Targeting Best Management Practices and Monitoring Stream Hydrology in the Chagrin Watershed:
Analysis of Riparian Corridor Connectivity and Urban Stormwater Infrastructure

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Introduction

The Chagrin River Watershed Partners, Inc. (CRWP) is a non-profit technical organization founded by the cities, villages, townships, counties, and park districts of the Chagrin watershed. The Chagrin watershed drains 267 square miles to Lake Erie, east of Cleveland, Ohio. CRWP provides land use assistance to 36 Member local governments as they attempt to grow while minimizing the impacts of development on the watershed and protecting water quality. CRWP's work centers on improving the rules of development by assisting Members to implement regulations that maintain the flood control, erosion control, and water quality protection functions of the Chagrin's riparian areas, wetlands, and open spaces while facilitating innovative new and redevelopment stormwater management practices.

The purpose of this project is to improve CRWP's understanding of the existing quality and integrity of the watershed's riparian corridors and gather additional information on the stormwater system infrastructure to determine areas for implementation of Best Management Practices (BMPs). This better understanding is essential to improving the ability of CRWP and member communities to work on riparian protection through a combination of riparian setback zoning; land acquisition; innovative site design; and stream restoration. To refine information on the impacts of impervious cover on hydrologic functions, CRWP needed to complete an analysis to understand how impervious areas are connected to streams. This enabled CRWP to determine areas requiring storm water BMPs, assess local changes in stream hydrology, and determine stream channel protection and restoration needs.

Both parts of this project utilized materials from prior CRWP studies on impervious cover and the previously developed CRWP GIS database. In addition, CRWP collected LiDAR data from the State of Ohio for Part I of this project. Using this data, CRWP assessed the integrity of riparian corridors in the Chagrin watershed. The analysis includes an examination of the height and areal extent of woody vegetation. The output of this analysis will enhance CRWP's ability to target riparian area protection and restoration activities. CRWP worked with URS to complete the LiDAR data manipulation and analysis and the stormwater system infrastructure analysis.

CRWP collected storm sewer data from CRWP Member Communities for Part II of this project to assist in determining the location of storm sewer collection systems and their outfalls in relationship to specific stream reaches. There are 24 NPDES Phase II designated communities in the watershed that are in various stages of developing a map of their outfalls and location of their storm sewer system. CRWP analyzed storm sewer system mapping and data to determine local changes in stream hydrology and priority BMP implementation or retrofit needs. The output of this analysis will enhance CRWP's ability to target member BMP implementation or retrofit needs and to assist communities to better protect and restore stream resources.

Data from both parts of this project have been used as a part of the analysis for local designation of Priority Conservation Areas (PCAs) and Priority Development Areas (PDAs) as a part of the Chagrin River Balanced Growth Plan. The Balanced Growth Plan will allow local communities to communicate their conservation and development priorities to the State of Ohio. In return, the State will align their programs to support the local communities' priorities. Part I of this project informed the selection of PCAs, while

Part II provided valuable information on the infrastructure for designation of potential PDAs. The Chagrin River Balanced Growth Program and this study will be included in the Chagrin River Watershed Action Plan.

Methods

Part I: Riparian Corridor Analysis: Targeting Riparian Setback Implementation through Riparian Corridor Connectivity Analysis in the Chagrin Watershed

In order to better understand the existing quality and integrity of the Chagrin River watershed's riparian corridors, CRWP worked with URS, Corporation (URS) to complete this analysis. The output of this analysis will enhance CRWP's ability to target riparian area protection and restoration activities by assessing the role of riparian areas in moderating stream temperature and the ability of these riparian areas to provide the necessary functions of flood control, erosion control, and water quality protection.

Data Acquisition

CRWP acquired LiDAR data for the Chagrin watershed from the State of Ohio Statewide Imagery Project to help analyze the integrity of riparian areas in the watershed. By integrity we mean that the riparian area is vegetated by trees or shrubs along its length. This could of course be accomplished by either analysis of aerial images, field observation, or both. However, LiDAR allows one to map vertical and horizontal extents of features at very high resolutions, so this technology holds promise for assembling riparian area maps using remote sensing. LiDAR stands for Light Distance and Ranging, and can be thought of as radar that uses light rather than radio waves to remotely sense objects. LiDAR sensors consist of a laser beam generator and sensor, generally mounted in an aircraft. The beam sweeps an area and is reflected off of surfaces. The density of the reflection is an indication of the type of surface from which the light has reflected. For example, the sensor can discriminate between vegetation and the ground. The sensor also measures the distance that the beam travels from the target and back. From these distance measurements, the height and horizontal extent of the objects on the ground can be determined. Thus, LiDAR data can be used to discriminate between broad types of vegetation (such as forest, shrub and field), to map topographies, and to identify structures that lie beneath a forested canopy. Since the sensor uses a short wavelength light beam, the vertical and horizontal resolution is better than traditional remote sensing tools.

LiDAR data were provided to CRWP in the raw LAS format. The raw data was processed by vegetation, ground, and building shots. These data were converted to Digital Elevation Map (DEM) files. Separate DEMs were prepared for vegetation and ground returns.

Riparian Area Delineation

CRWP determined that the CRWP model riparian setback widths as detailed in CRWP's model riparian setback regulation was an appropriate delineation of the riparian area. This determination was made due to the extensive stream and riparian setback layers previously developed by CRWP. The model riparian setback widths are determined as follows:

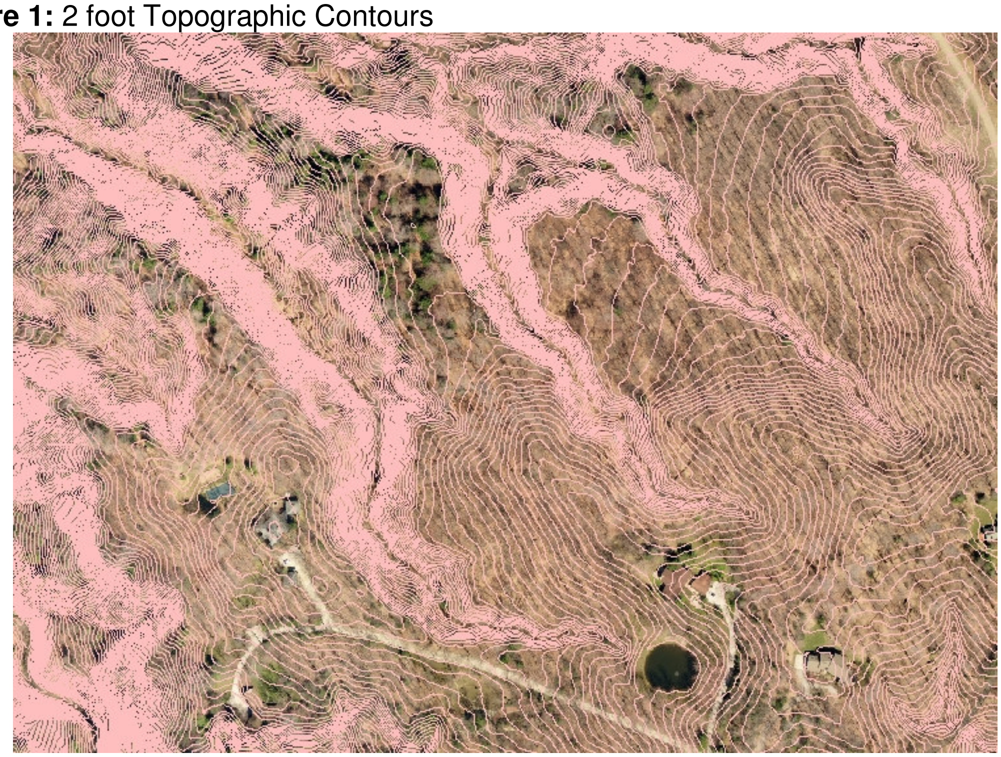
- 300 feet on either side of all watercourses draining an area greater than 300 square miles.

- 120 feet on either side of all watercourses draining an area greater than 20 square miles and up to 300 square miles.
- 75 feet on either side of all watercourses draining an area greater than ½ square mile and up to 20 square miles.
- 25 feet on either side of all watercourses draining an area less than ½ square mile and having a defined bed and bank.

These widths are extended to the 100 year floodplain or nearby wetland boundaries to create the full riparian setback width.

Topographic Analysis
Since LiDAR is able to map the ground surface, contour maps for all the CRWP member communities were developed. These were developed as 2 foot contour interval maps and were made available as GIS shapefiles. To produce these maps, CRWP first converted the raw ground return LiDAR data to a Triangular Irregular Network, or TIN. A TIN is essentially a rough 3 dimensional representation of a surface. Figure 1 shows the 2 foot contours as developed for an area of Hunting Valley. These topographic maps are accurate as of spring 2006, when the LiDAR flights were made.

Figure 1: 2 foot Topographic Contours

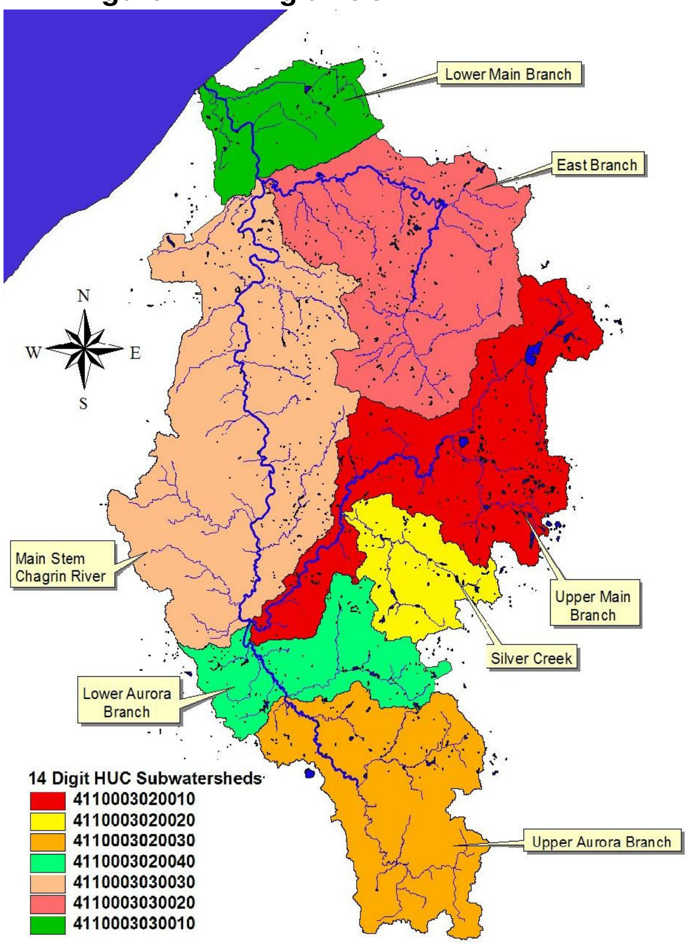


In addition to developing contour maps, an analysis was completed to identify areas that could offer storage, infiltration and other riparian functions. The LiDAR ground data was used to identify depressions or low spots throughout the watershed. Using Arcview, these depression "points" were saved as point locations, resulting in tens of thousands of points. Sink points were then buffered by 50 feet, and those points whose 50 foot buffer rings touched were aggregated into depressions. All depressions that lay within a riparian setback or that lay within 100 feet of the streams draining over 0.5 square mile were identified as potential storage areas. The storage areas were under laid by a soils layer and those storage features that contained A and B soils were identified Type A & B soils are those soil types that would allow percolation. Potential storage areas outside of the riparian setback in headwater areas were not included as these streams may be ephemeral channels that provide the storage function in these areas. This data was also used in the analysis for Part II of this project.

Subwatershed Delineation

The Chagrin River watershed is part of the 8 digit hydrologic unit code (HUC) 04110003, which also includes several Lake Erie direct tributaries and the Ashtabula River. These watersheds are further divided into seven - 14 digit HUC watersheds, shown in figure 2.

Figure 2: 14-Digit HUC



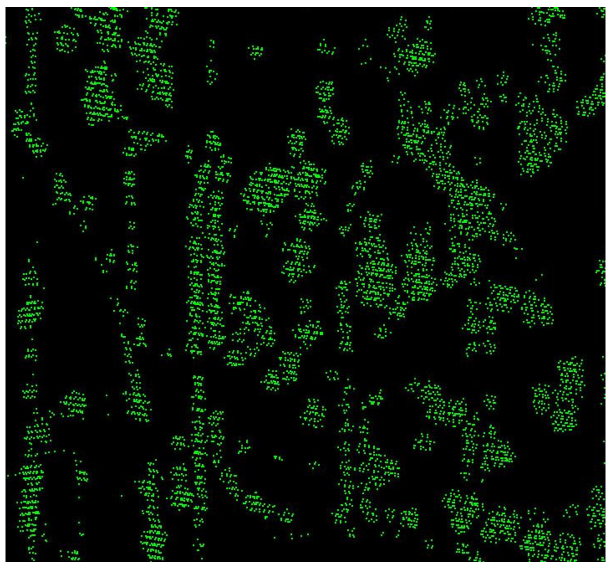
- **04110003-020-010:** Upper Main Branch Chagrin River to Aurora Branch, except Silver Creek. Includes Beaver and Dewdale Creeks, Springbrook, & Woodiebrook.
- **04110003-020-020:** Silver Creek, includes South Branch of Silver Creek
- **04110003-020-030:** Aurora Branch above McFarland Creek to Chagrin River, includes Linton Creek.
- **04110003-020-040:** Aurora Branch headwaters to above and including McFarland Creek.
- **04110003-030-010:** Chagrin River below East Branch to Lake Erie, includes Corporation Creek, Ward Creek.
- **04110003-030-020:** East Branch Chagrin River includes Pierson Creek, Stoney Brook.
- **04110003-030-030:** Main Branch Chagrin River below Aurora Branch to above East Branch includes Willey Creek, Pepper/Luce Creek, Griswold Creek, Caves Creek, Beecher's Brook, Upper 40/Foster's Run, Gulley Brook.

Land Cover Analysis
The height of vegetation was used to determine whether the dominant land cover in an area was forest, shrub, or herbaceous vegetation. Arcview was used to analyze the LiDAR data to identify areas that meet various height criteria. In order to establish true vegetation heights, the ground elevation data was subtracted from the vegetation height data. Vegetation categories were determined following the Cowardin classifications used for wetlands, as detailed below:

- Forest: Vegetation points with heights of 20 feet or more.
- Shrub: Vegetation points with heights between 5 and 20 feet.
- Herbaceous/Open: Vegetation points with heights of 5 feet or less.

Figure 3 shows the first analysis from the processed LiDAR data. In this image, forest areas are represented as green points. All other vegetation (less than 20 feet) and the ground return are shown in black.

