar near structure overbank ☐ Unconsolidated bed ☒ Embedded Cobbles Large cobbles w/ siltation
Turbidity/ Siltation	Describe: N/A In channel vegetation

Other

Known or observed problems **Unique features** **Field notes**	Historic Siltation from upstream development In channel walls & concrete controls – bed control

* Degree of incision = relative elevation of the "normal" low water compared to the floodplain/terrace. Normal water equal to the floodplain/terrace represents 100%.

Channel Stability Observation Form

Water Body:	Spring creek	**Date:**	8/4/15
Site/Location:	002 - Backyard d/s of Washington	**Time:**	1^{30}
		Crew:	AM, AW, RL
Photos:		**Weather:**	Sunny + warm
Channel Size:	15'+ wide 12-24" deep	**Observed problems:**	A. Flooding B. Degradation C. Bank Erosion D. Lack of Vegetation E. Sediment Loads
Channel Pattern:	Meandering Straight Braided [✓ Channelized/Altered]		

A. Flooding

Describe observed/known flooding problems:	None reported

B. Degradation/Bed Incision

Primary Bed Material:	Bedrock Boulders Cobbles Gravel Sand [✓ Silt] [✓ Clay]
Degree of incision*	[✓ 0-25%] 26-50% 51-75% 76-100% wide/silty bed
Exposed Roots	None Mild Moderate Severe Artificially widened channel
Head cutting or nick points	Describe: N/A

C. Bank Erosion/Widening

Primary Bank Materials	Bedrock Boulders Gravel/Sand Silt/Clay
Bank Protection	[✓ None] Left Bank Right Bank
Streambank Erosion	Left Bank: [✓ None] Fluvial Mass Wasting Right Bank: [✓ None] Fluvial Mass Wasting
Streambank Instability (% each bank failing)	Left Bank: [✓ 0-25%] 26-50% 51-75% 76-100% Right Bank: [✓ 0-25%] 26-50% 51-75% 76-100%
Vegetation Impacts	Exposed Roots [✓ Leaning Trees] J-shaped Trees

D. Lack of Vegetation

Established riparian woody-vegetative cover	Left Bank: 0-25% 26-50% 51-75% [✓ 76-100%] Right Bank: 0-25% 26-50% 51-75% [✓ 76-100%] invasives under tall trees

E. Sediment Loads

Aggradation	☐ Fresh sediment deposition: channel bar near structure overbank ☒ Unconsolidated bed ☐ Embedded Cobbles
Turbidity/ Siltation	Describe: Major silt collection. Unknown d/s control. or flat topography

Other

Known or observed problems **Unique features** **Field notes**	Setbacks on private property u/s side of washington is old mill site - severely altered to provide concrete pool + water flow channels.

* Degree of incision = relative elevation of the "normal" low water compared to the floodplain/terrace. Normal water equal to the floodplain/terrace represents 100%.

* Attractive nuisance

Channel Stability Observation Form

Water Body:	Spring creek	**Date:**	8/4/15
Site/Location:	003 - Behind Springcreek Apts.	**Time:**	1 30
		Crew:	Am, Aw, RC
Photos:	004 - d/s of waldorf school	**Weather:**	Sunny
Channel Size:	wide - 10-15' / 8-12" deep water	**Observed problems:**	A. Flooding B. Degradation C. Bank Erosion D. Lack of Vegetation E. Sediment Loads
Channel Pattern:	Meandering [✓ Straight] Around property lines Braided Channelized/Altered	NA	

A. Flooding

Describe observed/known flooding problems: NA - in ravine + controlled ponds

B. Degradation/Bed Incision

Primary Bed Material: Bedrock Boulders Cobbles Gravel Sand [✓ Silt] Clay

Degree of incision* 0-25% [✓ 26-50%] 51-75% 76-100%

Exposed Roots None [✓ Mild] Moderate Severe

Head cutting or nick points Describe: NA

C. Bank Erosion/Widening

Primary Bank Materials Bedrock Boulders Gravel/Sand [✓ Silt/Clay]

Bank Protection [✓ None] Left Bank Right Bank

high concrete on banks
↳ not instream channel

Streambank Erosion
Left Bank: None [✓ Fluvial] Mass Wasting minor
Right Bank: None [✓ Fluvial] Mass Wasting

Streambank Instability (% each bank failing)
Left Bank: [✓ 0-25%] 26-50% 51-75% 76-100%
Right Bank: [✓ 0-25%] 26-50% 51-75% 76-100%

Vegetation Impacts Exposed Roots Leaning Trees J-shaped Trees NA

D. Lack of Vegetation

Established riparian woody-vegetative cover
Left Bank: 0-25% 26-50% 51-75% [✓ 76-100%]
Right Bank: 0-25% 26-50% 51-75% [✓ 76-100%] invasives

E. Sediment Loads

Aggradation
☐ Fresh sediment deposition: channel bar near structure overbank
☒ Unconsolidated bed
☐ Embedded Cobbles

Turbidity/ Siltation Describe: Very Silty

Other

Known or observed problems Encroachment from adjacent buildings

Unique features D/S new culverts at light rail projects

Field notes waterfall @ Waldorf School

* Degree of incision = relative elevation of the "normal" low water compared to the floodplain/terrace. Normal water equal to the floodplain/terrace represents 100%.

