



Pheasant Branch 2018 Flood Damage Assessment and Five Year Plan

City of Middleton

February 2019



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Acronyms

BEHI	Bank Erosion Hazard Index
FEMA	Federal Emergency Management Agency
LiDAR	Light Detection and Ranging
NPS	Nonpoint Source
USGS	U.S. Geological Survey
WIDNR	Wisconsin Department of Natural Resources

1 History of City Middleton Projects in the Pheasant Branch Corridor

Pheasant Branch has historically had problems with streambank erosion and suspended sediment driven by land-use changes within its watershed. Increased flood peaks and water volumes have degraded streambanks throughout the reach over time. Sediment from bank erosion is also deposited within the channel reducing the channel's capacity and efficiency. Problems within the Pheasant Branch system ultimately lead to problems in Pheasant Branch Marsh as well as within Lake Mendota.

Since 1975, stormwater detention ponds, gabions, sheet piling, vane deflectors, and grade control structures have been installed to control channel erosion within Pheasant Branch. These stormwater management practices have been effective in mitigating the effects of increased urbanization within the watershed.¹ Yet, increases in annual precipitation and flood peak flows in the watershed have led to areas of significant bank erosion within Pheasant Branch over time.

Since 2007, the City of Middleton has been working with the Wisconsin Department of Natural Resources (WIDNR) and the Federal Emergency Management Agency (FEMA) to repair severely eroded slopes within the Pheasant Branch corridor. These efforts include nine construction projects, utilizing WIDNR Urban Non-Point Source Stormwater Construction grants, WIDNR Clean Water Fund grants, and FEMA grants to stabilize approximately 6,000 linear feet of eroded slopes and streambanks from 2007 to 2017 (Table 1).

Table 1: History of Pheasant Branch construction projects, 2007-2017.

Year	Project	Total Cost	Grant Funded	City Funded	Grant Agency
2007	Pheasant Branch Slope Stabilization (Park St. to Century Ave.)	\$47,000	\$31,500	\$15,500	FEMA & WIDNR NPS
2008	Pheasant Run Slope Stabilization (between Park St. and Century Ave.)	\$27,700	\$13,850	\$13,850	WIDNR Clean Water
2009	Gabion Removal and Slope Stabilization (between Park St. and Century Ave.)	\$28,500	\$25,700	\$2,800	FEMA
2009	Rootwad Slope Stabilization (between Park St and Century Ave.)	\$19,000	NA	\$19,000	NA
2010	Park St. to Century Ave. Streambank Stabilization & Habitat Enhancement Project	\$149,354	\$74,677	\$74,677	WIDNR Clean Water
2012	Park St. to Parmenter St. Streambank Stabilization	\$154,100	\$77,050	\$77,050	WIDNR NPS
2013	South Fork Pheasant Branch Streambank Stabilization	\$130,200	\$60,000	\$70,200	WIDNR NPS
2015	Kromrey Middleton School Stream Realignment	\$109,000	NA	\$109,000	NA
2017	Pheasant Branch Streambank Restoration North of Century Ave.	\$220,812	\$110,406	\$110,406	WIDNR NPS

¹ Gebert, W.A., Rose, W.J., and Garn, H.S., 2012. Evaluation of the effects of Middleton's stormwater-management activities on streamflow and water-quality characteristics of Pheasant Branch, Dane County, Wisconsin 1975-2008: U.S. Geological Survey Scientific Investigations Report 2012-5014, 27 p. plus appendixes.

Eight of these projects were completed along the mainstem of Pheasant Branch from Parmenter St. to the area north of Century Ave., and one project on the south fork of Pheasant Branch between Greenway Blvd. and Market St. within the City of Middleton (Figure 1).

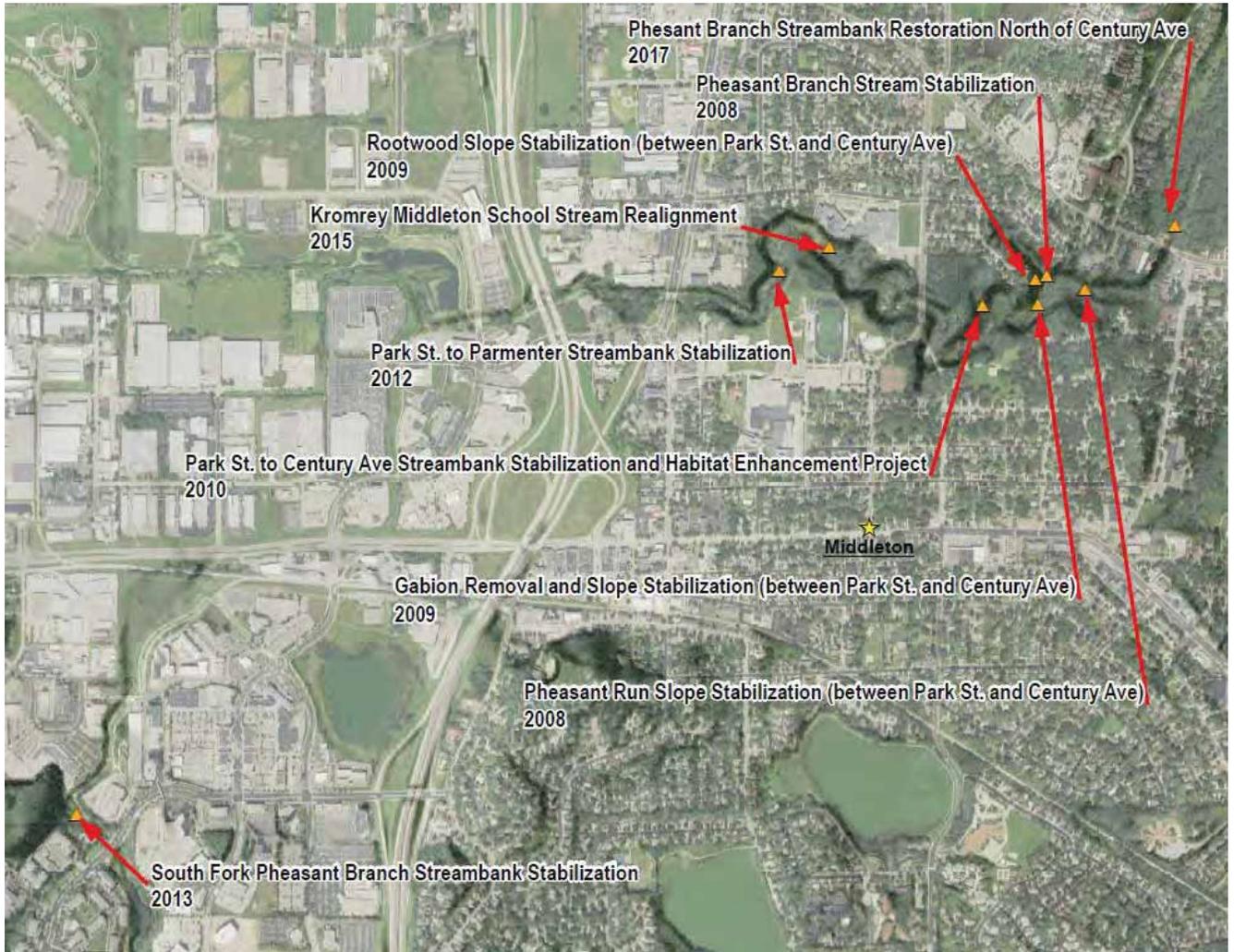


Figure 1: Channel erosion construction project locations within Pheasant Branch from 2007-2017.