Figure 3:



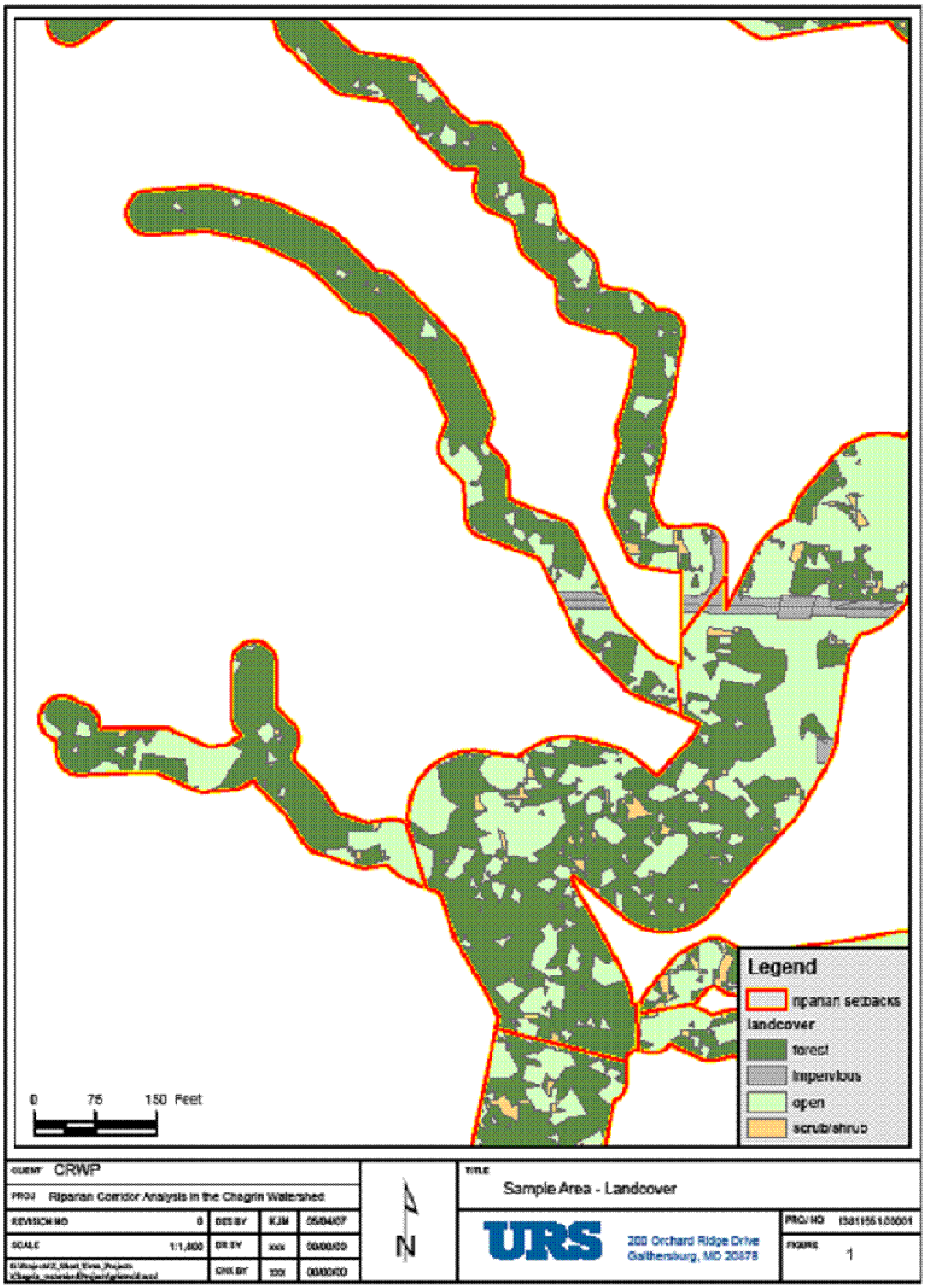
The herbaceous/open category included areas of open water, roads and other paved surfaces, and buildings. The open water areas were subtracted by overlaying the open coverage with the CRWP streams and lakes layers and removing the areas covered by water. Finally, buildings and roads were "subtracted" using appropriate planimetric data from CRWP. Table 1 details the data files used from CRWP GIS database for this analysis.

Table 1: CRWP data sets used for LiDAR analysis.

File name	**Date**	**Use**
Muni.shp	4/2006	Municipal boundaries
Buildings0206.shp	2/2006	Extract building footprints
HUC14.shp	2/2006	HUC 14 watersheds
Streams1262007.shp	12/2007	Streams and setback distances

The classified vegetation data were then clipped using the CRWP riparian setback layer to assess the current quality of the riparian corridor. Figure 4 shows an example of the data for a portion of Russell Township. The riparian corridor is shaded according to the predominant vegetation type within the corridor. Areas dominated by trees are shaded in dark green, areas dominated by shrubs are shaded in light green, and herbaceous dominated areas are shaded in orange.

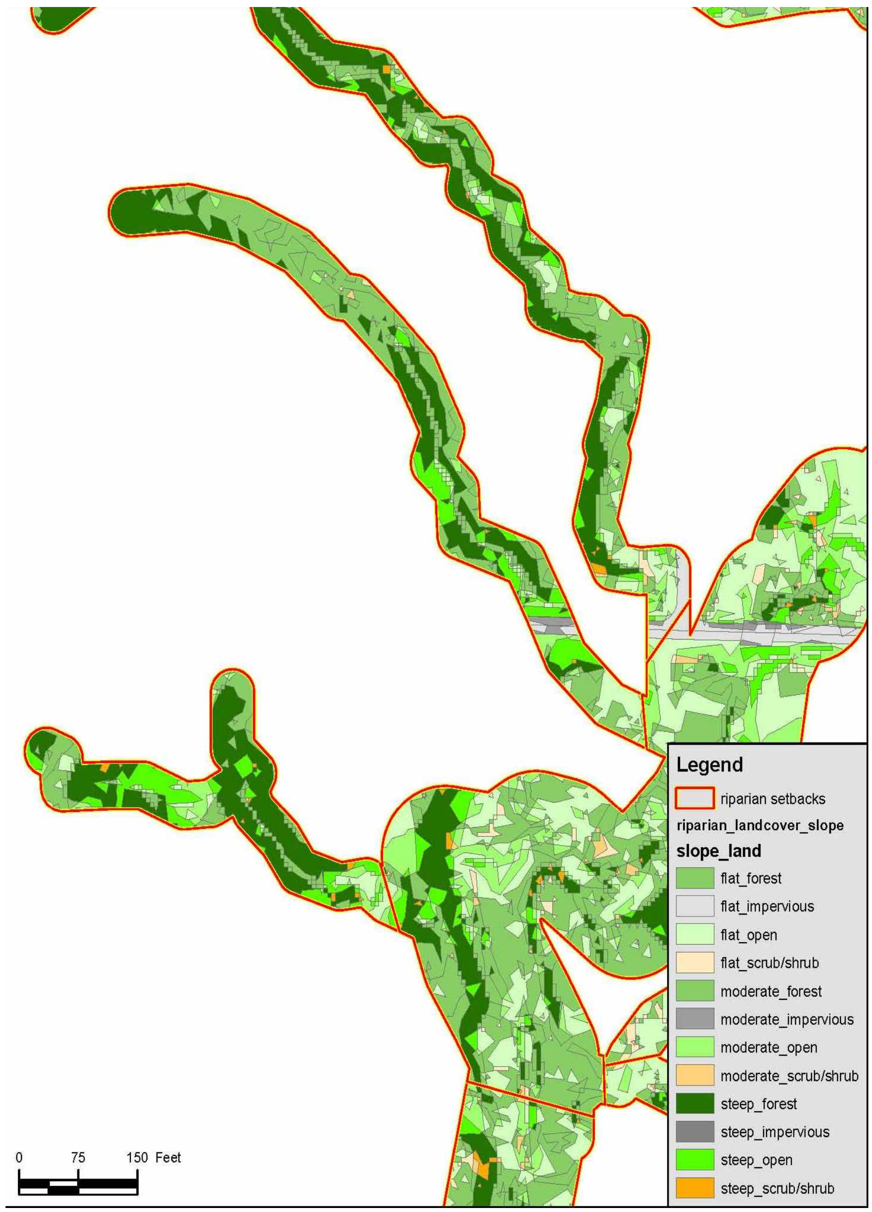
Figure 4:



The impervious cover value was estimated based on the CRWP GIS layers for building footprints and roads, but does not include driveways, sidewalks, parking lots, and other smaller impervious areas. Thus the impervious cover within the riparian corridor is a slight under estimate. In addition, the open water is a mix of the actual river width within the corridor and any ponds, lakes, or open water wetlands included within the corridor.

Figure 5 shows a land cover analysis combined with slope categories for a portion of Griswold Creek. Different colors represent combinations of cover and slope. This map reflects the low amounts of impervious cover and higher amounts of forest cover within the riparian corridor.

Figure 5:



Riparian Integrity Analysis

Riparian integrity was assessed in terms of deviation from a locally derived reference site. This is different from an approach where the comparison is made to a theoretical best standard, based most likely on a literature review. CRWP felt this approach was sound in a watershed like the Chagrin, where there are intact reaches that can serve as reference. The reference approach assumes that one measures against the best stream corridors available, rather than a state that might theoretically be achievable. Table 2 lists the metrics used to assess riparian integrity.

Table 2: Metrics for Riparian Integrity

Riparian Integrity Criterion	**Discussion**
Vegetation intact on banks	Vegetation data were analyzed by height categories: > 20 feet = forest 3 to 20 feet = shrub <3 feet = open This is a graded scale, where the highest score goes to stream reaches where both banks are forested, through the entire width of the riparian corridor.
Vegetation interspersion	This metric expresses the proportion of tree, shrub, and herbaceous vegetation, and the dispersion of the patches of each cover type.
Proportion of impervious cover	Percent impervious cover calculated for each subwatershed and community.
Quality of "near stream" vegetation	This metric analyzes cover within a narrow band, 30 feet (assumed to be equivalent to one tree canopy) within the riparian corridor.

Riparian corridor vegetation data was analyzed using Patch Analyst (http://flash.lakeheadu.ca/~rrempel/patch/index.html), an ArcView extension package developed by Dr. Robert Rempel at the Center for Northern Forest Research. Patch Analyst calculated various landscape ecological metrics detailed in Table 2 based on the number, size, shape and distribution of patches in a landscape. Tables 3 and 4 summarize the output data of the Patch Analyst program. Table 3 highlights the type of land cover and associated number and size of patches. Table 4 investigates the amount of edge associated with the patches. These factors are of interest as larger patches of forested land with a smaller amount of edge are more likely to be high quality forests and provide better habitat.

Table 3 shows the patch results of the landscape analysis of LiDAR vegetation data within the riparian corridor in each 14 digit subwatershed of the Chagrin. Total area by cover class (in ft^2), percent of each class in the riparian corridor, the number of patches in each class and the mean patch size is presented for each 14 digit sub-watershed. Note in this analysis the "open category" includes open water in addition to herbaceous material.

Table 3: Patch metrics for 14 digit sub-watersheds.

Name and 14 Digit HUC	**Class**	**Class area ($ft.^2$)**	**Percent Area**	**No. of Patches**	**Mean Patch Size ($ft.^2$)**
Chagrin River headwaters to Above Aurora Branch 0411003-020-010	Open	99492593.83	48.05	44082	2256.99
	Forest	98115302.78	47.39	105204	932.62
	Scrub	7622750.90	3.68	120982	63.01

Table 3: Patch metrics for 14 digit sub-watersheds.

Name and 14 Digit HUC	Class	Class area (ft.^{2})	Percent Area	No. of Patches	Mean Patch Size (ft.^{2})
4,753 acres in riparian corridor	Impervious	1814658.33	0.88	4898	370.49
Summary				275166	905.78
Silver Creek	Forest	27019821.28	49.80	32102	841.69
0411003-020-020	Open	24487499.21	45.13	13360	1832.90
	Scrub	2284318.08	4.21	34002	67.18
1245 acres in riparian corridor	Impervious	462332.76	0.85	1159	398.91
Summary				80623	785.17
Aurora Branch headwaters to	Forest	62345796.42	48.34	71481	872.20
above McFarland Creek	Open	60296017.55	46.75	31557	1910.70
0411003-020-030	Scrub	5501025.33	4.26	72331	76.05
2961 acres in riparian corridor	Impervious	843287.26	0.65	2200	383.31
Summary				177569	810.57
Aurora Branch above McFarland Creek.	Open	27666862.16	48.86	19915	1389.25
to the Chagrin River	Forest	26400751.02	46.63	37198	709.74
0411003-020-040	Scrub	1834660.30	3.24	32887	55.79
1300 acres in riparian corridor	Impervious	717272.64	1.27	1734	413.65
Summary				91734	642.11
Chagrin River below Aurora	Forest	144918575.16	53.74	165030	878.13
Branch	Open	113433390.37	42.06	79757	1422.24
0411003-030-010	Scrub	6576086.62	2.44	139046	47.29
6191 acres in riparian corridor	Impervious	4749919.49	1.76	10957	433.51
Summary				394790	695.29
East Branch Chagrin River	Forest	108199892.84	58.83	129160	837.72
0411003-030-020	Open	68994527.03	37.51	62282	1107.78
	Scrub	5115562.16	2.78	107712	47.49
4222 acres in riparian corridor	Impervious	1619179.65	0.88	4965	326.12
Summary				304119	579.78
Chagrin River below East Branch to	Open	43636330.33	68.36	15563	2803.85
Lake Erie	Forest	14989534.24	23.48	20130	744.64
0411003-030-030	Impervious	4054719.13	6.35	4121	983.92
1466 acres in riparian corridor	Scrub	1157194.45	1.81	22654	51.08
Summary				62468	1145.87

Table 4 shows the calculated edge metrics for the 14 digit sub-watersheds. For each subwatershed, the total linear edge, edge density (total edge by class divided by landscape area), mean patch edge, mean shape index and the mean perimeter to area ratio is presented. Mean shape index compares the shape of the patch to a square that has a mean shape index of 1. The higher the mean shape index the more complex the edge. Patches with more complex edges are generally less ecologically stable than patches with simple edges. Note in this analysis the “open category” includes open water in addition to herbaceous material. As riparian corridors are long and thin, they have a great deal of edge in relation to their interiors. Further, the riparian corridors are most narrow at the headwaters and widest along the main stems of larger streams. A more edgy landscape is seen in the headwater areas as a result of the relative width and length of the riparian corridors. For this reason, we recommend that riparian health be ranked by the patch, rather than the edge analysis.

Table 4: Edge metrics for 14 digit sub-watersheds.

Name and 14 Digit HUC	Class	Total edge (ft)	Edge Density	Mean Patch Edge (ft)	Mean Shape Index	Mean Perimeter to Area Ratio
Chagrin River headwaters to	Open	11721641.76	0.0566	265.905	1.814	2.201
Above Aurora Branch	Forest	14743621.44	0.0712	140.143	1.574	2.135
0411003-020-010	Scrub	3683896.25	0.0178	30.450	1.346	2.350
4,753 acres in riparian corridor	Impervious	384937.74	0.0566	265.905	1.814	2.201
Summary		30534097.19	0.0369	128.7723	1.6107	2.6055
Silver Creek	Forest	4571678.48	0.0843	142.411	1.613	1.991
0411003-020-020	Open	3259273.55	0.0601	243.958	1.858	1.828
	Scrub	1054531.60	0.0194	31.014	1.359	3.334
1245 acres in riparian corridor	Impervious	102095.06	0.0019	88.089	1.720	3.661
Summary		8987578.69	0.0414	126.3678	1.6376	2.7035
Aurora Branch headwaters to	Forest	4819890.17	0.0851	129.574	1.587	2.137
above McFarland Creek	Open	7761858.22	0.0602	245.963	1.791	2.185
0411003-020-030	Scrub	2378516.71	0.0184	32.884	1.359	2.926
2961 acres in riparian corridor	Impervious	185205.42	0.0014	84.184	1.715	5.086
Summary		20132015.12	0.0390	125.0551	1.6077	3.0964
Aurora Branch above McFarland Creek.	Open	4153336.85	0.0734	208.553	1.746	2.217
to the Chagrin River	Forest	4819890.17	0.0851	129.574	1.587	2.137
0411003-020-040	Scrub	947920.40	0.0167	28.824	1.355	2.856
1300 acres in riparian corridor	Impervious	136149.58	0.0024	78.518	1.637	5.627
Summary		10057296.99	0.0444	111.3671	1.5811	3.2095
Chagrin River below Aurora	Forest	23717888.43	0.0879	143.719	1.586	1.792
Branch	Open	16994175.80	0.0630	213.074	1.768	1.896
0411003-030-010	Scrub	3723360.80	0.0138	26.778	1.343	2.820
6191 acres in riparian corridor	Impervious	971186.33	0.0036	88.636	1.690	3.811
Summary		45406611.36	0.0421	118.0518	1.5966	2.5798
East Branch Chagrin River	Forest	18973133.63	0.1032	146.896	1.619	1.796
0411003-030-020	Open	12488249.36	0.0679	200.511	1.819	2.001
	Scrub	2888423.54	0.0157	26.816	1.351	2.711
4222 acres in riparian corridor	Impervious	393331.16	0.0021	79.221	1.724	3.549
Summary		34743137.69	0.0472	113.3612	1.6281	2.5143
Chagrin River below East Branch to	Open	3830558.48	0.0600	246.132	1.570	1.508
Lake Erie	Forest	2409129.37	0.0377	119.679	1.527	1.609
0411003-030-030	Impervious	475126.40	0.0074	115.294	1.567	2.879
1466 acres in riparian corridor	Scrub	633398.38	0.0099	27.960	1.333	2.109
Summary		7348212.63	0.0288	127.2661	1.4992	2.0265

Results

Topographic Maps

A series of new topographic maps for all CRWP Member communities was created from the LiDAR data. This data provides a set of two foot contours for the watershed that are from a single data set. Previous topographic contours have been developed by counties and local communities with different base data collected in separate years. The LiDAR data set allows CRWP to provide data and visual products to communities that can assist with the development of more accurate stream and subwatershed layers. Note that the LiDAR sensor has difficulty identifying water and water surface elevations, since the beam may reflect from the water surface, or penetrate some distance and then return refracted, or it may be absorbed. Thus the contours in large ponds and lakes may not be as they appear.