Channel Stability Observation Form

Water Body:	Minthorn Creek	**Date:**	8/4/15
Site/Location:	005- Backside of Blount Industrial facility	**Time:**	2
		Crew:	AM, AW, RL
Photos:	~~005~~	**Weather:**	Sunny
Channel Size:	5-6' wide 6-12" deep	**Observed problems:**	A. Flooding B. Degradation C. Bank Erosion [✓ D. Lack of Vegetation] E. Sediment Loads
Channel Pattern:	Meandering [✓ Straight] Braided [✓ Channelized/Altered] machine dug ditch to create developable land?		

A. Flooding

Describe observed/known flooding problems:	N/A

B. Degradation/Bed Incision

Primary Bed Material:	Bedrock Boulders Cobbles Gravel Sand [✓ Silt] Clay
Degree of incision*	[✓ 0-25%] 26-50% 51-75% 76-100%
Exposed Roots	[✓ None] Mild Moderate Severe
Head cutting or nick points	Describe: N/A

C. Bank Erosion/Widening

Primary Bank Materials	Bedrock Boulders Gravel/Sand [✓ Silt/Clay] concrete
Bank Protection	None [✓ Left Bank] [✓ Right Bank] → portion of concrete channel
Streambank Erosion	Left Bank: [✓ None] Fluvial Mass Wasting Right Bank: [✓ None] Fluvial Mass Wasting
Streambank Instability (% each bank failing)	Left Bank: [✓ 0-25%] 26-50% 51-75% 76-100% Right Bank: [✓ 0-25%] 26-50% 51-75% 76-100%
Vegetation Impacts	Exposed Roots Leaning Trees J-shaped Trees N/A

D. Lack of Vegetation

Established riparian woody-vegetative cover	Left Bank: [✓ 0-25%] 26-50% 51-75% [✓ 76-100%] Right Bank: [✓ 0-25%] 26-50% 51-75% [✓ 76-100%] portions are 100% open. Portions are fully vegetated

E. Sediment Loads

Aggradation	☐ Fresh sediment deposition: channel bar near structure overbank ☒ Unconsolidated bed ☐ Embedded Cobbles
Turbidity/ Siltation	Describe:

Other

Known or observed problems **Unique features** **Field notes**	Primarily drainage ditch potential private property planting / restoration site

* Degree of incision = relative elevation of the "normal" low water compared to the floodplain/terrace. Normal water equal to the floodplain/terrace represents 100%.

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Channel Stability Observation Form

Water Body: Minthom
Site/Location: 006 - Industrial center
007 - multiple sites d/s
Date: 8/4/15
Time: 2pm
Crew: AM, AW, RL
Photos:
Weather: Sunny
Channel Size: 10-12' wide / shallow
Channel Pattern: Meandering [✓ Straight] Braided [✓ Channelized/Altered]
channel routed to provide developable area.
Observed problems: ~~N/A~~ A. Flooding B. Degradation C. Bank Erosion [✓ D. Lack of Vegetation] E. Sediment Loads

A. Flooding

Describe observed/known flooding problems: None Reported. Channel is correctly sized

B. Degradation/Bed Incision

Primary Bed Material: Bedrock Boulders Cobbles Gravel Sand [✓ Silt] Clay
Degree of incision*: [✓ 0-25%] 26-50% 51-75% 76-100%
Exposed Roots: [✓ None] Mild Moderate Severe
Head cutting or nick points: Describe: N/A – FLAT channel

Stable drainage channel used as landscape feature.

C. Bank Erosion/Widening

Primary Bank Materials: Bedrock Boulders Gravel/Sand cobbles Silt/Clay
Bank Protection: [✓ None] Left Bank Right Bank some historic cobbles to set channel width
Streambank Erosion: Left Bank: [✓ None] Fluvial Mass Wasting
Right Bank: [✓ None] Fluvial Mass Wasting
Streambank Instability (% each bank failing): Left Bank: [✓ 0-25%] 26-50% 51-75% 76-100% Stable
Right Bank: [✓ 0-25%] 26-50% 51-75% 76-100%
Vegetation Impacts: Exposed Roots Leaning Trees J-shaped Trees

D. Lack of Vegetation

Established riparian woody-vegetative cover: Left Bank: [✓ 0-25%] 26-50% 51-75% 76-100%
Right Bank: [✓ 0-25%] 26-50% 51-75% 76-100%

Trees are wide spaced
Ivy! maintained as landscaping

E. Sediment Loads

Aggradation:
☐ Fresh sediment deposition: channel bar near structure overbank
☒ Unconsolidated bed
☐ Embedded Cobbles

Turbidity/ Siltation: Describe:

Other

Known or observed problems
Unique features
Field notes

Algae collection in shallow/slow channels-
Tadpoles

* Degree of incision = relative elevation of the "normal" low water compared to the floodplain/terrace. Normal water equal to the floodplain/terrace represents 100%.