1.1 2007-2010 Pheasant Branch Stabilization Projects between Park St. and Century Ave.

From 2007 to 2010, the City of Middleton performed approximately 2,000 linear feet of streambank and slope stabilization using ecologically-sensitive techniques including rootwad composites to protect the toe of the slopes and create additional deep pool and under-bank habitat. Slope grading was also performed on these slopes to bring them to a more stable angle and once completed the entire project areas were seeded with a mixture of native forbs and grasses. The dense growth and deep root systems of the native vegetation help to hold bank materials in place while allowing water to infiltrate through the soil instead of flowing overland to the stream (Figure 2).



Figure 2: Photo of eroded slope adjacent to Pheasant Branch between Park St. and Century Ave. in 2005 (left) and same slope after construction taken in 2009 (right).

1.2 2012 Park St. to Parmenter St. Streambank Stabilization Project

In 2012, the City of Middleton stabilized nearly 1,500 linear feet of streambanks and slopes between Park St. and Parmenter St. within the Pheasant Branch corridor using ecologically-sensitive techniques to mitigate erosion. To reduce the sediment load in the creek, stream energy dissipation structures and integrated bank treatments, including rootwad and toewood composites, cross-vanes, and single arm vanes were installed. These methods stabilized the banks while providing improved habitat for the insects, amphibians, reptiles, and fish found within the creek and riparian corridor (Figure 3).



Figure 3: Photo of eroded slope adjacent to Pheasant Branch between Park St. and Parmenter St. in 2010 (left) and same slope after construction taken in 2014 (right).

1.3 2013 South Fork Pheasant Branch Streambank Stabilization Project

In 2013, the City of Middleton completed nearly 1,000 linear feet of streambank stabilization in the south fork of Pheasant Branch between Greenway Blvd. and Market St. This project incorporated the re-use of trees that had to be removed from the site in order to grade collapsing streambanks. The trees were incorporated into the streambanks to provide extra bank protection, helping to dissipate stream energy by redirecting flows away from the banks while also providing valuable in-stream habitat for the riparian area. Bankfull benches were also graded into the new streambanks to allow high flows to get out of the channel and up onto the bench helping to dissipate stream energy through this reach during high flows (Figure 4).



Figure 4: Photo of collapsing streambanks and debris jams within the south fork of Pheasant Branch in 2012 (left) and same section of stream after construction taken in 2015 (right).

1.4 2015 Kromrey Middleton School Stream Realignment

The Pheasant Branch Kromrey Middle School Stream Relocation Project relocated approximately 500 linear feet of stream channel away from steep eroding slopes and streambanks by creating a new channel using ecologically-sensitive techniques to mitigate erosion. Relocation of this section of stream also increased flood flow capacity at the site allowing flood flows to rise up out of the bankfull channel and spread out over a newly created floodplain, dissipating energy, and offering increased protection at the toe of the steep slope above which a new addition to the Kromrey Middle School was built. As part of the project, an additional 0.04 acres of backwater oxbow wetland was created (Figure 5).



Figure 5: Photo of collapsing streambank adjacent to Pheasant Branch within near site of Kromrey Middle School addition 2013 (left) and same section of stream after construction taken in 2016 (right).

1.5 2017 Pheasant Branch Streambank Restoration Project North of Century Ave.

In 2017 the City of Middleton stabilized over 1,000 linear feet of severely eroding streambanks and eroded steep slopes using ecologically-sensitive techniques along Pheasant Branch north of Century Ave. The eroding streambanks and eroded slope locations varied in size, extent of active erosion, and in applicable treatment. Trees removed during restoration activities to grade streambanks and collapsing slopes to more stable angles and increase flood flow capacity of the channel within the project area were re-used in streambank stabilization treatments. These treatment techniques incorporated the removed woody material as part of the bank stabilization (Figure 6).



Figure 6: Photo of collapsing streambank adjacent to Pheasant Branch located North of Century Ave. in 2014 (left) and same section of stream after construction taken in 2017 (right).

2 Stream Naming and Stationing System

In order to aid the City of Middleton in identification of future project limits within the Pheasant Branch corridor, a three part stream naming and stationing system was developed (Figure 7).

This system consists of:

- 1) The **north fork** of Pheasant Branch starting at Airport Road and continuing to the Confluence Pond (~ 5,130 linear feet).
- 2) The **south fork** of Pheasant Branch starting at the City of Middleton's border east of Greenway Blvd. and continuing to the Confluence Pond (~ 8,760 linear feet).
- 3) The **mainstem** of Pheasant Branch starting at the outlet of the Confluence Pond and continuing north of Century Ave. (~ 13,580 linear feet).

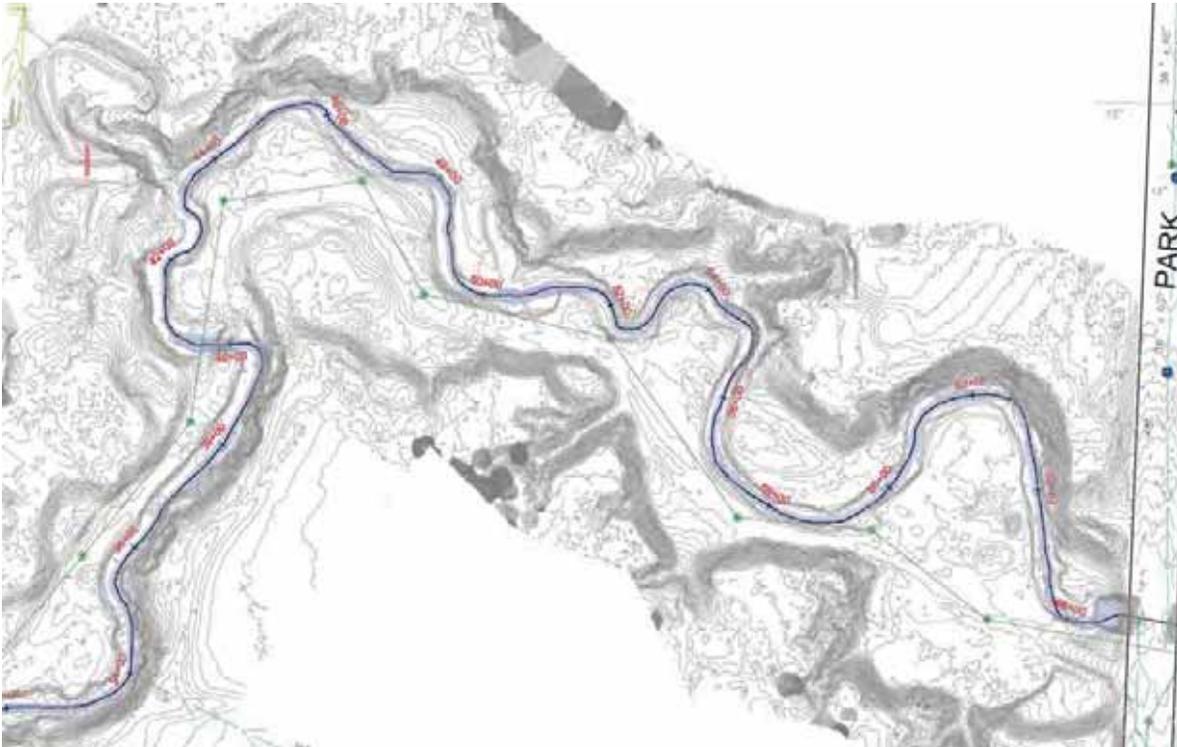


Figure 7: Example of Stream Stationing on the mainstem of Pheasant Branch between Parmenter St. and Park St.