Riparian Corridor Integrity: Overall Vegetation Analysis

Vegetated riparian corridors offer greater water quality function than do non-vegetated areas. The ability of streamside vegetation to intercept and process pollution carried in run off is well documented. This is particularly true for phosphorus, which generally reaches streams attached to soil particles. The filtering effect of streamside vegetation traps and removes these particles before they reach the stream. Streamside vegetation also helps prevent bank erosion by stabilizing soil along the banks. Finally, and very important for the coldwater streams in the Chagrin watershed, streamside vegetation helps shade the creek, keeping water temperatures within the tolerance ranges of cold water organisms.

Analysis of the entire Chagrin riparian corridors indicates a healthy, largely forested canopy. Land cover in the corridor is represented as follows:

- 43% forest
- 29% herbaceous
- 21% open water
- 4 % shrub
- 3 % impervious cover

The results show that almost half of the riparian corridor is forested. This reflects the high quality of the watershed. Further, 75% of the riparian corridor is covered in some vegetation, and the bulk of the remaining area is open water. In the Chagrin watershed, the overall assessment of riparian health is good, given that most of the riparian corridor is vegetated, primarily with forest cover. Note the above results are for the land cover within the riparian corridor only. Previous impervious cover studies of the watershed shows that approximately 9% of the watershed is covered with impervious cover. It is encouraging that most of the measured impervious cover within the watershed is located outside of the riparian corridor. This analysis highlights the importance of protection activities within the watershed to protect the flooding, erosion control and water quality functions of these corridors. Protection of riparian corridors is possible through fee simple purchase and conservation easements. These tools are limited by funding and willing property owners. Riparian setback regulations are another tool that allows communities to maintain the services provided by healthy riparian corridors, while still allowing property owners to develop and use their property.

Riparian Corridor Patch Analysis
The patch analysis performed using the Patch Analyst tool provided a wide range of data. This data allows CRWP to make conclusions about the relative health of the 14 digit watersheds within the Chagrin River watershed.

Upper Main Branch: Chagrin headwaters to Above Aurora Branch
Forest and open land covers were the dominant land classes. The dominance of the open land cover is influenced by large bodies of open water, including Bass Lake, and a large number of open water and herbaceous wetlands.

Silver Creek
Forest and open land covers were the dominant land classes. The dominance of the open land cover is influenced by large bodies of open water, including Lake Louise, Deer Lake and Paw Paw Lake. Much of the lower reaches of Silver Creek were identified as open in an area of a 3,200 linear foot stream restoration by the Geauga Park District.

Upper Aurora Branch: Headwater to above McFarland Creek
Forest and open land covers were the dominant land classes. The dominance of the open land cover is influenced by large bodies of open water including Sunny Lake, and a large number of open water and herbaceous and shrub wetlands in Mantua Township and on the Audubon Novak Sanctuary.

Lower Aurora Branch: Above McFarland Creek to Chagrin River
Forest and open land covers were the dominant land classes. The dominance of the open land cover is influenced by large bodies of open water including Tanglewood Lake, Lake Lucerne, and Luczek Lake.

Chagrin River Main Stem
Over fifty percent of this subwatershed is forested. The large percent of open space is made up of the actual river, as it becomes wider within the corridor and large old field and mowed areas within the Cleveland Metroparks and large estates in Hunting Valley and Gates Mills. Although a significant amount of open space is noted within this subwatershed, the majority of the stream edge is lined with trees and the open areas are within the larger floodplain area of the riparian corridor.

East Branch
The East Branch subwatershed is the most heavily forested subwatershed. Several large agricultural tracts in the upper reaches of the watershed and the various ponds on the Holden Arboretum make up a significant portion of the open land class within the subwatershed. Many of the streams within this subwatershed are designated as coldwater habitat by Ohio EPA. The maintenance of a forested stream corridor is extremely important in maintaining the shading on these coldwater streams. This subwatershed has the smallest percentage of open land cover as compared to the other subwatershed. Continued open space protection and riparian setback regulations are very important throughout this subwatershed to maintain these streams.

Lower Main Stem: Chagrin River below East Branch to Lake Erie
This subwatershed had the highest percentage of impervious cover and open space land covers. The Lower Main Branch includes the more urbanized areas in Eastlake, Willoughby, and Mentor near the mouth of the river. The open area was represented by the stream channel, lagoons at the mouth, nursery property along the river, and lawns.

With forest representing only 23% of the land cover within the corridor, it is very important to maintain the remaining tree canopy and promote riparian corridor restoration wherever possible.

Fragmentation affects a number of ecosystem processes. The more fragmented a landscape is, the more edges are present and the less core area for each cover type. Edges between patches tend to be attractors for a variety of invasive species, and expose species to microclimates that are generally more stressful than core interiors. As number of patches increase, and the size of patches decreases, the number of gaps in contiguous forest increases.

The Main stem of the Chagrin River (0411003-030-030) has the lowest number of patches, the mean size of which is rather large, while the Lower Main Branch watershed (0411003-030-010) has a high number of patches with a low mean size. The Main stem of the Chagrin River subwatershed includes a large amount of property protected by the Cleveland Metroparks and local land trusts, such as the Gates Mills Land Conservancy and the Western Reserve Land Conservancy, which increase the forested tracts while the Lower Main Branch is largely developed with suburban and urban land uses.

Table 5 ranks the metrics from Table 3 to examine which subwatershed has the healthiest or most intact riparian areas. Forest, open, and scrub land cover was ranked by percentage of each cover type in each watershed, thus a watershed ranked 1 for forest cover had the greatest percentage of forest in the riparian corridor among the seven 14 digit HUC sub-watersheds. Conversely, the watershed with the greatest percentage of impervious cover was ranked 1. The Lower Main Branch watershed (0411003-030-030) has the lowest ranking for forest, scrub and impervious cover; thus this subwatershed has the lowest percentages of good forest and scrub cover, and the highest percentage of bad impervious cover. The East Branch subwatershed (0411003-030-020) had the highest percentage of forest cover, and impervious cover was lowest in the Upper Aurora Branch subwatershed (0411003-020-030). The total score is simply the sum of the rankings, with the lowest score representing the best condition. Using this methodology, the Upper Aurora Branch subwatershed (0411003-020-030) ranked the healthiest in terms of the land use within the riparian corridor and lower main stem of the Chagrin subwatershed (0411003-030-030) ranked as the most deteriorated riparian corridor.

Table 5: Watersheds ranked by patch analysis.

Watershed Code	Forest Rank	Scrub Rank	Open Rank	Impervious Rank	Total score	Overall Rank
0411003-020-030: Upper Aurora Branch	4	1	3	1	9	1
0411003-020-020: Silver Creek	3	2	5	2	12	2
0411003-020-010: Upper Main Branch	5	3	2	3	13	3
0411003-030-020: East Branch	1	5	7	4	17	4
0411003-020-040: Lower Aurora Branch	6	4	4	5	19	5
0411003-030-010: Main Stem of Chagrin	2	6	6	6	20	6
0411003-030-030: Lower Main Branch	7	7	1	7	22	7

Storage
The LIDAR data also allows us to analyze whether or not there are depression areas that could perform critical water quality and storage functions. Figure 6 shows a portion of the Aurora Branch at the confluence with McFarland Creek as it crosses under State Route 422. Figure 7 shows the area along Erie Road in the City of Eastlake. Both figures show the CRWP setback area in green, property boundaries outlined in orange, and the depression storage areas shown in purple and yellow. The storage areas noted in yellow are located over class A or B soils, and thus have the potential to offer both storage and infiltration.

Figure 6: Storage Areas in Bainbridge Township

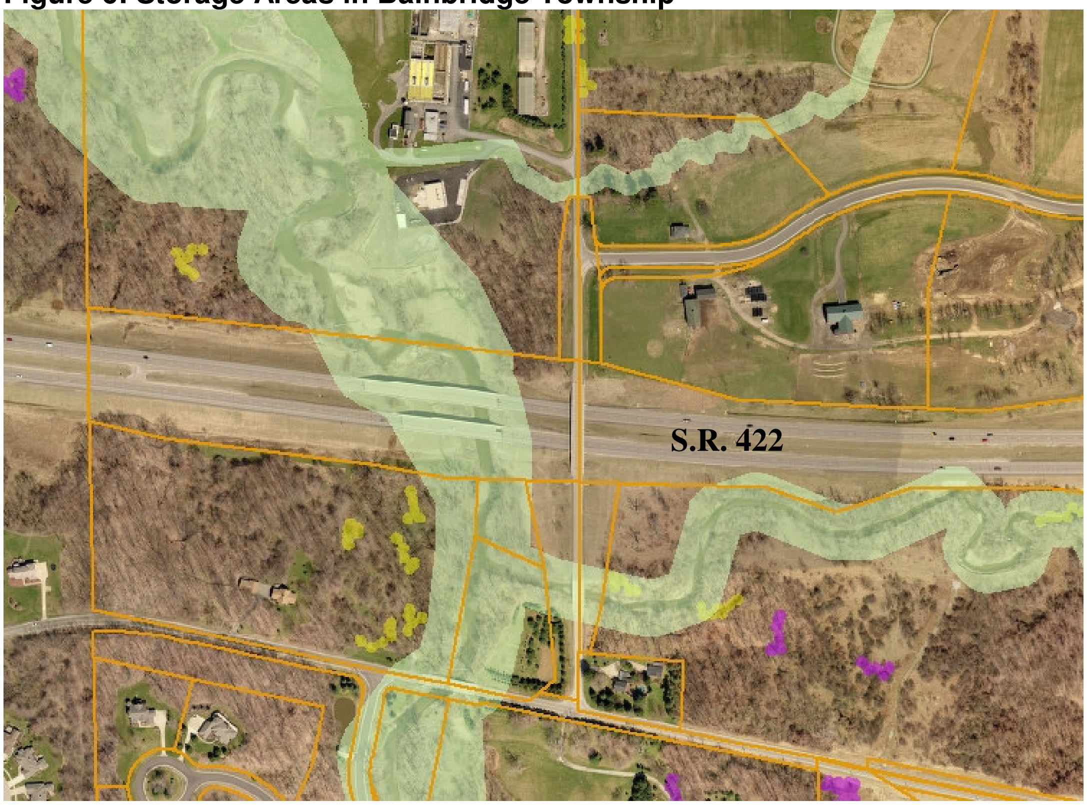


Figure 6 shows an area within Bainbridge Township. This Township adopted riparian setbacks into their local zoning code in February of 2004, however the storage areas that lay outside the delineated riparian setback will not be considered under this code. These storage areas may be candidates for protection activities such as easements or purchase. Geauga County and Bainbridge Township both own property within this area, however the large privately owned parcel west of the stream and south of State Route 422 has several storage areas noted outside of the riparian setback.

Figure 7: Storage area in Eastlake

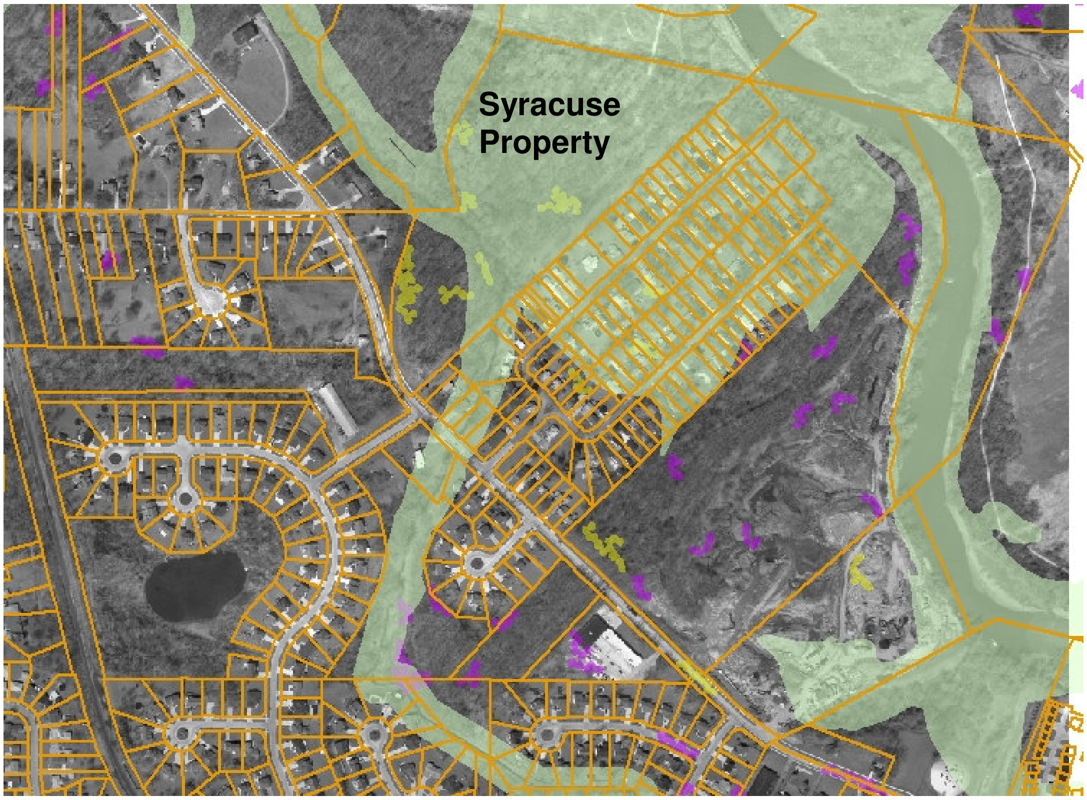


Figure 7 represents an area in Eastlake along Erie Road. The main channel of the Chagrin River can be seen along the right side of this figure while the smaller stream in the central portion of the picture is Corporation Creek. The expansive area of the model riparian setback shown is extended in this area to reflect the 100 year floodplain boundary. The City of Eastlake has not adopted riparian setback regulations. A portion of the area shown, noted as the "Syracuse Property", is protected by the City of Eastlake. Due to the level of development in this area and current flooding concerns, these storage areas present opportunities for storm water retrofits or acquisition to preserve their existing functions.

Both figures 6 and 7 highlight the importance of riparian setback regulations in maintaining the existing riparian corridor. Relatively undeveloped areas in the riparian corridor in figure 6 will remain undeveloped, due to the riparian setback regulations. However the riparian area in figure 7 has been largely developed due to lack of these regulations in this area. The storage areas present a unique piece of information that may guide site design or placement of stormwater BMPs as areas develop.

Regardless of location, the storage areas may assist in guiding further protection activities, site design, placement of a stormwater BMP such as a bioretention or infiltration basin, or this area could be protected as part of the open space within the development plan as these parcels develops.

Part II: Assessing Stormwater Infrastructures to Determine Local Changes in Stream Hydrology and Priority BMP Implementation or Retrofit Needs

In urban and urbanizing environments stormwater flows are often captured and conveyed in pipes, ditches, and pond features. As a result, urban stormwater does not necessarily follow contours and natural drainage areas. In addition, increased impervious cover has a dramatic impact on stream channel stability and water quality. CRWP completed an examination of watershed impervious area in 2004. This study provided data on impervious cover in the watershed and its distribution by political subdivision. To refine information on the impacts of impervious cover on hydrologic functions, CRWP completed this stormwater infrastructure analysis to understand how impervious areas are connected to storm sewer systems and outfall locations.