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Channel Stability Observation Form

Water Body:	Minthorn Creek	**Date:**	8/4/15
Site/Location:	008 - → Southern Branch	**Time:**	2:30 pm
		Crew:	An, AW, RL
Photos:		**Weather:**	Sunny
Channel Size:	4-6' wide shallow	**Observed problems:** N/A	A. Flooding B. Degradation C. Bank Erosion D. Lack of Vegetation E. Sediment Loads
Channel Pattern:	Meandering [✓ Straight] → channelized to support development Braided Channelized/Altered		

A. Flooding

Describe observed/known flooding problems:	None reported - heavy vegetation - ~~confined~~ channel in open area between parking lots -

B. Degradation/Bed Incision

Primary Bed Material:	Bedrock Boulders Cobbles Gravel Sand [✓ Silt] Clay
Degree of incision*	0-25% [✓ 26-50%] 51-75% 76-100%
Exposed Roots	None [✓ Mild] Moderate Severe vegetation is heavy
Head cutting or nick points	Describe: N/A

C. Bank Erosion/Widening

Primary Bank Materials	Bedrock Boulders Gravel/Sand [✓ Silt/Clay]
Bank Protection	[✓ None] Left Bank Right Bank
Streambank Erosion	Left Bank: None [✓ Fluvial] Mass Wasting Very minor Right Bank: None [✓ Fluvial] Mass Wasting
Streambank Instability (% each bank failing)	Left Bank: [✓ 0-25%] 26-50% 51-75% 76-100% Right Bank: [✓ 0-25%] 26-50% 51-75% 76-100%
Vegetation Impacts	Exposed Roots Leaning Trees J-shaped Trees N/A

D. Lack of Vegetation

Established riparian woody-vegetative cover	Left Bank: 0-25% 26-50% [✓ 51-75%] 76-100% Blackberries Right Bank: 0-25% 26-50% [✓ 51-75%] 76-100%

E. Sediment Loads

Aggradation	☐ Fresh sediment deposition: channel bar [✓ near structure] overbank d/s of culverts ☒ Unconsolidated bed ☐ Embedded Cobbles
Turbidity/ Siltation	Describe:

Other

Known or observed problems **Unique features** **Field notes**	Narrow setbacks, but no evidence of erosion

* Degree of incision = relative elevation of the "normal" low water compared to the floodplain/terrace. Normal water equal to the floodplain/terrace represents 100%.

Channel Stability Observation Form

Water Body:	Minthorn	**Date:**	8/4/15
Site/Location:	010-Minthorn Creek North branch @ Railroad	**Time:**	245
		Crew:	RL, AM, AW
Photos:		**Weather:**	Sunny
Channel Size:		**Observed problems:**	A. Flooding B. Degradation C. Bank Erosion D. Lack of Vegetation E. Sediment Loads
Channel Pattern:	Meandering Straight Braided [✓ Channelized/Altered] channelized for Railroad		

A. Flooding	
Describe observed/known flooding problems:	None reported
B. Degradation/Bed Incision	
Primary Bed Material:	Bedrock Boulders Cobbles Gravel Sand [✓ Silt] Clay
Degree of incision*	[✓ 0-25%] 26-50% 51-75% 76-100%
Exposed Roots	[✓ None] Mild Moderate Severe
Head cutting or nick points	Describe: N/A
C. Bank Erosion/Widening	
Primary Bank Materials	Bedrock Boulders Gravel/Sand [✓ Silt/Clay]
Bank Protection	[✓ None] Left Bank Right Bank
Streambank Erosion	Left Bank: [✓ None] Fluvial Mass Wasting Right Bank: [✓ None] Fluvial Mass Wasting vegetated ditch
Streambank Instability (% each bank failing)	Left Bank: [✓ 0-25%] 26-50% 51-75% 76-100% Right Bank: [✓ 0-25%] 26-50% 51-75% 76-100%
Vegetation Impacts	Exposed Roots Leaning Trees J-shaped Trees N/A
D. Lack of Vegetation	
Established riparian woody-vegetative cover	Left Bank: [✓ 0-25%] 26-50% 51-75% 76-100% Right Bank: [✓ 0-25%] 26-50% 51-75% 76-100% railroad limits vegetation on area
E. Sediment Loads	
Aggradation	☐ Fresh sediment deposition: channel bar near structure overbank ☒ Unconsolidated bed ☐ Embedded Cobbles Silty—similar to upstream system, but narrower channel
Turbidity/ Siltation	Describe:
Other	
Known or observed problems	concrete box culvert
Unique features	
Field notes	

* Degree of incision = relative elevation of the "normal" low water compared to the floodplain/terrace. Normal water equal to the floodplain/terrace represents 100%.

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