A complete set of the three part stream naming and stationing system can be found in Appendix A.

3 2018 Flood Damage Assessment

On August 20, 2018, over 11 inches of rain fell in less than 24 hours in the Middleton and Cross Plains area. At the peak of the storm, rain was falling at a rate of 2 to 4 inches per hour according to National Weather Service data. The resulting flooding caused widespread damage throughout Pheasant Branch and the public trails system located within the City of Middleton.

Since 1975, the Pheasant Branch system had endured three major flooding events with peak flows over 800 cubic feet per second (cfs), (Figure 8). These events caused massive flooding within Pheasant Branch, which has an average annual discharge of less than 10 cfs.

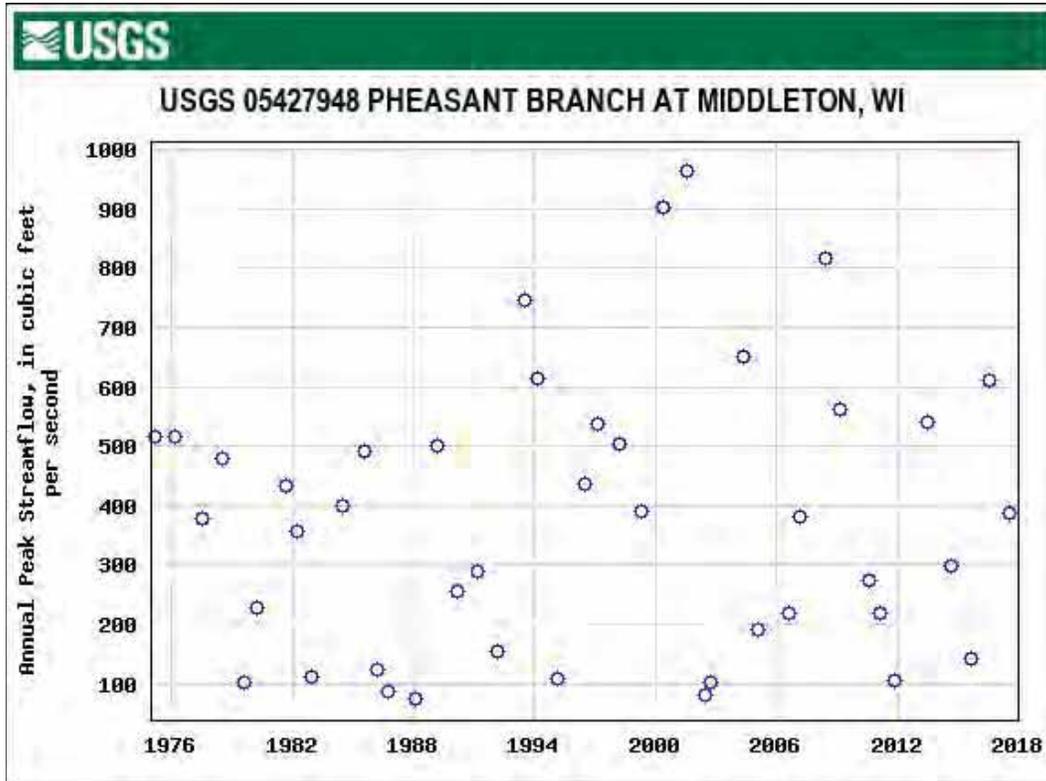


Figure 8: Annual peak flow at U.S. Geological Survey (USGS) stream gauge in Pheasant Branch.

Yet, estimated peak flows from the storm event on August 20, 2018, where over 11 inches of rain fell in less than 24 hours, are estimated at over 3,000 cfs., or nearly three to four times higher than any flows recorded in this watershed over the last 43 years (Figure 9).

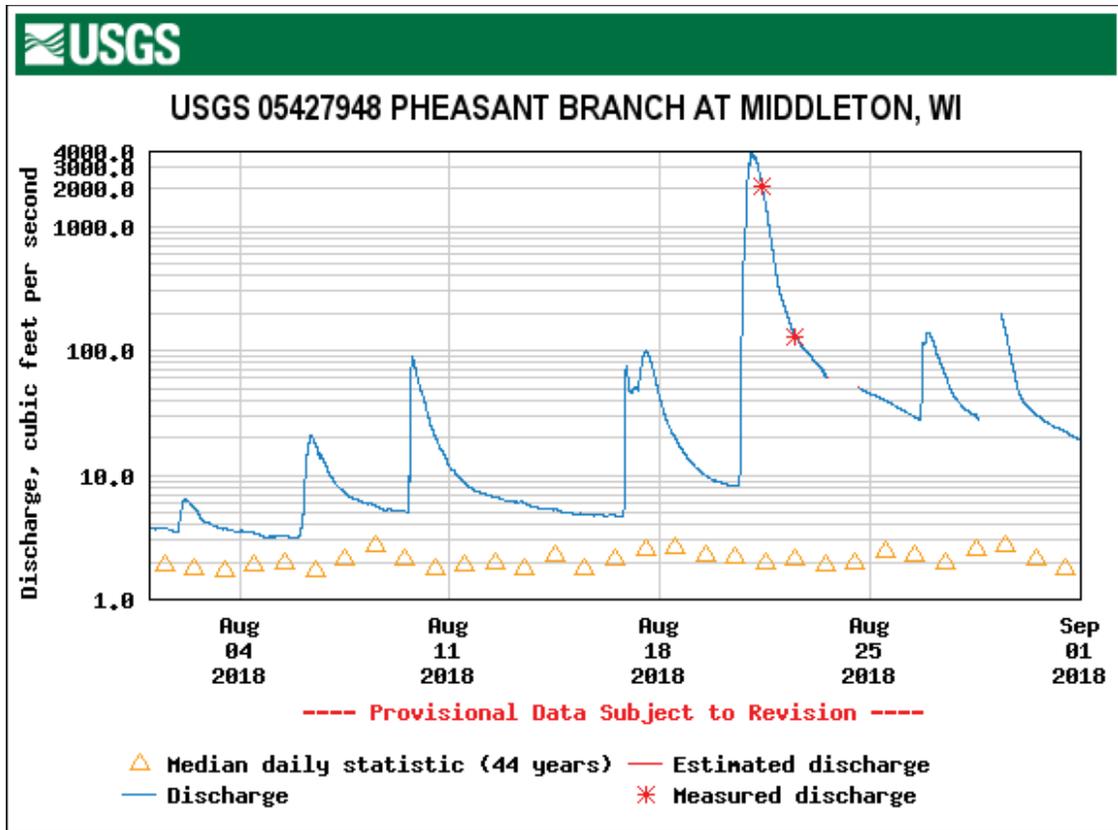


Figure 9: Flood discharge for August 20, 2018 flood event at Pheasant Branch stream gauge in Middleton.

3.1 Pheasant Branch Streambank Erosion Assessment

Cardno performed a complete streambank erosion assessment of both the left and right bank for the north fork, south fork and mainstem of Pheasant Branch. Streambank erosion assessments were performed using the Bank Erosion Hazard Index (BEHI) model developed by Dr. David Rosgen². The BEHI model evaluates the susceptibility of a streambank to erosion for multiple erosional processes. Individual BEHI variables are recorded through visual assessments and physical measurements to determine the combined risk for specific streambank sections to future streambank erosion (Figure 10).