Methods

Data Acquisition

Twenty-four of CRWP's member communities are required to complete mapping of their stormwater system for the Ohio EPA NPDES Phase II stormwater permit. CRWP staff contacted all of the communities in the watershed and determined the status of stormwater system mapping throughout the watershed. Data were gathered from the existing systems in any available format. Communities that were not required to map their stormwater system through the Phase II stormwater program did not have information available on their communities' stormwater system. For those communities that had electronic data, CRWP was able to identify and map point features such as outfalls, manholes, catch basins and inlets, and some line features, such as ditches and pipes. Depending upon the community, these features carried a variety of attributes. Table 6 details the data collected by CRWP from member communities.

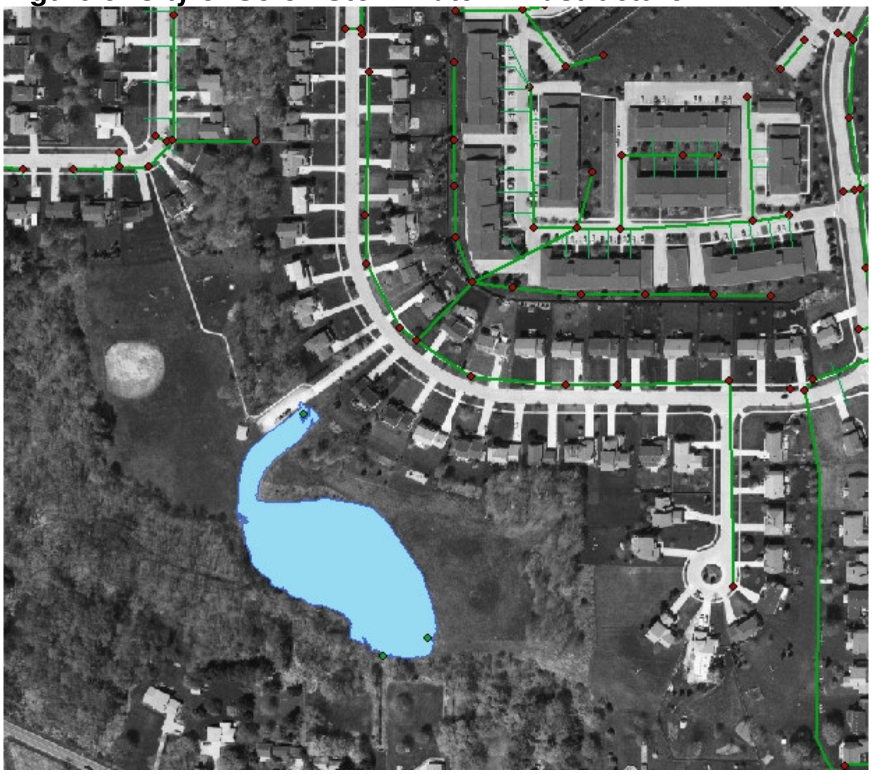
Table 6: Stormwater System Data Collected from Communities

Community	***County***	***Phase II***	***Available Stormwater Data***
Auburn Township	Geauga	No	Stormwater basins in Access database
Aurora	Portage	Yes	Outfalls only
Bainbridge Township	Geauga	Yes	Outfalls in Phase II Urbanized Area, stormwater basins in Access database
Bentleyville	Cuyahoga	Yes	Outfalls, Catch basin, Storm sewer pipes, Manholes, and Culverts
Chagrin Falls Township	Cuyahoga	No	None
Chagrin Falls Village	Cuyahoga	Yes	CADD Drawing
Chardon	Geauga	No	CADD Drawing
Chardon Township	Geauga	No	Stormwater basins in Access database
Chester Township	Geauga	Yes	Outfalls in Phase II Urbanized Area, stormwater basins in Access database
Claridon Township	Geauga	No	Stormwater basins in Access database
Eastlake	Lake	Yes	CADD Drawing
Gates Mills	Cuyahoga	Yes	Outfalls only for a small area of community
Hunting Valley	Cuyahoga	No	None
Kirtland	Lake	Yes	Outfalls, Catch basin, Storm sewer pipes, Ditches, and Culverts
Kirtland Hills	Lake	No	None
Mantua Township	Portage	No	None
Mayfield Heights	Cuyahoga	Yes	Outfalls only

Community	County	Phase II	Available Stormwater Data
Mayfield Village	Cuyahoga	Yes	CADD Drawing and Outfalls
Mentor	Lake	Yes	Outfalls, Stormwater Structures (includes manholes, headwalls, inlet headwalls, yard drains) Storm sewer pipes, basins, and Culverts
Moreland Hills	Cuyahoga	Yes	Outfalls, Catch basins, Storm sewer pipes, Ditches, Manholes, Headwalls, Outfall parcels, and Culverts
Munson Township	Geauga	No	Stormwater basins in Access database
Newbury Township	Geauga	No	Stormwater basins in Access database
Orange Village	Cuyahoga	Yes	Outfalls only
Pepper Pike	Cuyahoga	Yes	Outfalls and Culverts
Russell Township	Geauga	Yes	Outfalls in Phase II Urbanized Area, stormwater basins in Access database
Solon	Cuyahoga	Yes	Outfalls, Stormwater Structures (includes manholes, headwalls, inlet headwalls, yard drains) Storm sewer pipes, Detention basins, and Culverts
South Russell	Geauga	Yes	Stormwater Structures (includes manholes, headwalls, inlet headwalls) Storm sewer pipes, and Culverts
Waite Hill	Lake	No	None
Wickliffe	Lake	Yes	Outfalls and PDF map of storm sewer system
Willoughby	Lake	Yes	Stormwater Structures (includes manholes, headwalls, inlet headwalls) Storm sewer pipes, and Culverts
Willoughby Hills	Lake	Yes	Outfalls Only
Woodmere	Cuyahoga	Yes	Outfalls Only

It is important to note that while most communities had some data, it was often not complete. For example, the basin and outfall data for Geauga County communities is limited to outfalls within the Phase II urbanized areas of communities and new basins that have been permitted or built since the tracking mechanisms were established. Of the CRWP members, the Cities of Solon and Mentor had the most extensive data sets. Figure 8 shows a portion of the City of Solon with the various data layers shown. The storm water structures including manholes and yard drains are included in this data set. Storm water mains as well as laterals are delineated for the City. In addition, the City of Solon distinguished between ponds and lakes and detention basins in their community. Although this data set is extensive, the City of Solon found it necessary to complete additional, and more detailed, stormwater infrastructure mapping to complete modeling of their storm sewer system.

Figure 8: City of Solon Stormwater Infrastructure



Impervious Cover:
CRWP completed an impervious cover study in December 2004. This study investigated current and projected impervious cover based on build-out to the underlying zoning. Results from this study indicated that in 2004, the Chagrin River watershed was approximately 9% impervious. Based on underlying zoning, the watershed is predicted to reach a level of 17 % impervious cover. The study provided several build-out scenarios that would allow communities to control their increases in stormwater runoff volumes and rates, such as:

- Reduce overall impervious cover by 5% on new development sites,
- Provide extended detention,
- Provide extended conveyance.

This study did not investigate retrofits for those areas where impervious cover areas had already been created by past development activities. The data on the existing impervious cover was used to investigate opportunities for minimizing impervious cover or mitigating the impacts of existing impervious cover.

Aquatic Life Use and Attainment
As a part of the Chagrin River Watershed Action Plan, CRWP researched Ohio EPA documents to detail the aquatic life use designation and their associated attainment status of sampled streams within the watershed. Figure 9 shows the designated aquatic life use of streams within the Chagrin River watershed. Figure 10 illustrates whether those streams are attaining or meeting those aquatic life use designations. Note that not all designated streams have been sampled to determine their attainment status.

Figure 9: Aquatic Life Use

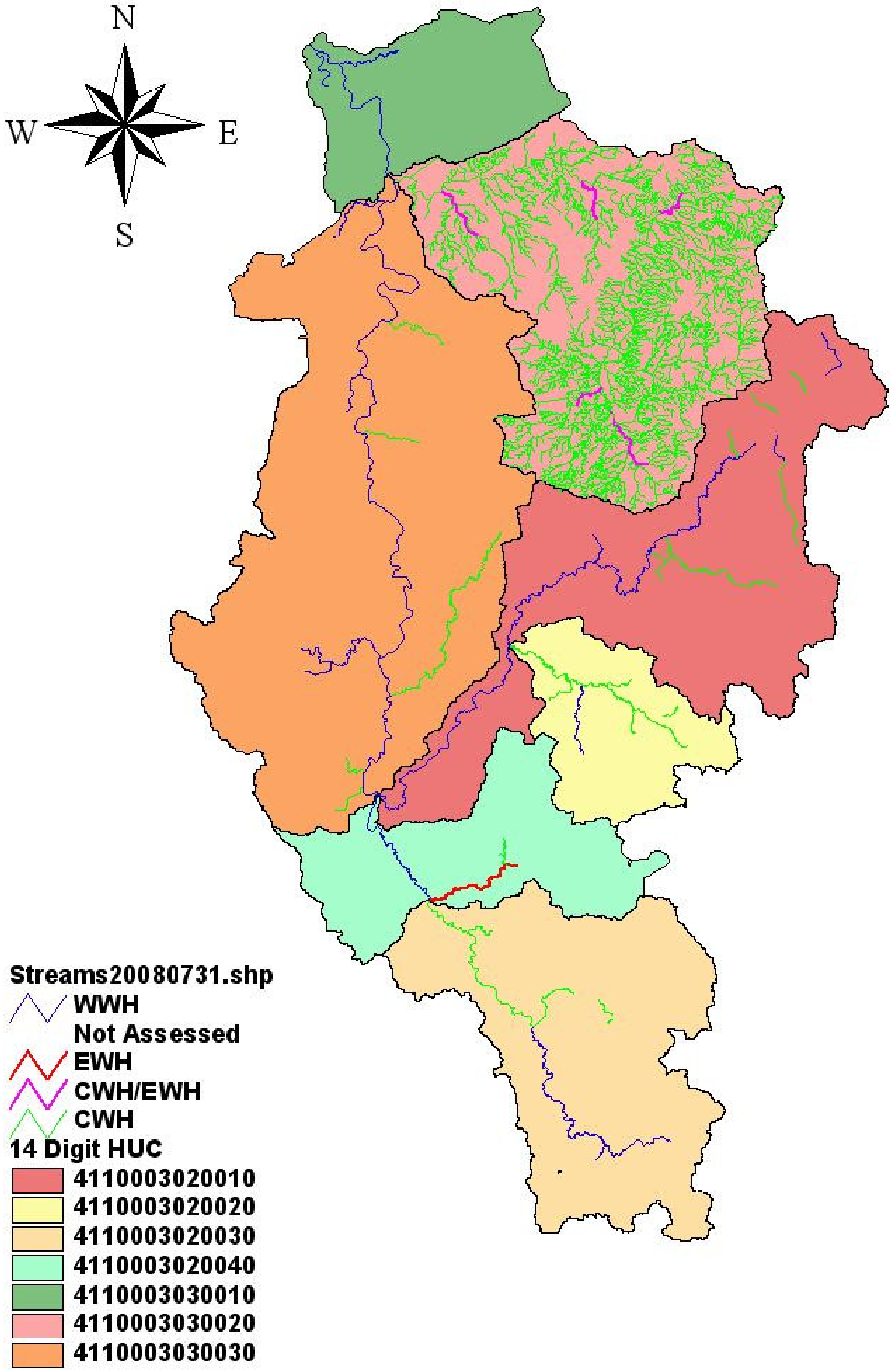
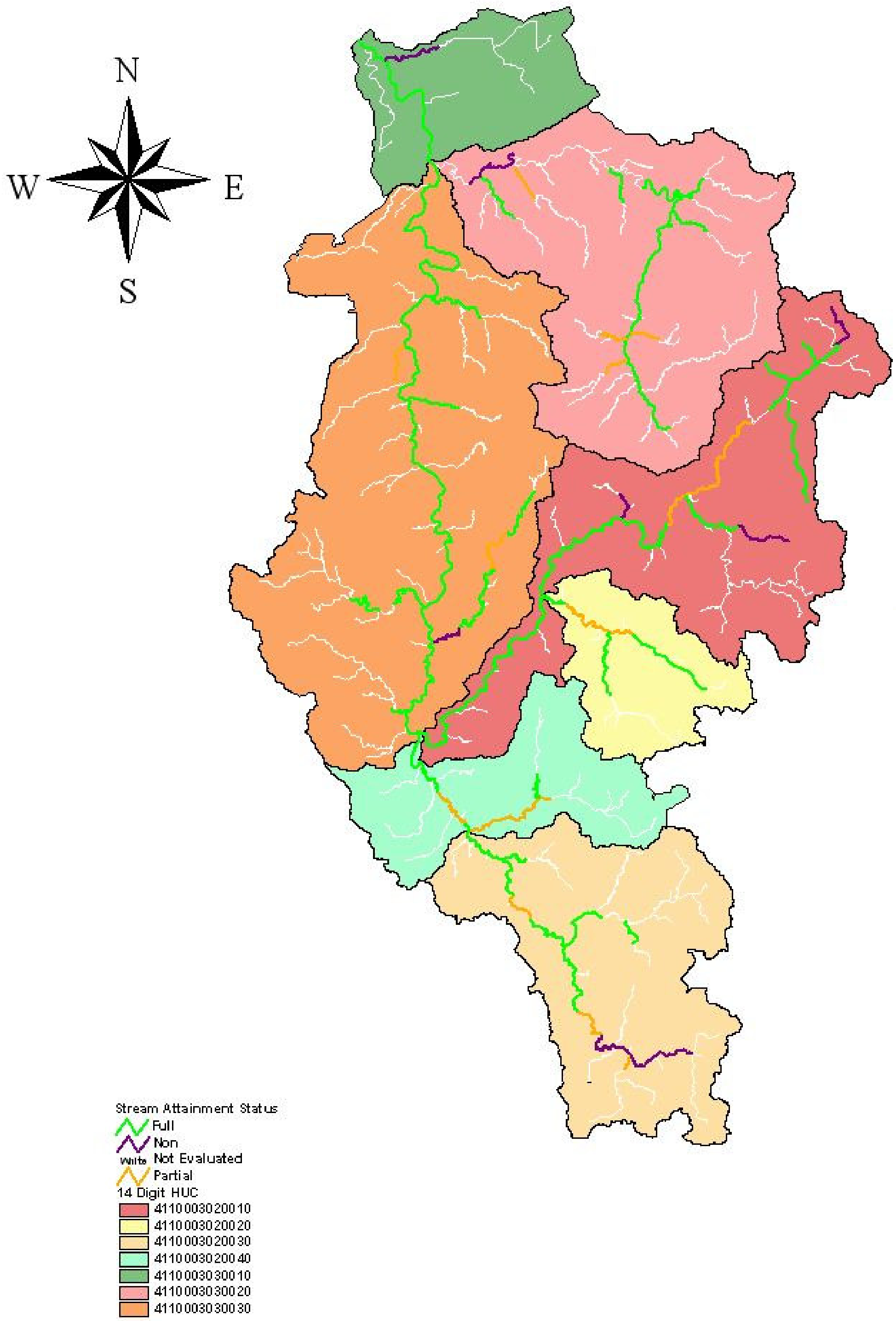


Figure 10: Attainment Status



Stormwater Management System:
As detailed in Table 6, CRWP was able to determine the status of storm sewer mapping throughout the watershed. The available data, whether in electronic or paper formats, had widely divergent attributes and no common database existed for storm sewer data throughout the watershed. Data was not available in enough consistency and detail to allow CRWP to delineate drainage areas or sewersheds for each outfall point. However, the provided data allowed CRWP to make significant revisions to the CRWP stream layer to more accurately represent the flow of water from open channels into storm sewers and then daylighting into open channels again. The ability to track the water through a storm sewer system is a vital piece of information, particularly in the more developed areas of the watershed.

This project highlighted the need to more accurately map stormwater infrastructures. Additional data on inlets, outlets, and stormwater conveyance would have been required with information on flow direction to be able to determine the exact drainage areas to each outfall. To address this problem, CRWP developed a stormwater infrastructure data dictionary, attached as Appendix A and discussed further in the results section.