Figure 10: Example BEHI model streambank erosion risk assessment for mainstem of Pheasant Branch between Park St. and Century Ave.

A complete set of the BEHI model streambank erosion risk assessments for the left and right bank of the north fork, south fork, and mainstem of Pheasant Branch can be found in Appendix B.

² Rosgen, David. WARSSS - Watershed Assessment of River Stability and Sediment Supply

3.2 North Fork Pheasant Branch Damage Assessment

The north fork of Pheasant Branch came through the August 2018 flood with relatively low damage and lasting streambank erosion. This is evident in BEHI model bank assessments for this area with no streambanks in this region showing High, Very High, or Extreme rates of bank erosion. The stream in much of the north fork of Pheasant Branch has access for flood waters to rise out of the channel onto the flood plain, which helped dissipate energy during the August 2018 flood event (Figure 11). The lack of shallow rooted tree species near the channel in this area also helped mitigate flood damage as uprooted downed trees in other areas caused extensive damage.



Figure 11: Post-flood photo of the north fork of Pheasant Branch viewing downstream (10/22/18).

3.3 South Fork Pheasant Branch Damage Assessment

The south fork of Pheasant Branch did sustain damage during the August 2018 flood event including damage to one of the bridges that cross the channel, damage to the porous pavement trail to the east of the channel, and exposure of fiber optic cable lines near the Market St. crossing (Figure 12).



Figure 12: Fiber optic cable lines exposed in south fork Pheasant Branch following August 2018 flood (8/25/18).

Streambank erosion was also a problem within the south fork of Pheasant following the August 2018 flood. Streambank assessments in this area identified 1,272 linear feet of streambank as having a High potential for future erosion, 373 linear feet of Very High and 387 linear feet showing Extreme streambank erosion (Figure 13).



Figure 13: Post-flood Extreme streambank erosion in the south fork of Pheasant Branch viewing downstream (8/25/18).

Severe down-cutting of the channel is also evident in some areas of the south fork of Pheasant Branch. This down-cutting is mainly found in the section between Greenway Blvd. and Market St. Channel down-cutting will need to be addressed in this section in future restoration plans. Damage to exposed fiber optic lines as well as erosion adjacent to the abutments of each of the two pedestrian bridges that cross the south fork between Greenway Blvd. and Market St. will need to be addressed.

3.4 Mainstem Pheasant Branch Damage Assessment (Between the Confluence Pond and Parmenter St.)

Some areas of the mainstem of Pheasant Branch between the confluence pond and Parmenter St. did experience various degrees of bank erosion following the August 2018 flood event. Streambank assessments within this area determined that approximately 1,520 linear feet of streambanks showed High bank erosion rates with an additional 197 linear feet exhibiting Very High and 264 linear feet of Extreme streambank erosion (Figure 14).



Figure 14: Extreme streambank erosion as a result of August 2018 flood event near Deming Way viewing downstream (1/15/19).

3.5 Mainstem Pheasant Branch Damage Assessment (Between the Parmenter St. and Park St.)

The mainstem of Pheasant Branch between Parmenter St. and Park St. experienced significant damage following the August 2018 flood event. All three pedestrian bridges that cross the channel between Parmenter St. and Park St. were damaged (Figure 15).



Figure 15: Photo of damaged bridge near Parmenter St. following August 2018 flood viewing downstream (8/25/18).

Extensive damage also occurred at the Donna Drive sedimentation pond where flood waters overtopped the pond, eroding the pond bank, causing a complete failure of the pond and stream embankment (Figure 16).



Figure 16: Photo of Donna Dr. sedimentation pond failure following August 2018 flood event (8/25/18).

Much of the damage to the existing bridges and streambanks in this section was caused by debris jams consisting of mainly shallow rooted tree species that collapsed into the stream during the August 2018 flood event. Streambank assessments performed through this reach identified approximately 3,892 linear feet of streambanks showing evidence of High bank erosion with 453 linear feet of Very High and 625 linear feet of Extreme streambank erosion. Much of the pedestrian trail system adjacent to Pheasant Branch was also damaged during the August 2018 flood event. These areas will also need to be repaired along with restoration of streambanks and the stream channel in this section of Pheasant Branch (Figure 17).



Figure 17: Photo of pedestrian trail damage between Parmenter St. and Park St. following August 2018 flood event (8/25/18)

3.6 Mainstem Pheasant Branch Damage Assessment (Between Park St. and Century Ave.)

The mainstem of Pheasant Branch between Park St. and Century Ave. experienced significant damage during the August 2018 flood event including damage to each of the three pedestrian bridges located in this section of stream (Figure 18).



Figure 18: Photo of damaged pedestrian bridge between Park St. and Century Ave. following August 2018 flood event (8/25/18).

The public trail system within this section was also damaged and well as multiple areas of significant streambank erosion. Streambank erosion assessments within this reach found that approximately 2,289 linear feet of streambank showed evidence of High bank erosion with 503 linear feet of Very High and 444 linear feet showing evidence of Extreme streambank erosion. Much of the damage to bridges and streambanks in this section was caused by debris dams comprised of shallow rooted trees that collapsed into the channel during the August 2018 flood event. Extreme streambank erosion also occurred directly downstream of the Park St. crossing as flood flows were concentrated through the culverts running beneath the roadway (Figure 19).



Figure 19: Photo of Extreme streambank erosion directly downstream of Park St. as a result of August 2018 flood event (10/11/18).

3.7 Mainstem Pheasant Branch Damage Assessment (North of Century Ave.)

The mainstem of Pheasant Branch north of Century Ave. experienced significant damage during the August 2018 flood event. Streambank erosion assessment through this section of Pheasant Branch showed evidence of High bank erosion on approximately 939 linear feet of streambanks with 1,179 linear of Very High and 636 linear feet of Extreme streambank erosion within this reach (Figure 20).



Figure 20: Extreme streambank erosion directly downstream of Century Ave. as a result of the August 2018 flood event (1/15/19).

Much of the damage within this section of Pheasant Branch was caused by debris jams from shallow rooted tree species that collapsed into the stream during the August 2018 flood event (Figure 21).



Figure 21: Photo of debris jam located in section of Pheasant Branch north of Century Ave. as a result of August 2018 flood event (8/25/18).

Some of the streambank gabion protection installed directly downstream of Century Ave are also beginning to fail as a result of the August 2018 flood event (Figure 22).



Figure 22: Failing gabion baskets as a result of August 2018 flood event located directly downstream of Century Ave. (1/16/19).

This section of Pheasant Branch also experienced severe down-cutting of the main stream channel as a result of the August 2018 flood event. Future restoration efforts in this section will need to address streambank erosion, failing gabions and channel down-cutting moving forward.

A comprehensive archive of post-flood photos following the August 2018 flood event for the north fork, south fork, and mainstem of Pheasant Branch is located in Appendix C.

3.8 LiDAR Assessment of Pheasant Branch

As part of the August 2018 flood damage assessment, Cardno sub-contracted Wisconsin Environmental Restorations, LLC to fly the north fork, south fork, and mainstem of Pheasant Branch with a drone and record up-to-date LiDAR measurements of the channel. LiDAR information collected during these drone flights was then compared with 2017 LiDAR data acquired from Dane County to provide an assessment of streambank sediment lost during the August 2018 flood event (Figure 23).

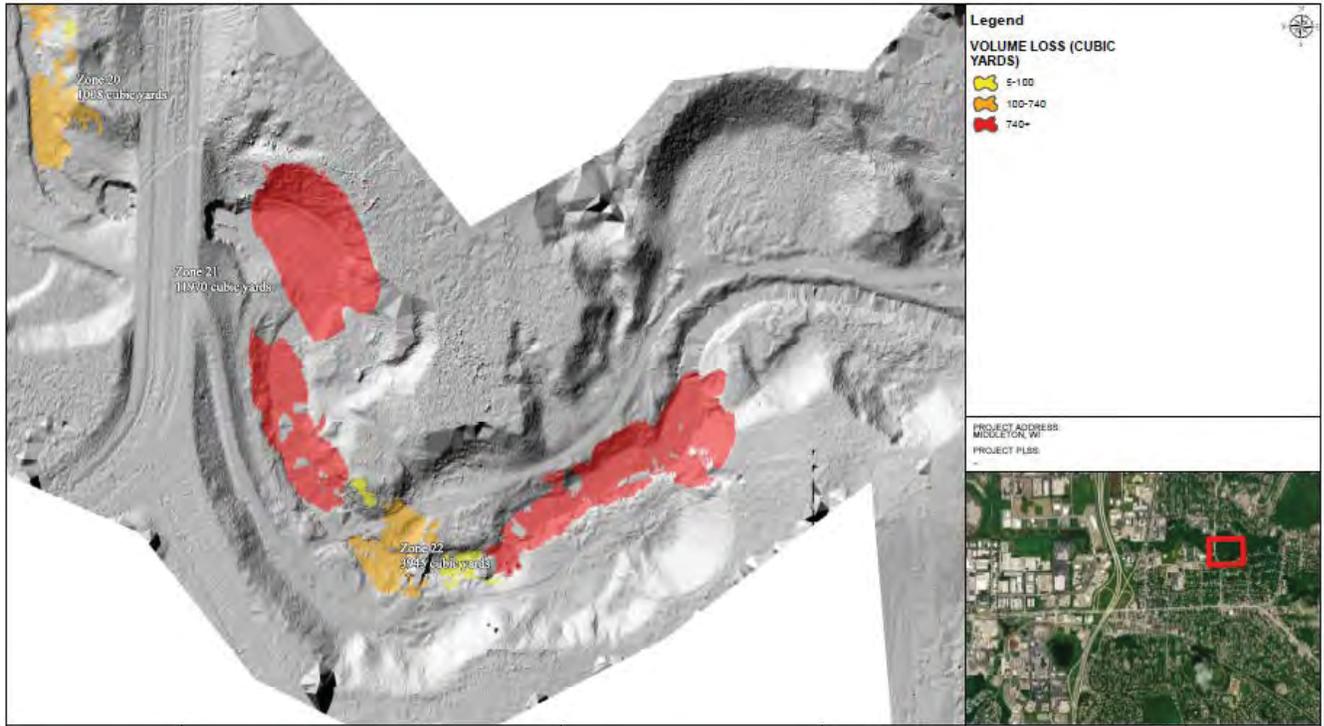


Figure 23: Example of comparison between 2017 and 2018 LiDAR data directly downstream of Park St. on the mainstem of Pheasant Branch.

A complete analysis of the differences between the 2017 and 2018 LiDAR data sets for the north fork, south fork, and mainstem of Pheasant Branch can be found in Appendix D. Initial estimates of sediment loss throughout the Pheasant Branch corridor total approximately 55,000 to 60,000 cubic yards of sediment lost from the channel and streambanks during the August 2018 flood event. Areas where no detectable change occurred indicated by no color in the sediment loss analysis maps (Figure 23 and Appendix D) does not necessarily mean no appreciable loss of the streambank and channel material occurred. For data analysis purposes, a “no change” scenario resulted when there was less than 1 foot vertical separation from pre-flood to post-flood land surfaces. Underlying noise common to all LiDAR datasets resulting from a number of factors such as auto/manual classification of LiDAR data points limited the initial analysis. A more detailed analysis could be performed on the two data sets to refine a sediment loss estimate; however this would require extensive cross section analysis of at least 300 locations and is outside of the scope of this report.

4 General Restoration Recommendations

The rainfall event on August 20, 2018 (into the morning of August 21) was one of, if not the largest rainfall events ever recorded in the State of Wisconsin over a 24 hour period. There were, however, some areas within the Pheasant Branch corridor that made it through this flood event with very little bank erosion and/or damage to steep slopes.

4.1 Floodplain Access and Flood Flow Capacity

One of the areas that made it through the August 2018 flood event with little damage was approximately 500 linear feet of relocated channel near the Kromrey Middle School constructed in 2015. Relocation of this section of stream between Parmenter St. and Park St. increased flood flow capacity at the site allowing flood flows to rise up out of the bankfull channel and spread out over a newly created floodplain area to dissipate stream energy while offering increased protection at the toe of the steep slope above which a new addition to the Kromrey Middle School was built (Figure 24).



Figure 24: Photo of relocated section of Pheasant Branch in 2017 (left) and same section of stream after 2018 flooding taken on 8/25/18.

Channel access to the floodplain is also apparent in the north fork of Pheasant Branch. There is little evidence of channel incision throughout this reach, allowing flood flows to rise up out of the channel and spread out over the floodplain. Consequently, the north fork of Pheasant Branch saw significantly less damage than other sections of Pheasant Branch during the August 2018 flood event.

Moving forward floodplain access should be considered during all restoration efforts within the south fork and mainstem of Pheasant Branch. Erosion from the August 2018 flood event moved thousands of cubic yards of streambank materials through the Pheasant Branch system. This additional flood flow capacity should be utilized in future restoration designs moving forward. Wherever possible, bankfull benches and floodplain access should be created to allow flood flows to rise out of the channel and onto benches and floodplain areas dissipating stream energy while also keeping an efficient low flow and bankfull channel to help move legacy flood sediments efficiently through the system. There may also be areas within the south fork and mainstem of Pheasant Branch where the stream channel can be realigned away from existing steep slopes to provide additional floodplain access, yet these areas need to be chosen carefully due to current sanitary sewer lines and other infrastructure that is located near the existing channel in many locations.

4.2 Damaged and Shallow Rooted Trees Adjacent to Pheasant Branch

Much of the damage to bridges, infrastructure and streambanks caused by the August 2018 flood event was caused by or exacerbated by shallow rooted tree species such as box elder (*Acer negundo*) that collapsed into the channel during flooding. These early successional or pioneering tree species have shallow root systems that do a poor job of stabilizing streambanks. They do, however, provide shade to streambanks preventing other more beneficial plant species from establishing or occurring. Many remaining box elder and other shallow rooted tree species that didn't collapse into the stream during the August 2018 flood event have been severely undermined and have the potential for causing damage in the future. Future restoration efforts in the south fork and mainstem of Pheasant Branch should take into consideration removing all the down and damaged trees adjacent to the streambank to prevent damage in future flooding events. Trees removed during restoration activities can be stockpiled and re-used to stabilize banks and provide additional stream habitat throughout the Pheasant Branch corridor.

4.3 Bridges and Stream Crossings

All of the pedestrian bridges throughout the south fork and mainstem of Pheasant Branch sustained some type of damage during the August 2018 flood event (Figure 25).



Figure 25: Damaged bridge between Park St. and Century Ave. as a result of August 2018 flood event (8/25/18).

As budgets allow, it is recommended to give future consideration to lengthen these crossings to allow additional flood flow capacity as well as additional room for debris to pass through them during floods. Additionally there may be opportunities during restoration activities to re-align some sections of the current channel in order to locate bridge crossings over straighter sections of channel instead of near meander bends in the channel where some of the crossings are currently located.