The most abundant electronic data on stormwater infrastructure were data sets on storm outfalls. Using this data, in conjunction with the riparian corridor analysis, previously completed impervious cover data, and Ohio EPA water quality data, relationships between storm sewer outfalls and receiving stream water quality were developed.

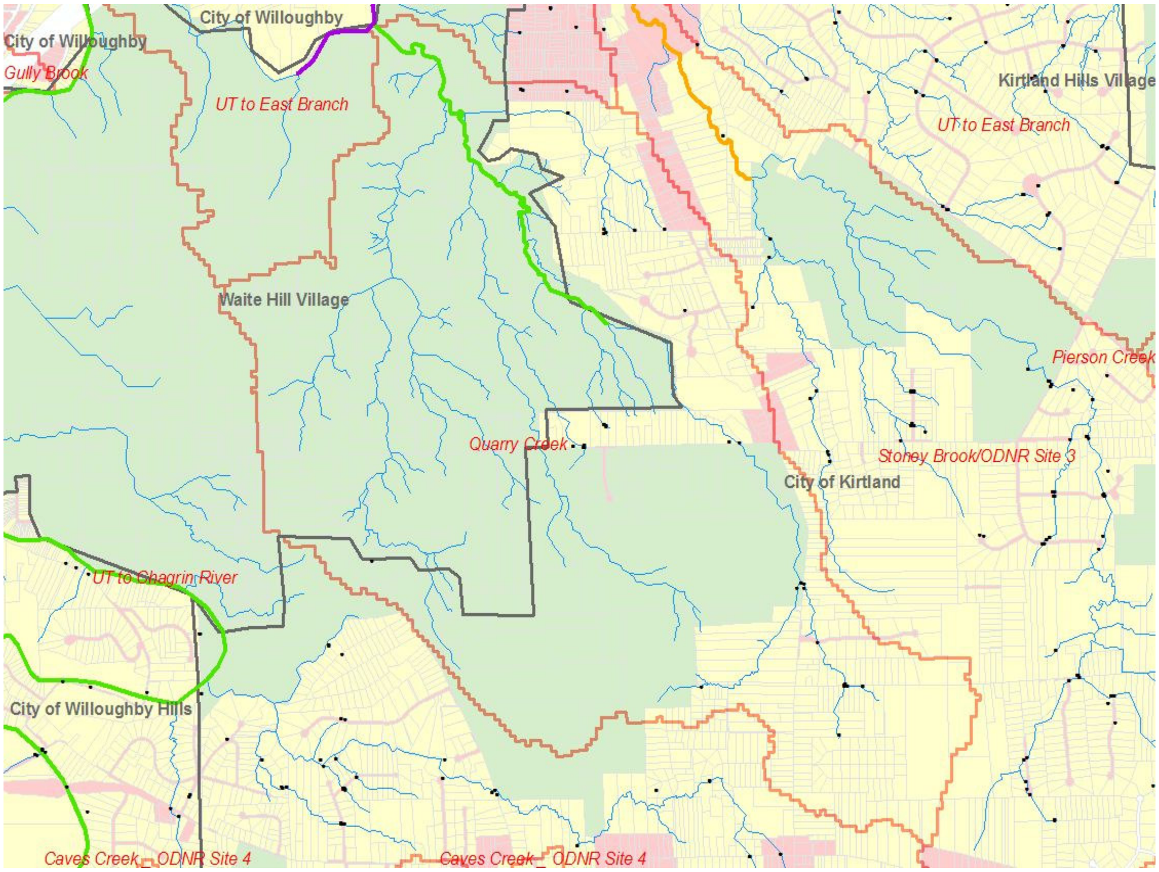
Figures 11 and 12 illustrate storm sewer outlet maps with impervious cover and stream attainment data. In these maps, the average impervious cover in an area is shown by shading:

- Areas with impervious cover less than 9% are shown in green,
- Areas with 9.1 and 30% impervious cover are shown in yellow,
- Areas with greater than 30% impervious cover are shown in pink.

The receiving streams are color coded depending upon whether or not the stream is attaining its Ohio EPA designated aquatic life use. Green streams are in full attainment, orange streams are in partial attainment and purple streams are in non-attainment status. Black dots represent stormwater outfalls.

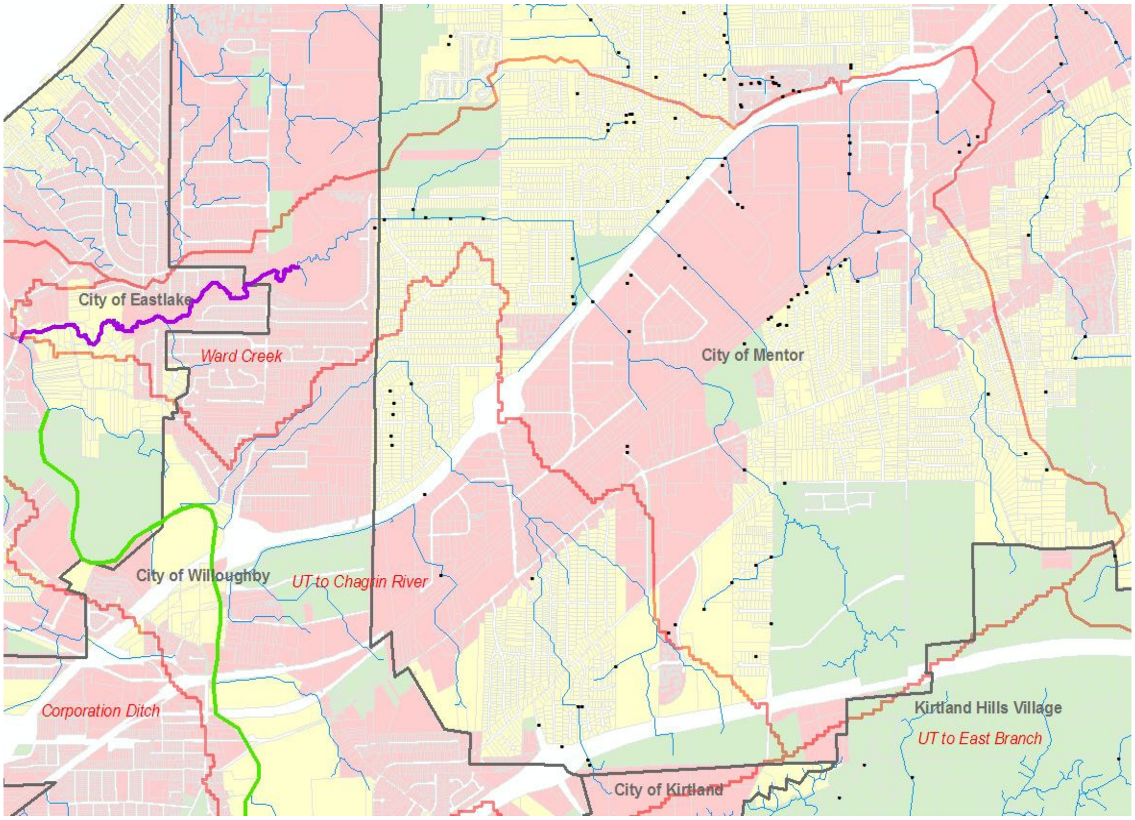
Figure 11 shows the stormwater system for a portion of the East Branch subwatershed (HUC 4110003030020) with finer detail of two smaller drainages within the subwatershed, Quarry Creek and Stoney Brook. Stormwater systems data was not available in the Village of Waite Hill; however the development in this area is low density residential with significant amounts of open space. Quarry Creek flows from Kirtland into Waite Hill. This stream is in full attainment of its dual coldwater habitat/exceptional warmwater habitat aquatic life uses. Conversely a large number of outfalls are found within the Stoney Brook subwatershed and this stream is partially attaining its coldwater habitat aquatic life use. BMP retrofits may be appropriate to target within the Stoney Brook subwatershed to mitigate the impacts of the stormwater inputs to this stream.

Figure 11: Storm sewer outfalls, Kirtland area.



A similar situation is shown in Figure 12 for the Mentor, Willoughby, and Eastlake areas. This area is part of the Lower Chagrin River subwatershed (HUC 4110003030010) and contains the smaller drainage of Ward Creek. In the City of Mentor Ward Creek is referred to as Newell Creek. Outfall data were available for Mentor, but not for Eastlake. There is an abundance of impervious cover and storm sewer outfalls in the upper reaches of the Ward Creek watershed. Note that the main stem of Ward Creek, just below the label for the City of Eastlake, is shown in purple, indicating it is not in attainment of its warmwater habitat aquatic life use designation. The lower corridor of this stream in Willoughby and Eastlake is in a greenspace corridor, partially protected by Lake Metroparks; however this section still does not meet Ohio EPA standards largely due to the stormwater discharges. Further upstream in the City of Mentor, numerous segments of this stream have been piped. This area should be further investigated for BMP installation and retrofit opportunities.

Figure 12: Storm sewer outfalls, Mentor and Eastlake Area



Results

Stormwater Infrastructure Data Dictionary

As CRWP began collecting data, it became apparent that there was a need to establish a common data framework so communities are collecting the same data on their stormwater system. Not all communities can afford to create a robust stormwater infrastructure database, however the Phase II stormwater regulations require some mapping of the Municipal Separate Storm Sewer System (MS4). Funds that are expended to comply with Phase II requirements, track BMP performance, or perform hydraulic modeling to solve local flooding problems, need to be collected in a consistent manner across the watershed. A cohesive data collection effort will aid in integration of retrofit solutions at the subwatershed level and across political subdivision boundaries.

CRWP worked with URS to develop the stormwater infrastructure data dictionary included in Appendix A. This database contains an outline for data that should be collected for all stormwater systems in the watershed. Fields are included to describe the existing system and to help track the installation and efficacy of installed stormwater BMPs. The stormwater infrastructure data dictionary details the primary data types needed for communities to comply with Ohio EPA Phase II Stormwater Management requirements for mapping their MS4, tracking location of outfalls, solving illicit discharge issues, and modeling their systems to solve local flooding problems. This stormwater infrastructure data dictionary is consistent with the Northeast Ohio Regional Sewer

District Database used by the Cuyahoga County Health District to assist communities with storm sewer outfall mapping and illicit discharge detection.

This stormwater infrastructure data dictionary is included as a model and guide to highlight the type of data that needs to be collected for communities to accurately map stormwater infrastructure. This stormwater infrastructure data dictionary database will be available to all CRWP member communities to facilitate their data collection efforts and help members comply with current and future stormwater management regulations. Communities can modify this stormwater infrastructure data dictionary to include any community specific requirements. Other additions to this stormwater infrastructure data dictionary could include tracking mechanisms for location of existing BMPs, including annual inspection and maintenance.

Analysis of relationship between stormwater infrastructure, stream quality, and impervious cover

A clear relationship has been established linking the increase in impervious cover that accompanies traditional development to decreases in water quality (USEPA 2000). Increases in impervious surface areas lead to increases in the frequency and volume of runoff, which can change the physical characteristics of receiving streams. In general, as impervious cover in a stream's watershed increases, the stream experiences lower base flows, due to the decrease in local infiltration, and greater peak flows, due to increased runoff volumes (Bird, et al 2002). In addition to the hydrodynamic changes that are deleterious to water quality, uncontrolled increases in stormwater runoff can lead to erosion, flooding and other physical problems (Inman 1995). MacRae (1996) showed that stream channels in urban areas have cross sections that are 2 to 5 times greater than similar channels in un-urbanized areas and that this enlargement can begin even at less than 10% impervious cover. Wolman (1967) described a "cascade" of problems that streams face as urbanization progresses.

Recently, research has shown a link between increases in impervious cover and changes in the structure and composition of aquatic communities in receiving streams. Some aquatic population changes are no doubt due to increased pesticides and other chemical washing from urban surfaces (Center for Watershed Protection 1989). Aquatic community changes appear to begin to occur in many watersheds when impervious cover reaches 10%. Booth and Jackson (1994) showed a "demonstrable loss of aquatic system function" in streams with 10% impervious cover in their watersheds. Schueler (1994) also cites this 10% impervious cover figure in a wide ranging summary across a range of geographic conditions. In a study in the lowlands surrounding Puget Sound, May et al (1997) showed indicators of ecosystem health decline most rapidly when impervious cover reaches between 5% and 10%. Some particular species respond even more quickly. Boward et al (1999) found that Brook Trout were absent from any streams where impervious cover in the watershed was greater than 2%. In Ohio, Yoder (1991) showed that urban stream sites had "fair" to "very poor" fish and macroinvertebrate communities while communities in relatively unimpacted reference sites.

Phase II designated communities are required to control their stormwater discharges from new developments, and to some degree, redeveloping sites. However, many developed communities also have concerns dealing with historic stormwater problems. Many of the problems that aquatic communities face also translate into problems for residents and local communities. As streams become unstable, aquatic communities lose habitat, while residents and communities may lose property or sustain damage to infrastructure.

Table 7 summarizes the data on impervious cover, use attainment status and the number of outfalls for those watersheds for which outfall data were available. Intuitively, one would hope to see a relation that shows streams in watersheds with high impervious cover values are not attaining their use designations. Note however that many of the streams that are in attainment have impervious cover values greater than 10%.

Table 7: Sub-watershed size, estimated impervious area and use attainment status for those watersheds where outfall information was available.

Sub-Watershed	Watershed Size (acres)	Estimated Impervious Area (acres)	Estimated Percent Impervious Cover	Water Quality Use Designation**	Attainment Status	Number of Outfalls
Pepper/Luce Creek	6545.864	1957.85	29.91	WWH	Full	99
Gully Brook	3354.271	777.42	23.18	WWH	Not Evaluated	75
Caves Creek	3796.881	608.76	16.03	WWH	Full	104
Griswold Creek	4553.363	561.64	12.33	WWH	Full	99*
UT RM 15.42	1503.164	175.84	11.70	WWH	Full	7
So. Br. Silver Creek	3423.167	317.53	9.28	WWH	Full	46
Ward Creek	4976.239	1450.44	29.15	WWH	Non	76*
Quarry Creek	2587.515	498.28	19.26	CWH	Full	33
McFarland Creek	7139.192	1214.93	17.02	EWH	Partial	79*
Willey Creek	3329.623	366.58	11.01	CWH	Full	74

* Number of outfalls underestimated due to a lack of data for entire watershed.
** WWH = Warmwater Habitat, CWH=Coldwater Habitat, EWH=Exceptional Warmwater Habitat

Table 7 may be useful to guide stormwater management decisions. For example, Ward Creek and McFarland Creek both have high percentages of impervious cover, high numbers of outfalls, and streams that are partially or not attaining their use designations. Clearly, retrofitting BMPs into these watersheds would be desirable. Other watersheds in full attainment of their use designations that also have high numbers of outfalls are threatened. Preventative measures should be taken to protect existing riparian corridors and effectively treat stormwater from any new developments. Table 8 further details all streams that are not fully attaining their aquatic life use designations and recommended actions for riparian corridor and BMP retrofit opportunities for these areas are included in the Conclusions.

BMP Retrofit

The Center for Watershed Protection has developed the Basics of Stormwater Retrofits that recommended strategies to complete retrofit projects at a watershed level focused on implementing easier approaches first. Listed below are the recommended retrofit methods listed by increasing difficulty:

- Demonstration retrofits.
- Retrofits on public lands.
- Encourage on-site retrofits in neighborhoods.
- Piggyback retrofits on municipal construction projects
- Mitigation retrofits on private land.

- ➢ Subsidize on-site retrofits on private land.
- ➢ Trigger retrofits on part of rezoning or public/private partnerships.
- ➢ Require storm water treatment on redevelopment projects.

Locating potential new BMPs is different than retrofitting existing BMPs to augment either the water quality or quantity functions. One major factor in installing new BMPs in an existing built area is space constraint. Therefore areas where public lands or existing BMPs are located should be first targeted as locations for BMP retrofits.

CRWP recommends targeting restoration and retrofit projects towards impacted stream segments that are not fully attaining their aquatic life uses. In addition, Table 8 lists stream segments by 14 digit subwatershed that are in partial or non attainment of their aquatic life uses. Ohio EPA has determined 22 stream segments in the Chagrin River watershed that are not in full attainment of their designated uses. Six of the seven -14 digit HUC subwatersheds have at least one stream segment in non or partial attainment. Streams sampled in the Silver Creek subwatershed were in full attainment, however an attainment status of the lower reach of Silver Creek was not assessed due to the recent stream restoration activities.