4.4 Future Streambank Stabilization Techniques

Pheasant Branch has historically had problems of streambank erosion and suspended sediment due to urban land-use changes within the basin and increases in annual precipitation and peak stream flows over time. Damage caused by the August 2018 flooding event only magnifies this problem.

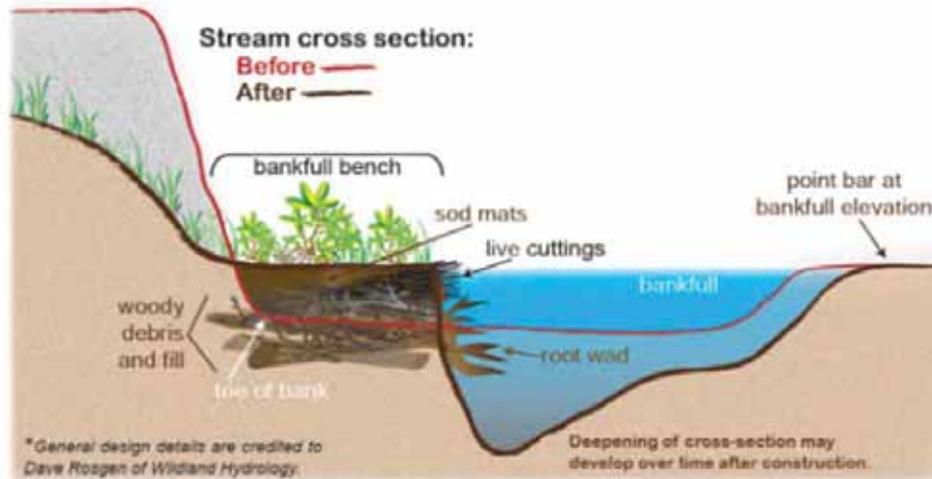
The identified areas of active streambank erosion throughout the south fork and mainstem of Pheasant Branch vary in size, extent of active erosion, and in applicable treatments. In many cases, eroded slopes and streambanks could be repaired through the use of integrated bank treatments including rootwads composites and toewood (Figure 26).



Figure 26: Underwater photo taken of installed rootwad composite (8/20/12)

4.4.1 Rootwad composites

Rootwad composite revetments and toewood are installed consisting of a combination of rootwads, (the intact lower trunk and root mass of mature trees), branches and stone. These structures provide a biological streambank stabilization alternative that aids in dissipating energy and near-bank stress from stream flows, increasing channel roughness while avoiding accelerating flows downstream of where they are installed. They also promote scour in the near bank area providing pool habitat which is currently lacking in the Pheasant Branch system due to the legacy of bank sediments found within the channel. Small spaces found within the rootwads and wood installed provide cover for small fish, as well as reptiles and small mammals found in the riparian habitat. These structures also create a diversity of micro-flow conditions, due to their non-uniformity, which can enhance aquatic invertebrate diversity allowing benthic organisms to select specific positions within the geometry of the local flow conditions. The habitat benefits associated with these structures will help address degraded habitat which is an additional impairment listed for the watershed.



Construction of a Toe Wood-Sod Mat: MNDNR, http://files.dnr.state.mn.us/publications/waters/toe_wood_sod_mat_dec2013.pdf

Figure 27: Example cross section of toewood design

4.4.2 Cross vane and flow deflection structures

Cross vane grade controls and flow redirection structures such as single arm vanes and J-Hooks can be used to deflect stream flow away from the streambank toward the center of the channel mitigating back erosion at sites within the project areas. Flow deflection structures (including single arm vanes, cross-vanes and J-Hooks) have been utilized under various channel conditions for over 30 years throughout most regions of the U.S. There is a large volume of technical information regarding field applications and hydraulic research related to these structures. Once installed, these structures induce deposition in near-bank areas while accelerating flows back toward the center of the channel creating scour pools essentially transforming areas of erosion into areas of deposition, further protecting the toe of the streambank. Trees procured during restoration activities could also be incorporated into the flow redirections structures in order to create addition instream and under bank habitat while providing grade control (Figure 28).



Figure 28: Rootwad log vane J hook combo designed and installed by Cardno on the Knife River in 2016 (6/26/17).

4.4.3 Native Vegetation

Establishing native vegetation on restored slopes and streambanks is recommended for restoration designs in the south fork and north fork moving forward. Once established, the deep dense roots of native grasses and forbs act to increase bank stability and trap bank sediments in place. Another benefit to using natives is once established, only minimal management is needed. Maintenance on newly restored areas to limit encroachment of invasive species as well as early successional tree species is recommended for all restored areas for at least three years following construction activities.

The use of the engineering techniques described above are recommended for use during restoration of damaged areas in the south fork and mainstem of Pheasant Branch as opposed to some of the more traditional “hard armoring” techniques such as sheet-piling and gabion baskets. These “hard armoring” techniques can accelerate local flows causing erosion issues downstream of where they are installed and offer little to no available stream habitat once installed.



Figure 29: Photo of failed gabion baskets between Park St. and Century Ave taken in 2008 (left) and directly downstream of Century Ave taken in 2018 (right).

There may be certain areas with the Pheasant Branch corridor that require additional protection measures (such as where infrastructure or private property are at risk due to bank failure). Installation of sheet-piling may be warranted in these specific areas, yet we recommend that this “hard-armoring” be buried within the slope so a more natural look as well as additional streambank habitat can still be installed in these areas.

Before the August 2018 catastrophic flood event, the south fork and mainstem of Pheasant Branch offered a unique opportunity for areas residents and visitors to Middleton to enjoy native riparian plants and animals within an urban setting (Figure 30). We recommend that future restoration efforts not only seek to repair damage sustained during the August 2018 flood, but to use this flood event as an opportunity to create and enhance this urban riparian area moving forward.



Figure 30: Photo of North American river otter (*Lontra canadensis*) taken within the Pheasant Branch corridor near Park St. in 2013.

5 Five Year Pheasant Branch Restoration Plan

The following five year Pheasant Branch restoration plan was developed to list projects, project prioritization, and provide preliminary cost estimates to help guide the City of Middleton in repairing damage within the Pheasant Branch corridor caused by the August 2018 flood event. Potential restoration priorities are comprised of three tiers. Tier One projects were identified as damaged areas that pose a risk to public safety, Tier Two projects were identified as damaged areas that pose a risk to public or private property and Tier Three projects involve the maintenance of areas restored in Tier One and Tier Two. The following cost estimates are intended to aid City staff in the budgeting process, yet more detailed construction cost estimates for each project would be available once project designs are completed.

5.1 Tier One – High Priority Areas that Pose a Risk to Public Safety

Two Tier One projects to repair areas that experienced damage during the August 2018 flood event that pose a risk to public safety are identified in Table 2 below. These areas suffered the most extensive damage during flooding and the City of Middleton has already begun the process of designing repairs for each of these projects. The high cost anticipated for each of these projects is due to the extent of the damage sustained and complexity required in restoration design and construction. A more detailed total cost estimate for each of these projects will be available once restoration designs are completed.

Table 2: List of Tier One – High Priority Areas that Pose a Risk to Public Safety Projects

Year	Project	Total Cost Estimate	Anticipated Project Completion
2019	Donna Dr. Sedimentation Pond Repair (Design and Construction)	\$ 500,000	2019
2019	Major Streambank and Slope Repair Downstream of Park St. Crossing (Design and Construction)	\$ 300,000	2019

5.2 Tier Two – Highly Eroded Slopes and Unstable Areas that Pose a Risk to Private and Public Property

The Tier Two projects identified in Table 3 below are recommended to repair streambanks identified during the Pheasant Branch streambank assessment, (Appendix B), as showing evidence of High, Very High or Extreme streambank erosion caused by the August 2018 flood event. Projects listed within the mainstem of Pheasant Branch are listed in order from upstream to downstream.

Table 3: List of Tier Two – High Priority Areas that Pose a Risk to Public or Private Property

Year	Project	Total Linear Feet of Restoration	Total Cost Estimate	Anticipated Project Completion
2019	South fork Pheasant Branch Streambank Restoration Project (Design)	2,032	\$ 22,000	2020
2019	Confluence Pond to Parmenter St. Pheasant Branch Streambank Restoration Project (Design)	1,981	\$ 18,000	2020
2019	Parmenter St. to Park St. Pheasant Branch Streambank Restoration Project (Design)	4,970	\$ 37,000	2020
2019	Park St. to Century Ave. Pheasant Branch Streambank Restoration Project (Design)	3,236	\$ 31,000	2020
2019	North of Century Ave. Pheasant Branch Streambank Restoration Project (Design)	2,754	\$ 27,000	2020

2020	South fork Pheasant Branch Streambank Restoration Project (Construction)	2,032	\$ 243,000	2020
2020	Confluence Pond to Parmenter St. Pheasant Branch Streambank Restoration Project (Construction)	1,981	\$ 162,000	2020
2020	Parmenter St. to Park St. Pheasant Branch Streambank Restoration Project (Construction)	4,970	\$ 380,000	2020
2020	Park St. to Century Ave. Pheasant Branch Streambank Restoration Project (Construction)	3,236	\$ 290,000	2020
2020	North of Century Ave. Pheasant Branch Streambank Restoration Project (Construction)	2,754	\$ 275,000	2020

5.3 Tier Three – Maintenance

Establishing native vegetation on restored slopes and streambanks throughout the project areas listed above will be essential to the long term success of the projects. Once established the dense deep roots of native grasses and forbs will act to increase the stability of the project sites. Another benefit to using natives is once established, only minimal management is needed. For this reason we are recommending maintenance on newly restored areas for three years to limit encroachment of invasive species as well as early successional tree species. Three trips by crews to each site is recommended for the first year following construction with two visits per site for the remaining two years of maintenance activities. Additional funds are also included to support minor repair of any small areas within each project area that may exhibit erosion as the channel adjusts over time (Table 4).

Table 4: List of Tier Three – Maintenance Cost for Restoration of Tier One and Tier Two Project Areas

Year	Project Area	Total Cost Estimate
2021	South Fork Pheasant Branch Project Area Maintenance	\$ 4,000
2021	Mainstem Pheasant Branch from Confluence Pond through North of Century Ave Project Area	\$ 16,000
2022	South Fork Pheasant Branch Project Area Maintenance	\$ 2,500
2022	Mainstem Pheasant Branch from Confluence Pond through North of Century Ave Project Area	\$ 12,500
2023	South Fork Pheasant Branch Project Area Maintenance	\$ 2,500
2023	Mainstem Pheasant Branch from Confluence Pond through North of Century Ave Project Area	\$ 12,500

5.4 Future Project Consideration within the Pheasant Branch Corridor

The five year Pheasant Branch restoration plan described above is provided to aid the City of Middleton with a list of projects and project prioritization to help guide the repair of damage from the August 2018 flood event. Future projects to be considered to help restore and enhance the Pheasant Branch corridor in years to come include:

- Replacement of under-sized pedestrian bridges found throughout the Pheasant Branch corridor with larger bridges that provide additional capacity for flood flows and debris flows during flooding events.
- Mitigation of barriers to upstream migration of fish in the mainstem of Pheasant Branch through retro-fitting of fish passage structures to aid fish passage over and through current migration barriers and/or replacement of fish passage barriers such as the stream crossing underneath Park St.

6 Potential Funding Sources for Pheasant Branch Restoration

Prior to the August 2018 flood event the City of Middleton submitted a WIDNR Urban Non-Point Source (UNPS) stormwater construction grant request for \$124,000 to continue work on eroding slopes between Parmenter St. and Park St. Following the August 2019 flood event Cardno and the City of Middleton worked with WIDNR Urban Non-Point Source (UNPS) stormwater construction grant coordinators to find potential funding for restoration of areas the City of Middleton and the DNR had worked on in the past. On December 10, 2018 the City of Middleton submitted a grant request of \$573,776 to aid in the restoration of three areas of the mainstem of Pheasant Branch as well as the south fork of Pheasant Branch. All five grant requests are described in Table 5 below.

Table 5: WIDNR Urban Non-Point Source Stormwater Construction Grant Requests

Project Area	Total Requested from WIDNR	Total Cost Estimate
Pre-Flood - Parmenter St. to Park St. Pheasant Branch Streambank Restoration Project (Design and Construction)	\$124,000	\$248,375
South fork Pheasant Branch Streambank Restoration Project (Design and Construction)	\$ 132,688	\$265,375
Parmenter St. to Park St. Pheasant Branch Streambank Restoration Project (Design and Construction)	\$ 148,588	\$ 297,175
Park St. to Century Ave. Pheasant Branch Streambank Restoration Project (Design and Construction)	\$ 147,025	\$ 294,050
North of Century Ave. Pheasant Branch Streambank Restoration Project (Design and Construction)	\$ 145,475	\$ 290,950
Total	\$ 697,776	\$ 1,395,925

On, January 15, 2019 the City of Middleton was notified that all five grants requests were awarded for a total of \$697,776. These WIDNR UNPS grants require a 50% match from the City in order to utilize the funds and if approved are good through December 31, 2020. Awards of these grants heavily influenced the time line of Tier 2 projects listed in this report in order to take advantage of potential grant funding.

The City of Middleton is also currently in the process of working with FEMA to provide additional funding for restoration of the Pheasant Branch corridor. If awarded, FEMA funds could be used as a match to grant funding requests listed in Table 5.

The WINDNR UNPS grant funding and matching funds would completely cover the total project cost for restoration of the south fork of Pheasant Branch and of the mainstem of Pheasant Branch between Parmenter St. and Park St. This funding and matching funds would also cover a substantial portion of the remaining two project areas on the mainstem of Pheasant Branch between Park St and Century Ave and north of Century Ave where previous work with the WIDNR has occurred (Table 6).

Table 6: Total Project Costs and WIDNR Funding for Tier Two Projects

Year	Project	Total Project Cost	Potential WIDNR Grant and Matching Funds	Additional Funding Required
2019-2020	South fork Pheasant Branch Streambank Restoration Project (Design & Construction)	\$ 265,000	\$ 265,375	\$ 0
2019-2020	Confluence Pond to Parmenter St. Pheasant Branch Streambank Restoration Project (Design & Construction)	\$ 180,000	\$ 0	\$ 180,000
2019-2020	Parmenter St. to Park St. Pheasant Branch Streambank Restoration Project (Design & Construction)	\$ 417,000	\$ 545,175	\$ 0
2019-2020	Park St. to Century Ave. Pheasant Branch Streambank Restoration Project (Design & Construction)	\$ 321,000	\$ 294,050	\$ 26,950
2019-2020	North of Century Ave. Pheasant Branch Streambank Restoration Project (Design & Construction)	\$ 302,000	\$ 290,950	\$ 11,050
	Total	\$ 1,485,000	\$ 1,395,550	\$ 218,000

Restoration of the nearly 2,000 linear feet of severely eroded streambanks from the confluence pond to Parmenter St. was not eligible for WIDNR UNPS grant funding following the August 2018 flood since no previous WIDNR UNPS grant funding had been used in this area. Optimally this project area would be designed and constructed with the other three project areas listed on the mainstem of Pheasant Branch in order to work from upstream to downstream so sediment being delivered from highly eroded streambanks and loose debris caused by the August 2018 flood does not impact newly constructed areas downstream. However if available budgeting for these projects is limited, the Confluence Pond to Parmenter St. Pheasant Branch Streambank Restoration Project design and construction could be delayed without the loss of any awarded grant funding. Maintenance costs for the project areas for 2021-2023 are not included in the total project costs in Table 6 above.