Table 8: Streams in Partial or Non Attainment

14 Digit HUC	Stream	ALU	Attainment
04110003-020-010: Upper Main Branch			
	Chagrin River (RM 49.1)	WWH	Non
	Chagrin River (RM 45.2)	WWH	Partial
	Chagrin River (RM 42.6)	WWH	Partial
	Marsh Hawk Run (Trib. at RM 38.32)	WWH	Non
	Dewdale Creek	CWH	Non
04110003-020-040: Lower Aurora Branch			
	Aurora Branch (RM 3.4)	WWH	Partial
	McFarland Creek (RM 2.3)	EWH	Partial
	McFarland Creek (RM 0.2)	EWH	Partial
04110003-020-030: Upper Aurora Branch			
	Aurora Branch (RM 16.6)	WWH	Non
	Aurora Branch (RM 14.5)	WWH	Non
	Aurora Branch (RM 12.0)	WWH	Non
	Aurora Branch (RM 7.4)	WWH	Partial
04110003-030-020: East Branch			
	East Branch (RM 16.3)	CWH	Partial
	East Branch (RM 10.3)	CWH	Partial
	East Branch (RM 2.4)	CWH	Non
	Stoney Creek	CWH	Partial
	Unnamed Trib. (RM 14.62)	CWH	Partial
	Unnamed Trib. (RM 14.8)	CWH	Partial
	Unnamed Trib. (RM 15.35)	CWH/EWH	Partial/Full
04110003-030-010: Lower Chagrin			
	Ward Creek	WWH	Non
04110003-030-030: Main Stem Chagrin			
	Griswold Creek (RM 4.4)	CWH	Partial
	Griswold Creek (RM 0.1)	CWH	Non

Several of the stream segments in table 8 are impacted by point sources:

- Aurora Branch RM 14.5, 12.0, and 7.4 - Impacted by discharge from Sunny Lake
- Aurora Branch RM 3.4 - Impacted by bridge construction and wastewater treatment plant discharge.
- Marsh Hawk Run (Trib. at RM 38.32) – Impacted by discharge from major municipal point source.
- Dewdale Creek - Impacted by septic discharge.

Activities are already underway to eliminate these sources of pollutants from Sunny Lake and the wastewater treatment plants to the Aurora Branch and Marsh Hawk Run. CRWP will continue to work with the City of Aurora and Geauga County on these areas. In addition, Newbury Township and the Geauga County Health Department will continue to investigate and eliminate sources of septic discharge into Dewdale Creek. Riparian corridor and stormwater BMPs are unlikely to be effective in removing the sources of impairment on these stream segments.

However the other streams that are not fully attaining their aquatic life uses should be ranked high for retrofit and restoration activities. There are a large number of factors that affect whether a retrofit may actually be implemented, including cost, property ownership, and social considerations. In the Conclusions section, CRWP has detailed several potential project locations that have both riparian corridor restoration and BMP components. These potential projects will serve as a guide for future project selection.

While it is possible to establish specific subwatershed retrofit priorities in the Chagrin, the challenge will be to select and site the retrofit BMPs that will provide value and benefit to restoring watershed health. Prior to implementing these retrofit BMPs, additional modeling and baseline digital mapping of storm sewer systems including existing BMPs and water quantity basins will need to be completed. The key to subwatershed retrofit is determining the total water quality treatment volume (WQv) needed to meet restoration objectives. Also, as watershed imperviousness increases, the more difficult and costly it is to retrofit.

Table 9 provides base construction costs for new stormwater management practices. It is important to note that these costs are typically incurred by the developer of a site rather than the community.

Table 9: Base Construction Costs for New Stormwater Practices BMPs 2006 $ per impervious acre treated				
Retrofit Type	**Low End**	**Median**	**High End**	**Source:**
Constructed Wetlands[1]	$ 2,000	$ 2,900	$ 9,600	Cost Equation
Extended Detention[1]	2,200	3,800	7,500	Cost Equation
Wet Ponds[1]	3,100	8,350	28,750	Cost Equation
Water Quality Swales[2]	10,900	18,150	36,300	Derived
Bioretention	19,900	25,400	41,750	Cost Equation
Infiltration[3]	19,900	25,400	41,750	Derived
Residential Rooftop	10,900	27,200	49,000	Derived
Filtering Practices	18,150	58,100	79,900	Cost Equation
Non-Residential Roof	21,800	90,750	1,100,000	Derived

[1] Based on typical range of CDA and IC noted on the basic approach section
[2] Derived from cost per square foot
[3] Assumed to be comparable to Bioretention costs

A wide range of costs for various retrofit options exists. In comparison, Table 10 provides a summary of cost information from Schueler et al. 2007. It is easy to see that retrofitting is more costly than stormwater management implemented during a construction project. Thus as communities redevelop, it is important to integrate stormwater management and impervious cover minimization into the site design of any redevelopment projects.

Table 10: Retrofit Construction Costs 2006 $ to Treat an Impervious Acre			
Retrofit Type	**Low End**	**Median**	**High End**
Pond Retrofit	$ 3,600	$ 11,100	$ 37,100
New Storage Retrofit	$ 9,000	$ 19,400	$ 32,200
Urban On-Site Retrofit[2]	$ 58,000	$ 88,000	$ 150,000
[1]Low end is the 25% quartile value, high end is the 75th quartile value [2] Mean contributing drainage area to practice = 0.58 acres			

Table 11 provides base construction costs for retrofitted stormwater management practices. It is easy to see that retrofitting existing ponds is much more economical than creating intensive new BMPs such as green roofs. Several measures are cost effective and are feasible on most redevelopment projects, such as impervious cover conversion, small scale bioretention or filters, swale retrofits, and storage units ranging from cisterns and rain barrels to dry wells.

Table 11: Range of Retrofit Costs (2006 $ per cubic foot of runoff treated)		
Retrofit Technique	**Median Cost**	**High End**
Pond Retrofits	$ 3.00	$1.00 to 10.00
Rain Gardens	$ 4.00	$3.00 to 5.00
New Storage Retrofits	$ 5.00	$2.50 to 9.00
Larger Bioretention Retrofits	$ 10.50	$7.50 to 17.25
Water Quality Swale Retrofit	$ 12.50	$7.00 to 22.00
Cisterns	$ 15.00	$6.00 to 25.00
French Drain/Dry Well	$ 12.00	$10.50 to 13.50
Infiltration Retrofits	$ 15.00	$10.00 to 23.00
Rain Barrels	$ 25.00	$12.50 to 40.00
Structural Sand Filter	$ 20.00	$16.00 to 22.00
Impervious Cover Conversion	$ 20.00	$18.50 to 21.50
Stormwater Planter	$ 27.00	$18.00 to 36.00
Small Bioretention Retrofits	$ 30.00	$25.00 to 40.00
Underground Sand Filter	$ 65.00	$28.00 to 75.00
Stormwater Tree Pits	$ 70.00	$58.00 to 83.00
Permeable Pavers	$ 120.00	$96.00 to 144.00
Extensive Green Rooftops	$ 225.00	$144.00 to 300.00
Intensive Green Rooftops	$ 360.00	$300.00 to 420.00
Note: Costs shown are base construction costs and do not include additional design and engineering costs, which can range from 5 to 40%		

The data assembled during this study allows CRWP to indicate those watersheds where retrofitted BMPs are most needed to control stormwater and improve water quality.

Conclusions and Recommendations

The Chagrin River watershed is at a critical level of development, with approximately 9% of the watershed covered with impervious cover. As the watershed continues to develop, the impervious cover is estimated to increase to approximately 17%. Today, most of the streams within the Chagrin River watershed are high quality and continue to attain their designation aquatic life uses. However, there are areas where residents and communities experience erosion, flooding, and water quality problems. CRWP works with communities to ensure as the watershed continues to develop, the high quality streams are maintained and these problems areas are resolved. To accomplish this goal, a wide variety of tools from land acquisition, planning, storm water management, riparian setback regulations, restoration, and retrofits to existing development sites are all needed.

In Part I, this project provided information on the high quality streams and intact riparian corridors that would benefit from protection through easements, acquisition, alternative site design, or riparian and wetland setback regulations. In Part II, CRWP investigated the existing stormwater infrastructure and the potential for BMP installation and retrofit. These two parts of this study allowed CRWP to identify riparian corridor restoration locations and BMP retrofit recommendations. These recommendations link the existing health of riparian corridors and streams with the existing impervious cover and stormwater infrastructure to provide a wide range of recommendations that maintain streams and improve water quality.

Part I of this project analyzed the integrity of the Chagrin River watershed's riparian corridors. Analysis of the entire CRWP riparian corridor system indicates that current state of cover in the system is: 43% forest; 29% herbaceous; 21% open water; 4% shrub; 3% impervious cover. In addition to investigating the amount of forest, shrub, and open areas within the riparian corridors, this study allowed CRWP to investigate the continuity of forest cover and the relative integrity of the riparian corridor. This will assist CRWP in recommending riparian setback regulations to CRWP member communities.

Currently there are 13 communities within the Chagrin River watershed that have adopted riparian setback regulations. In addition, the Village of Waite Hill has an environmentally sensitive areas ordinance that minimizes impacts to streams, wetlands, and steep slopes. Table 12 details the communities who have already adopted riparian setback regulations.

Table 12: Communities that adopted Riparian Setback or similar regulations:	
Chagrin Falls Village	Adopted - Not CRWP current model
Hunting Valley	Adopted - Not CRWP current model
Waite Hill	Adopted - Sensitive Areas Ordinance
Auburn Township	Adopted
Aurora	Adopted
Bainbridge Township	Adopted
Bentleyville	Adopted
Kirtland	Adopted
Moreland Hills	Adopted – Does not include 100 year floodplain
Orange Village	Adopted

Pepper Pike	Adopted
Russell Township	Adopted
Willoughby Hills	Adopted
Woodmere	Adopted

The stream corridors protected through the local zoning codes in the above 14 communities represent 47% of the stream miles within the watershed. CRWP continues to work with all of the remaining CRWP members to adopt the riparian setback regulations. This study highlights communities with high quality riparian corridors that should focus on riparian setback regulations. The communities that are ranked lower for protection of riparian corridors through planning and zoning are the locations where riparian corridor and stream restoration activities will likely have the most benefit. In addition, these communities are the areas where stormwater sewer systems are prevalent. The opportunities for restoration and retrofit are explored below.

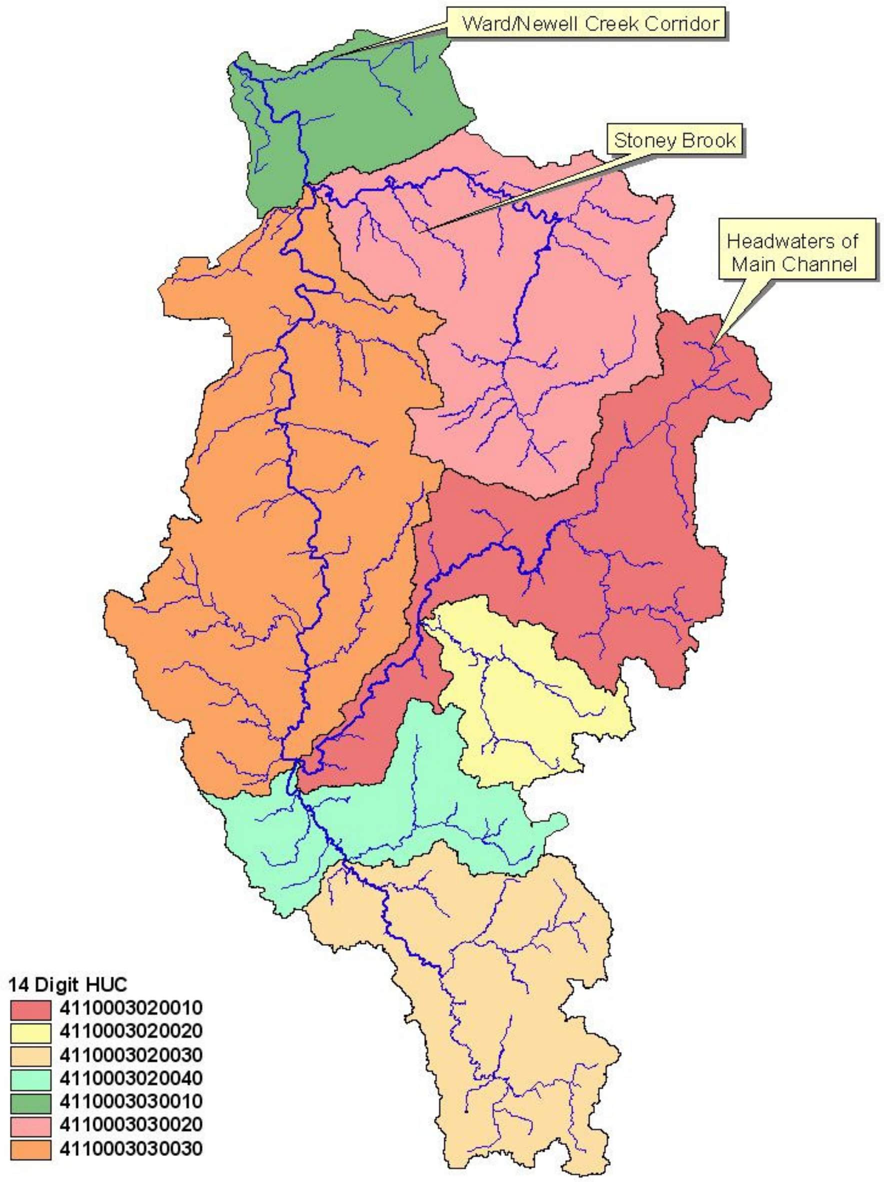
Table 13 ranks the communities that should consider riparian setback regulations. The ranking below was completed by multiplying the relative ranking of the health of the riparian corridor by the area of the community within the watershed. The watershed rank of riparian corridor integrity is from Table 5 of this report and the highest ranked watershed present in the community was used. This table represents a ranking of the communities with the highest quality stream corridors that are not currently protected by a riparian setback regulation. The large amount of area of Chester, Newbury, and Munson Townships makes all of them excellent candidates for adoption of riparian setback regulations. These communities are also less developed.

Table 13: Ranked list of communities that <u>should</u> adopt riparian setback regulations

Community	Watershed Rank of Riparian Corridor Integrity*	Area in Watershed (Acres)	Area Rank	Total Score
Chester Township	3	15000	1	4
Newbury Township	2	11900	3	5
Munson Township	3	14000	2	5
Solon	1	5350	7	8
Chardon Township	4	9550	4	8
Mantua Township	1	4650	9	10
Gates Mills	6	5800	6	12
Mentor	7	6200	5	12
South Russell	2	2500	12	14
Kirtland Hills	4	3300	10	14
Willoughby	6	4700	8	14
Mayfield Heights	6	2700	11	17
Chardon	3	1400	15	18
Mayfield Village	6	2500	13	19
Claridon Township	3	420	17	20
Eastlake	7	2200	14	21
Wickliffe	6	600	16	22
Chagrin Falls Township	6	360	18	24

Part II of this project highlighted priority areas where BMP implementation or retrofit would be appropriate to restore streams and minimize flooding and erosion problems. Potential areas for BMP retrofit are discussed below and shown on Figure 13. CRWP will continue to work with member communities to further investigate these opportunities and implement the below recommendations.

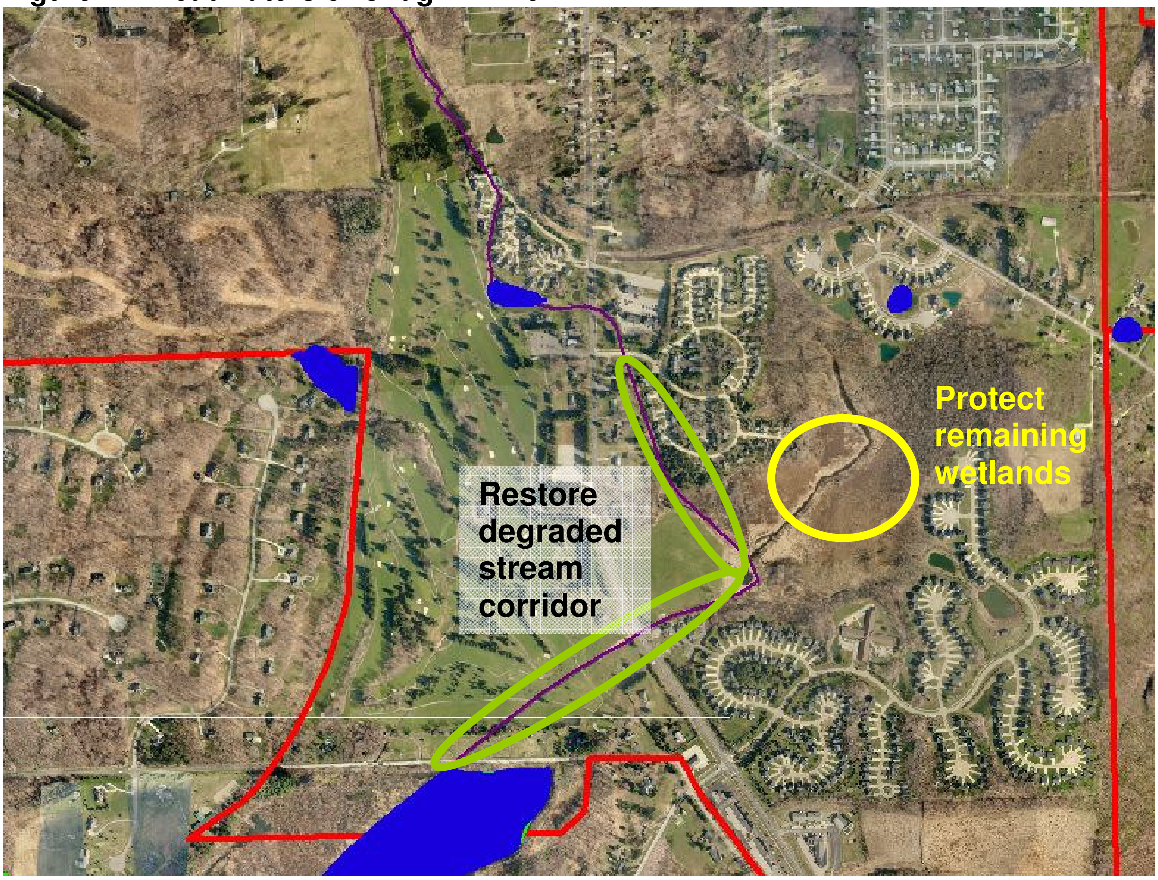
Figure 13: Potential Retrofit Locations



Headwaters of Main Channel

The main channel of the Chagrin River upstream of Bass Lake in the City of Chardon is illustrated in Figure 14. This area is in non-attainment and has been impacted by riparian vegetation removal, hydromodification, and suburban runoff. Stream channel and riparian corridor restoration in this area is important to mitigate the impacts of development on this stream. In addition the wetland in this area should be protected from further development through purchase or easements. Installation of specific BMP retrofits would not effectively improve this stream unless riparian corridor restoration was also completed.

Figure 14: Headwaters of Chagrin River



Ward/Newell Creek

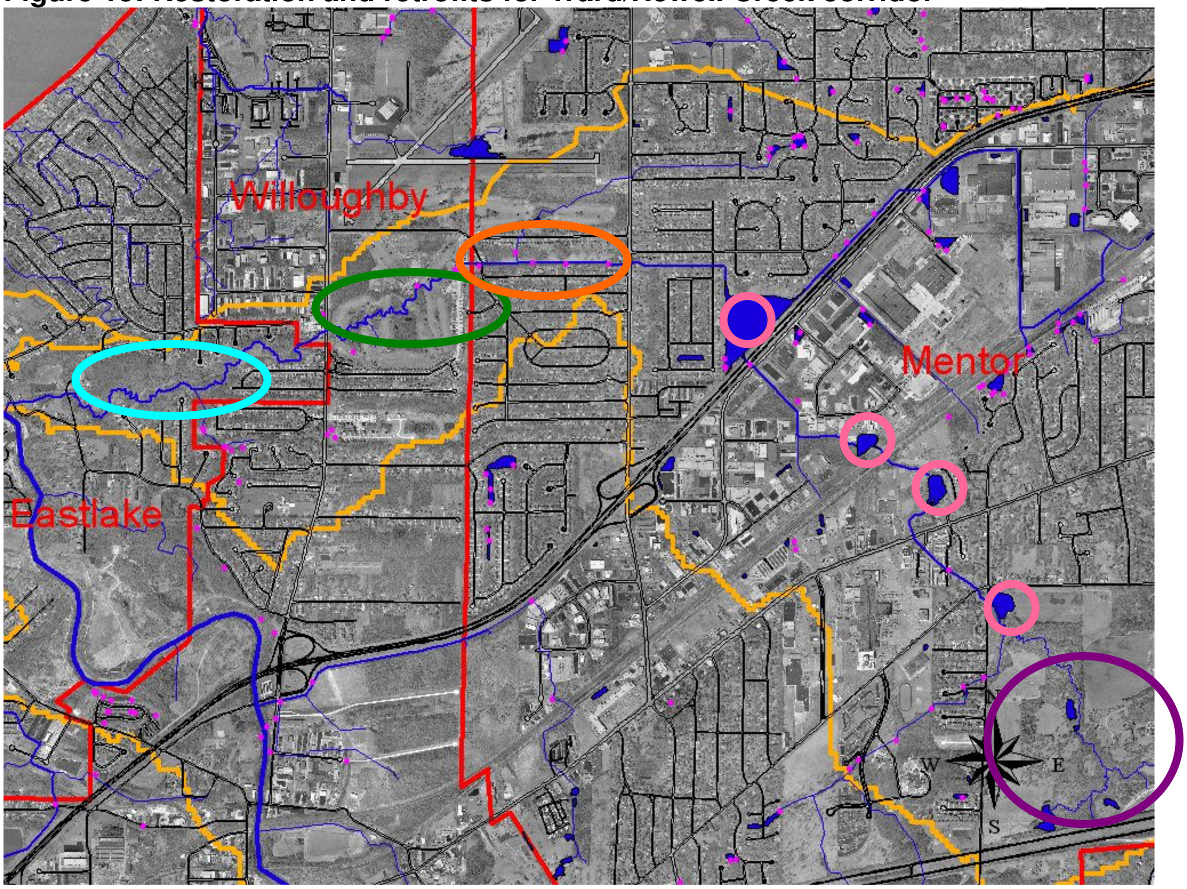
Figure 15 shows the Ward/Newell Creek corridor. BMPs that may be appropriate here would include, stream corridor restoration and protection within the City of Willoughby Lost Nation Golf Course, and additional water quality and quantity treatment of stormwater discharges within the City of Mentor. Additional hydraulic monitoring would need to be completed to locate the most advantageous retrofit locations within the City of Mentor. Figure 12, below details specific locations for potential restoration and BMP retrofits within the Ward/Newell Creek corridor. The potential restoration and retrofit opportunities are detailed below including some discussion on their ease of implementation.

Figure 15 details the following:

- Streams and ponds in blue
- Community outline in red
- Subwatershed outline in orange
- Stormwater outfalls in purple
- Light blue oval – area of existing protected wooded riparian corridor.
- Green oval – Potential stream corridor restoration area.
- Purple Circle – Ensure riparian corridors are protected and effective stormwater BMP's are implemented on a new development sites.

- Pink Circles – Existing ponds potential storm water retrofit areas
- Orange oval – area of intensive steam restoration.

Figure 15: Restoration and retrofits for Ward/Newell Creek corridor



The following details potential restoration and retrofit strategies as detailed in Figure 15. Riparian corridor protection is not enough to restore this impacted stream reach. This stream is heavily impacted by episodic stormwater flows. Retrofits to add additional stormwater storage is essential to allow this stream to meet WWH. Retrofitting existing ponds is more economical approach to retrofitting and is suggested below.

- The lower section of this watershed near the light blue oval does not currently meet its warmwater habitat use. This lower reach is largely protected by the City of Eastlake and Lake Metroparks. Efforts should be made through additional easement or land purchase to extend this protected area to the mouth of Ward Creek.
- The area circled in green is the location of the City of Willoughby owned Lost Nation golf course. There are numerous areas that mowing is occurring up to the edge of the stream. Restoration opportunities include creating a continuous forested riparian corridor in this reach and providing protection measures such as setbacks or easements.
- The area circled in purple is the site of a new development. It is critical that the stream corridor be protected during the site design of this development and that effective stormwater BMPs for both quantity and quality are installed as this area develops.

- The areas circled in pink are all existing ponds which should be investigated for retrofit opportunities. Additional hydrologic modeling is necessary to determine how much stormwater needs to be controlled to stabilize downstream stream and sediment flow.
- The area circled in orange is a section of stream that is currently in a pipe with an overflow concrete channel above it. This area could be daylighted and a natural stream channel with riparian vegetation could be restored in this location. CRWP does not recommend completing this work until additional stormwater storage has been implemented upstream.
- Finally, this stream has a good amount of open channel remaining in the City of Mentor, and it is important that these channels are not further impacted in the future. Adoption of riparian setbacks would protect these channels from additional encroachment as areas redevelop.

Stoney Brook
The Stoney Brook watershed shown in Figure 11 is in partial attainment. This watershed is protected through riparian setback regulations in the City of Kirtland and large amounts of open space protected by the Lake Metroparks. Unfortunately the riparian corridor in this area is also impacted by cutting in the utility corridor and package plant discharges. The package plants along State Route 306 are being tied into a central sewer to eliminate this source of pollutants. As Stoney Brook is a coldwater habitat stream, it is important to cool down any stormwater discharges. Any new BMPs or retrofits should use infiltration or bioretention practices rather than ponds, which may further warm stormwater discharges.

As detailed throughout this report, each 14 digit subwatershed will benefit from strategies ranging from riparian protection to BMP construction. CRWP will continue to work with Member communities on adoption of best local land use practices, sound planning, stream restoration, and BMP construction and retrofits. This project assisted in focusing those efforts. In addition to the above recommendations for adoption of riparian setback regulations and BMP retrofit locations, CRWP will continue to encourage Member communities to use the stormwater infrastructure data dictionary to ensure a consistent data collection methodology that could assist in refining the selection of BMP retrofits in the future.

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Appendix A:
Chagrin River Watershed Stormwater Infrastructure Data Dictionary

STORMWATER INFRASTRUCTURE GIS DATA BASE GOALS AND OBJECTIVES
Goal: Provide consistent stormwater infrastructures mapping methodology for the Chagrin River Watershed.

Objectives:
- Recommend data collection for Phase II maps for the purpose of developing a common standard for the watershed.
- Determine location of stormwater collection systems and their outfalls in relationship to specific stream reaches based on available data.
- Determine the location of directly connected impervious surfaces and the location of outfalls to streams.
- Determine priority areas where storm water BMPs can be installed or retrofitted to reduce flooding, erosion, and water quality problems.
- Identify location of existing storm water BMPs to the extent data are readily available.
- Develop criteria to evaluate data to assess priority areas needing BMP implementation or retrofit.
- Prepare map showing sewershed areas for the watershed.

			Recommended Data Fields for:						
Data Field Name	**Field Type**	**Description**	**Phase II Illicit Discharge Detection**	**Phase II Illicit Discharge Source Tracking & Corrective Action**	**Storm Sewers Asset Management System**	**Storm Sewer System Modeling**	**BMP Location Tracking**	**BMP Maintenance (need to add data fields)**	**BMP Effectiveness Assessment(need to add data fields)**
STORM SEWER OUTFALL - POINT									
COMM_ID	Text (50)	Unique CRWP community ID number				✓			
OUTFALL_ID	Text (25)	Outfall ID number				✓			
NORTHING	Double (25,6)	Northing Coordinate of the outfall in a north-south direction, expressed in US survey feet, measured in the state plane coordinates, North American Datum 1983 State Plane Ohio North FIPS 3401. Minimum horizontal accuracy of 2.0 feet.				✓			
EASTING	Double (25,6)	Easting Coordinate of the outfall in an east-west direction, expressed in US survey feet measured in the state plane coordinates, North American Datum 1983 State Plane Ohio North FIPS 3401.				✓			
INV_ELEV	Double (10,2)	Surveyed elevation of the outfall invert in feet, measured to two decimal places. Minimum vertical accuracy of 0.04 feet. Elevation surveys shall be conducted in reference surveyed benchmarks tied to the North American Vertical Datum of 1988				✓			
TYPE	Text (25)	Outfall type: P = Pipe, D = Ditch, O=other				✓			
P_SHAPE	Text (25)	Pipe shape: C=circular, R=Rectangular, E=Elliptical, Eg=Egg, O=Other				✓			
P_DIAMETER	Double (10,2)	Measured diameter of pipe opening, in inches				✓			
P_HEIGHT	Double (10,2)	Measurement for a non-circular pipe. Measured height size of the pipe opening, in inches				✓			
P_WIDTH	Double (10,2)	Measurement for a non-circular pipe. Measured width size of the pipe opening, in inches				✓			
P_MATRL	Text (25)	Indicate the type of pipe material, RCP, VIT, PVC, DI, brick CPP, HDPE, or other	✓						

Data Field Name	Field Type	Description	Recommended Data Fields for: Phase II Illicit Discharge Detection	Phase II Illicit Discharge Source Tracking & Corrective Action	Storm Sewers Asset Management System	Storm Sewer System Modeling	BMP Location Tracking	BMP Maintenance (need to add data fields)	BMP Effectiveness Assessment(need to add data fields)
P_ERSCNTRL	Text (25)	Pipe erosion control: rip rap, concrete apron, other, or none	✓						
D_B_WIDTH	Double (10,2)	Ditch bottom width in inches	✓						
D_HEIGHT	Double (10,2)	Ditch side slope height, from bottom of channel to top, inches	✓						
D_T_WIDTH	Double (10,2)	Distance in inches across channel at top	✓						
D_TYPE	Text (25)	Ditch Type: G=grass, C=concrete, M=mud, O=other	✓						
PHOTO	Text (255)	File name and path of the photo of the outfall	✓						
STREAM	Text (255)	Indicate the receiving stream to which the outfall discharges	✓						
DATA_SOURC	Text (25)	Outfall data source: 01 As-builts, 02 Field checks, 03 Design plans 04 NPDES Permit, 05 Other (fill in comments)	✓						
OWNERSHIP	Text (25)	Outfall ownership: Pu=Public, Pr=private, ND=not determined	✓						
DRY WEATHER SCREENING DATA - POINT									
DATE_INSP	Date	Date of dry weather inspection		✓					
ODOR	Text (25)	N=None, M=musty, S=sewage, SO=solvent, Su=Sulfur, O=Oil, G=Gasoline, Ot=Other		✓					
COLOR	Text (25)	N=None, Y=Yellow, G=Green, B=Brown, Gr=Gray, O=Other		✓					
TURBIDITY	Text (25)	C=Clear, Cl=Cloudy, O=Opaque		✓					
FLOTABLES	Text (25)	N=None, OS=Oil Sheen, S=Sewage, F=Foam/Bubbles, A=Algae		✓					
POTENTIAL ILLICIT DISCHARGE	Text (25)	Low Probability – No positive visual observations identified and minimal flow. Medium Probability – One positive visual observation and minimal flow. High Probability – Two positive visual observations, one positive visual observation and/or significant flow		✓					
SOURCE	Text (25)	Possible Source: N=None, H=HSTS, I=Industrial, C=Commerical, O=Other		✓					
TRACKING	Text (50)	Source Tracking: IC=Investigation Complete, Source Confirmed, ICNS= Investigation Completed, Source Not Determined, NC=Investigation Not Completed.		✓					
STORM SEWER STRUCTURES									
ID	Text (25)	Unique identifier of the inlet			✓				
TYPE	Text (25)	YCB, 2-2A, 2-2B, 2-3, 2-4, 2-5, 2-6, 3A, YD, MH, or other			✓				
MATERIAL	Text (25)	Plastic, brick, precast, or other			✓				
SIZE	Double (10,2)	Measured distance of the structure inside the inlet or storm manhole, in inches			✓				
NORTHING	Double (25,6)	Northing Coordinate of the outfall in a north-south direction, expressed in US survey feet, measured in the state plane coordinates, North American Datum 1983 State Plane Ohio North FIPS 3401. Minimum horizontal			✓				

Data Field Name	Field Type	Description	Phase II Illicit Discharge Detection	Phase II Illicit Discharge Source Tracking & Corrective Action	Storm Sewers Asset Management System	Storm Sewer System Modeling	BMP Location Tracking	BMP Maintenance (need to add data fields)	BMP Effectiveness Assessment(need to add data fields)
		accuracy of 2.0 feet.							
EASTING	Double (25,6)	Easting Coordinate of the outfall in an east-west direction, expressed in US survey feet measured in the state plane coordinates, North American Datum 1983 State Plane Ohio North FIPS 3401.				✓			
RIM_ELEV	Double (10,2)	Rim Elevation. Surveyed elevation of the top of the inlet in feet, measured to two decimal places. Minimum vertical accuracy of 0.04 feet, Elevation surveys shall be conducted in reference surveyed benchmarks tied to the North American Vertical Datum of 1988				✓			
SUMP_ELEV	Double (10,2)	Sump elevation. Surveyed elevation of the sump of the inlet in feet, measured to two decimal places. Minimum vertical accuracy of 0.04 feet, Elevation surveys shall be conducted in reference surveyed benchmarks tied to the North American Vertical Datum of 1988.				✓			
GRATE	Text (25)	Size of the opening of the inlet; single inches for circular, length by width in inches for a square opening and length in feet for curb inlet.				✓			
SURFACE	Text (25)	Indicate one of the following: asphalt, concrete, gravel, grass, or other.				✓			
MARKER	Text (25)	Labeled inlet “drains to stream” , Y=yes, N=No				✓			
IN_PHOTO	Text (255)	File name and path of the photo of the inside of the inlet				✓			
OUT_PHOTO	Text (255)	File name and path of the photo of the outside of the inlet				✓			
STORM SEWER CONDUITS									
ID	Text (50)	Unique identifier of the segment, combination of the upstream and downstream inlets separated by a hyphen or a predefine unique ID				✓			
OWNER	Text (50)	Owner of pipe				✓			
US_INLET	Text (25)	Identify the inlet from which the flow in the conduit originates using the “ID” from the storm sewer inlets table.				✓			
DS_INLET	Text (25)	Identify the downstream inlet or outfall of the conduit using the “ID” from the storm sewer inlet table or the outfall table.				✓			
US_INVERT	Double (10,2)	Surveyed elevation of the pipe invert where the flow originates, measured to two decimal				✓			

Data Field Name	Field Type	Description	Phase II Illicit Discharge Detection	Phase II Illicit Discharge Source Tracking & Corrective Action	Storm Sewers Asset Management System	Storm Sewer System Modeling	BMP Location Tracking	BMP Maintenance (need to add data fields)	BMP Effectiveness Assessment(need to add data fields)
		Recommended Data Fields for:							
		places. Minimum vertical accuracy of 0.04 feet, Elevation surveys shall be conducted in reference surveyed benchmarks tied to the North American Vertical Datum of 1988							
DS_INVERT	Double (10,2)	Surveyed elevation of the pipe invert where the flow discharges, measured to two decimal places. Minimum vertical accuracy of 0.04 feet, Elevation surveys shall be conducted in reference surveyed benchmarks tied to the North American Vertical Datum of 1988				✓			
SHAPE	Text (25)	Pipe shape: C=circular, R=Rectangular, E=Elliptical, Eg=Egg, O=Other				✓			
DIAMETER	Double (10,2)	Measured diameter size of the pipe opening, in inches.				✓			
HEIGHT	Double (10,2)	Measurement for a non-circular pipe. Measured height size of the pipe opening, in inches				✓			
WIDTH	Double (10,2)	Measurement for a non-circular pipe. Measured width size of the pipe opening, in inches				✓			
AREA	Double (10,2)	Calculated area of the pipe opening, in square feet				✓			
TYPE	Text (25)	Indicate the type of material of the conduit using one of the following: RCP, VIT, PVC, DI, brick, CPP, HDPE or other.				✓			
LENGTH	Double (10,2)	Calculated distance between the upstream and downstream inlets to the nearest foot				✓			
SLOPE	Double (10,2)	Calculated slope of the conduit reported as a percentage to the nearest hundredth.				✓			
CAPACITY	Double (10,2)	Calculated maximum capacity of the conduit using Manning's formula, in cubic feet per second (cfs) to the nearest thousandth				✓			
STORM SYSTEM CULVERTS - LINE									
ID	Text (25)	The unique identifier of the culvert.				✓			
COMMUNITY	Text (50)	Political subdivision where culvert exists.				✓			
OWNER	Text (50)	Owner of culvert				✓			
USNORTHING	Double (25,6)	Northing Coordinate of the upstream flowline of the culvert in a north-south direction, expressed in US survey feet, measured in the state plane coordinates, North American Datum 1983 State Plane Ohio North FIPS				✓			

			Recommended Data Fields for:						
Data Field Name	**Field Type**	**Description**	**Phase II Illicit Discharge Detection**	**Phase II Illicit Discharge Source Tracking & Corrective Action**	**Storm Sewers Asset Management System**	**Storm Sewer System Modeling**	**BMP Location Tracking**	**BMP Maintenance (need to add data fields)**	**BMP Effectiveness Assessment(need to add data fields)**
		3401. Minimum horizontal accuracy of 2.0 feet							
USEASTING	Double (25,6)	Easting Coordinate of the upstream flowline of the culvert in an east-west direction, expressed in US survey feet measured in the state plane coordinates, North American Datum 1983 State Plane Ohio North FIPS 3401. Minimum horizontal accuracy of 2.0 feet				✓			
US_INVERT	Double (10,2)	Surveyed elevation of the invert where the flow enters the culvert, measured to two decimal places. Minimum vertical accuracy of .04 feet. Elevation surveys shall be conducted in reference surveyed benchmarks tied to the North American Vertical Datum of 1988				✓			
DSNORTHING	Double (25,6)	Northing Coordinate of the downstream flowline of the culvert in a north-south direction, expressed in US survey feet, measured in the state plane coordinates, North American Datum 1983 State Plane Ohio North FIPS 3401. Minimum horizontal accuracy of 2.0 feet				✓			
DSEASTING	Double (25,6)	Easting Coordinate of the downstream flowline of the culvert in an east-west direction, expressed in US survey feet measured in the state plane coordinates, North American Datum 1983 State Plane Ohio North FIPS 3401. Minimum horizontal accuracy of 2.0 feet				✓			
DS_INVERT	Double (10,2)	Surveyed elevation of the invert where the flow discharges the culvert, measured to two decimal places. Minimum vertical accuracy of 0.04 feet. Elevation surveys shall be conducted in reference surveyed benchmarks tied to the North American Vertical Datum of 1988.				✓			
SHAPE	Text (25)	Pipe shape: C=circular, R=Rectangular, E=Elliptical, Eg=Egg, O=Other				✓			
DIAMETER	Double (10,2)	Measured diameter size of the pipe opening, in inches.				✓			
HEIGHT	Double (10,2)	Measurement for a non-circular pipe. Measured height size of the pipe opening, in inches				✓			
WIDTH	Double (10,2)	Measurement for a non-circular pipe. Measured width size of the pipe opening, in				✓			

Data Field Name	Field Type	Description	Recommended Data Fields for: Phase II Illicit Discharge Detection	Phase II Illicit Discharge Source Tracking & Corrective Action	Storm Sewers Asset Management System	Storm Sewer System Modeling	BMP Location Tracking	BMP Maintenance (need to add data fields)	BMP Effectiveness Assessment(need to add data fields)
		inches							
AREA	Double (10,2)	Calculated area of the pipe opening, in square feet.				✓			
TYPE	Text (25)	Indicate the type of material of the culvert using one of the following, RCP, VIT, PVC, DI, brick CPP, HDPE, or other				✓			
LENGTH	Double (10,2)	Calculated distance between the upstream and downstream culvert opening to the nearest foot.				✓			
SLOPE	Double (10,2)	Calculated slope of the conduit reported as a percentage to the nearest hundredth				✓			
CAPACITY	Double (10,2)	Calculated maximum capacity of the conduit using Manning's formula, in cubic feet per second (cfs) to the nearest thousandth.				✓			
HEADWALL	Text (25)	Indicate one of the following: full, half, or none				✓			
ERSCNTRL	Text (25)	Indicate one of the following, rip rap, concrete, other or none				✓			
PHOTO	Text (255)	File name and path of the photo of the culvert				✓			
STREAM	Text (255)	Indicate the receiving stream which the culvert traverses							
DATE_INSP	Date	Date of the last observation of the culvert during dry weather.							
OBSERVATIN	Text (25)	Indicate one of the following, clear, grey, or none.							
MAINTNANCE	Text (50)	Date and record number of the last maintenance performed on the conduit							
STATUS	Text (50)	B100=100% blocked by debris, B50: 50% obstructed by debris, BM= minor obstruction of pipe by debris, BP=broken pipe, BC= pipe collapsed.							
DATE_INSTL	Date								
STORM WATER POST CONSTRUCTION BEST MANAGEMENT PRACTICES BASE DATA									
IDBMP	Text (50)	Community code & unique number					✓		
COMMUNITY	Text (50)	Political subdivision where BMP is located					✓		
OWNERSHIP	Text (25)	BMP ownership: P=Private, Pu=Public, ND=not determined					✓		
OWNER_NAME	Text (50)	Owner name					✓		
CONTACT	Text (255)	Contract Information, address, city, state, phone number					✓		
DATE_CONTR	Date	Date constructed					✓		
PLANS	Text (255)	Location of filed plans					✓		
ENGINEER	Text (255)	Name of firm designing BMP					✓		

Data Field Name	Field Type	Description	Phase II Illicit Discharge Detection	Phase II Illicit Discharge Source Tracking & Corrective Action	Storm Sewers Asset Management System	Storm Sewer System Modeling	BMP Location Tracking	BMP Maintenance (need to add data fields)	BMP Effectiveness Assessment(need to add data fields)
			Recommended Data Fields for:						
APPROVING AGENCY	Text (255)	Approver of plans, name of individual					✓		
NORTHING	Double (25,6)	Northing Coordinate of the BMP outlet in a north-south direction, expressed in US survey feet, measured in the state plane coordinates, North American Datum 1983 State Plane Ohio North FIPS 3401. Minimum horizontal accuracy of 2.0 feet.					✓		
EASTING	Double (25,6)	Easting Coordinate at the outlet in an east-west direction, expressed in US survey feet measured in the state plane coordinates, North American Datum 1983 State Plane Ohio North FIPS 3401.					✓		
MAINTAINER	Text (255)	Name of organization/individual responsible for maintaining BMP					✓		
INFLOWP	Text (10)	Number of inflow pipes					✓		
INFLOWD	Text (10)	Number of inflow ditches/swales					✓		
BMP_TYPE	Text (25)	DB=Detention Basin, GF=Grass Filter Strip, IF=Infiltration Basin, BF=Biofiltration (rain garden), PP=Porous Pavement, RP=Retention Pond, PT=Percolation Trench, DW=Dry Well, WS=Wetland Swale, WB=Wetland Basin, HD= Hydrodynamic Devices (oil-water separators, swirl-type concentrators, prefabricated devices).					✓		
BMP_BRAND	Text (50)	Name of BMP (Hydrodynamic Devices)					✓		
BMP_DWG	Text (50)	Drawing of BMP in plan, profile, and layout view in bitmap format (pdf?)					✓		
DETENTION BASIN DATA (incomplete) Extended detention (ED) dry basins are designed to completely empty at some time after stormwater runoff ends. These are adaptations of the detention basins used for flood control. The primary difference is in outlet design; the extended detention basin uses a much smaller outlet that extends the retention time for more frequent events so that pollutant removal is facilitated. The term "dry" implies that there is no significant permanent water pool between storm runoff events.									
WQVOLUME		Volume of storm runoff that is captured and slowly drained over a period of time.							
WQUANTITY VOLUME		Require if system construction prior to OEPA WQv requirement							
WQ DETENTION SURFACE AREA		Area of the water surface in the detention basin at full water quality detention volume							
WQ DETENTION BASIN LENGTH		Measured as the distance between inflow and outflow. If there is more then one inflow point, use the average distance between the inflow points and the outflow weighed by the tributary impervious area.							
BOTTOM AREA		Area in sq. feet excluding side slopes but							

Data Field Name	Field Type	Description	Phase II Illicit Discharge Detection	Phase II Illicit Discharge Source Tracking & Corrective Action	Storm Sewers Asset Management System	Storm Sewer System Modeling	BMP Location Tracking	BMP Maintenance (need to add data fields)	BMP Effectiveness Assessment(need to add data fields)
		including the bottom stage area.							
VOLUME EMPTYING TIME		Emptying time of the water quality detention volume (water quantity volume if applicable)							

Retention Pond

Retention ponds are also commonly known as "wet ponds" because they have a permanent pool of water, unlike detention basins, which dry out between storms. The permanent pool of water is replaced in part or in total by stormwater during a storm event. The permanent pool of water is replaced in part or in total by stormwater during a storm event. The design is such that any available surcharge capture volume is released over time. The hydraulic residence time (HRT) for the permanent pool over time can provide biochemical treatment. A dry weather base flow, pond liner and/or high groundwater table are required to maintain the permanent pool.

Grass Filter Strip

Grass filter strips, sometimes called biofilters or buffer strips, are vegetated areas designed to accept sheet flow provided by flow spreaders which accept flow from an upstream development. Vegetation may take the form of grasses, meadows, forests, etc. The primary mechanisms for pollutant removal are filtration, infiltration, and settling.

Filtration (Rain Gardens)

Porous Pavement

Poured-in-place porous concrete or asphalt is generally placed over a substantial layer of granular base. The pavement is similar to conventional materials, except for the elimination of sand and fines from the mix. If infiltration to ground water is not desired, a liner may be used below the porous media along with a perforated pipe and a flow regulator to slowly drain the water stored in the media over a 6 to 12 hour period.

Wetland Channel and Swale

A wetland channel is a channel designed to flow very slowly, probably less than two feet per second at the two-year flood peak flow rate. It has, or is designed to develop, dense wetland vegetation on its bottom. A swale, sometimes called a biofilter, is a shallow grass-lined channel with zero, or little, bottom width designed for shallow flow near the source of storm runoff.

Wetland Basin

A wetland basin is a BMP similar to a retention pond (with a permanent pool of water) with more than 50% of its surface covered by emergent wetland vegetation, or similar to a detention basin (no significant permanent pool of water) with most of its bottom covered with wetland vegetation.

Data Field Name	Field Type	Description	Phase II Illicit Discharge Detection	Phase II Illicit Discharge Source Tracking & Corrective Action	Storm Sewers Asset Management System	Storm Sewer System Modeling	BMP Location Tracking	BMP Maintenance (need to add data fields)	BMP Effectiveness Assessment(need to add data fields)

Recommended Data Fields for: (columns 4–10)

Hydrodynamic Devices

The hydrodynamic device BMP category includes BMPs such as oil-water separators, sand interceptors, swirl-type concentrators, sedimentation vaults, and other prefabricated and package-type treatment devices.

Chagrin River Watershed Community ID Codes

ID numbers are critical to separating the data by political subdivision. We propose a text based descriptor, but a two digit numerical system is a possible way to go. Once the ID Code is identified, element codes (i.e. outlet number, inlet number, etc.) can simply be identified in numerical order that they are entered into the system by the community.

SOURCE FOR SUGGESTED DATA ELEMENTS:

City of Cortland Asset Management System – URS
Bowling Green University Utility Asset Management System – URS
CHIA Storm sewer Investigation - URS
National Stormwater BMP Database Data Elements – ASCE & USEPA
ODOT MS4 Storm Water Outfall Inventory Manual
Allegheny County GIS Sewer Data Dictionary
Lake County (Illinois) Outfall Inventory Data Dictionary