Pheasant Branch 2018
Flood Damage Assessment
and Five Year Plan

APPENDIX

A

THREE PART STREAM NAMING AND
STATIONING SYSTEM SET

DATE	DESCRIPTION

INITIAL DRAFT

SITE MAP
 SCALE: 1" = 100'
 0 75 150 Feet

- LEGEND
- EXISTING GRADE
 - PHEASANT BRANCH CHANNEL
 - EXISTING SANITARY SEWER LINE
 - EXISTING STORM WATER LINE



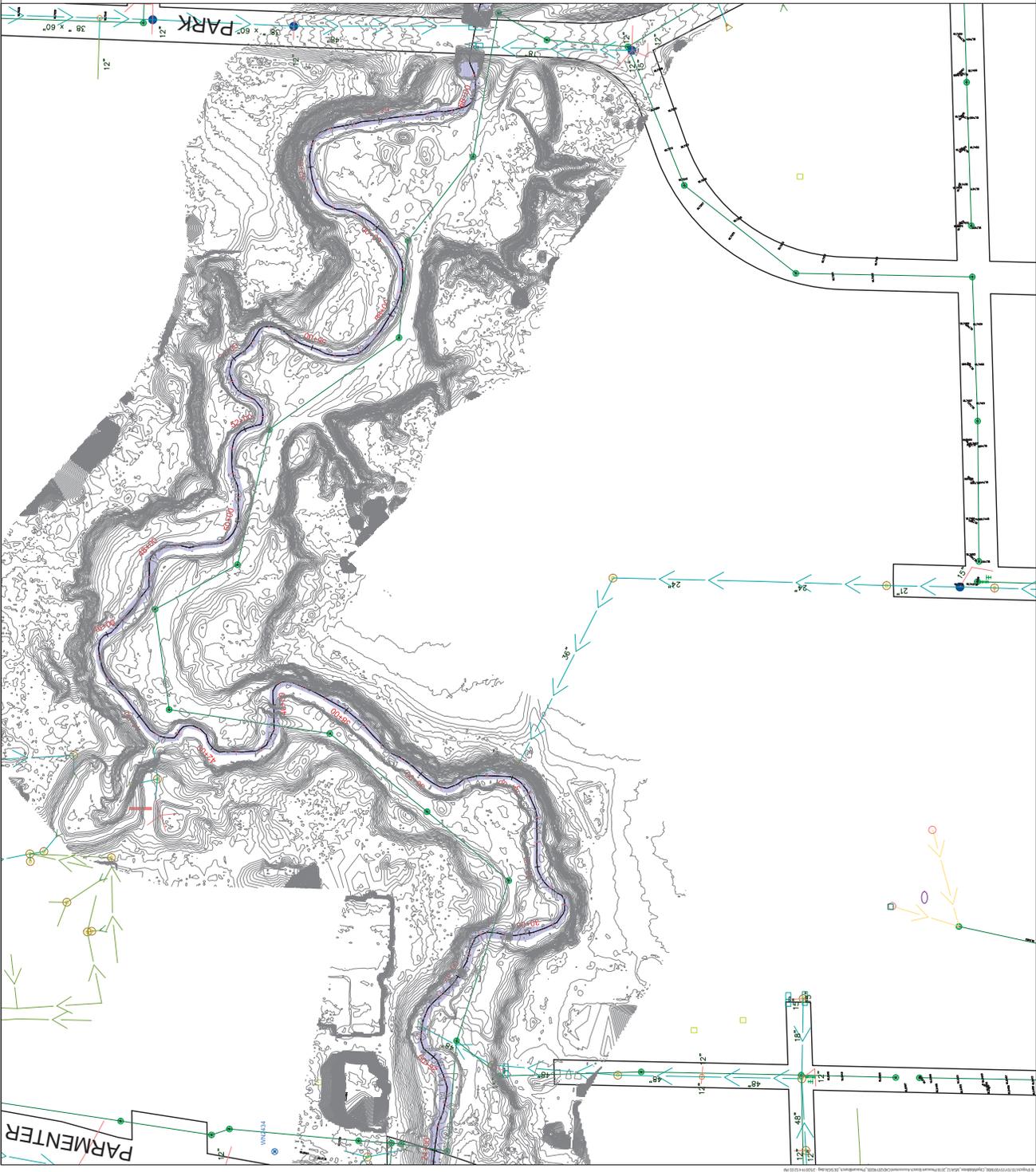
P:\Projects\17030040_South Fork Pheasant Branch Assessment\0201\0205_StreamStations_South Fork.dwg, 1/29/19 4:32:19 PM

DATE	DESCRIPTION

INITIAL DRAFT

SITE MAP
 SCALE: 1" = 100'
 0 50 100 FEET

LEGEND
 — EXISTING GRADE
 — PHEASANT BRANCH CHANNEL
 — EXISTING SANITARY SEWER LINE
 — EXISTING STORM WATER LINE



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 P:\Projects\18710710\18710710\Mainstem Paramenter to Park Street\Mainstem Paramenter to Park Street.dwg, 1/23/19 10:11:19 AM

Pheasant Branch 2018
Flood Damage Assessment
and Five Year Plan

APPENDIX

B

BEHI MODEL STREAMBANK EROSION RISK
ASSESSMENTS FOR THE LEFT AND RIGHT
BANK OF THE NORTH FORK, SOUTH FORK,
AND MAINSTEM OF PHEASANT BRANCH



Bank Erosion Rate Category

- Low
- Moderate
- High
- Very High
- Extreme



Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri, Japan, METI, Esri, China

Bank Erosion Survey Map - North Fork of Pheasant Branch

Pheasant Branch Bank Assessment
Dane County, Wisconsin



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Project No. J15V01142



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Bank Erosion Rate Category

- Low
- Moderate
- High
- Very High
- Extreme

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China

Bank Erosion Survey Map - South Fork of Pheasant Branch

Pheasant Branch Bank Assessment
Dane County, Wisconsin



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Project No. J15V01112

DATE: 10/20/2018 10:50:00 AM. PROJECT: Bank Erosion Survey Map - South Fork of Pheasant Branch. MAP: Bank Erosion Survey Map - South Fork of Pheasant Branch. SCALE: 1:10000. SOURCE: Aerial Imagery, Topography, DEM, Soil, NCEC, Roads, Water.



Bank Erosion Rate Category	
—	Low
—	Moderate
—	High
—	Very High
—	Extreme

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri, Japan, METI, Esri, China

Bank Erosion Survey Map - Mainstem of Pheasant Branch from start to Parmenter Street

Pheasant Branch Bank Assessment
Dane County, Wisconsin



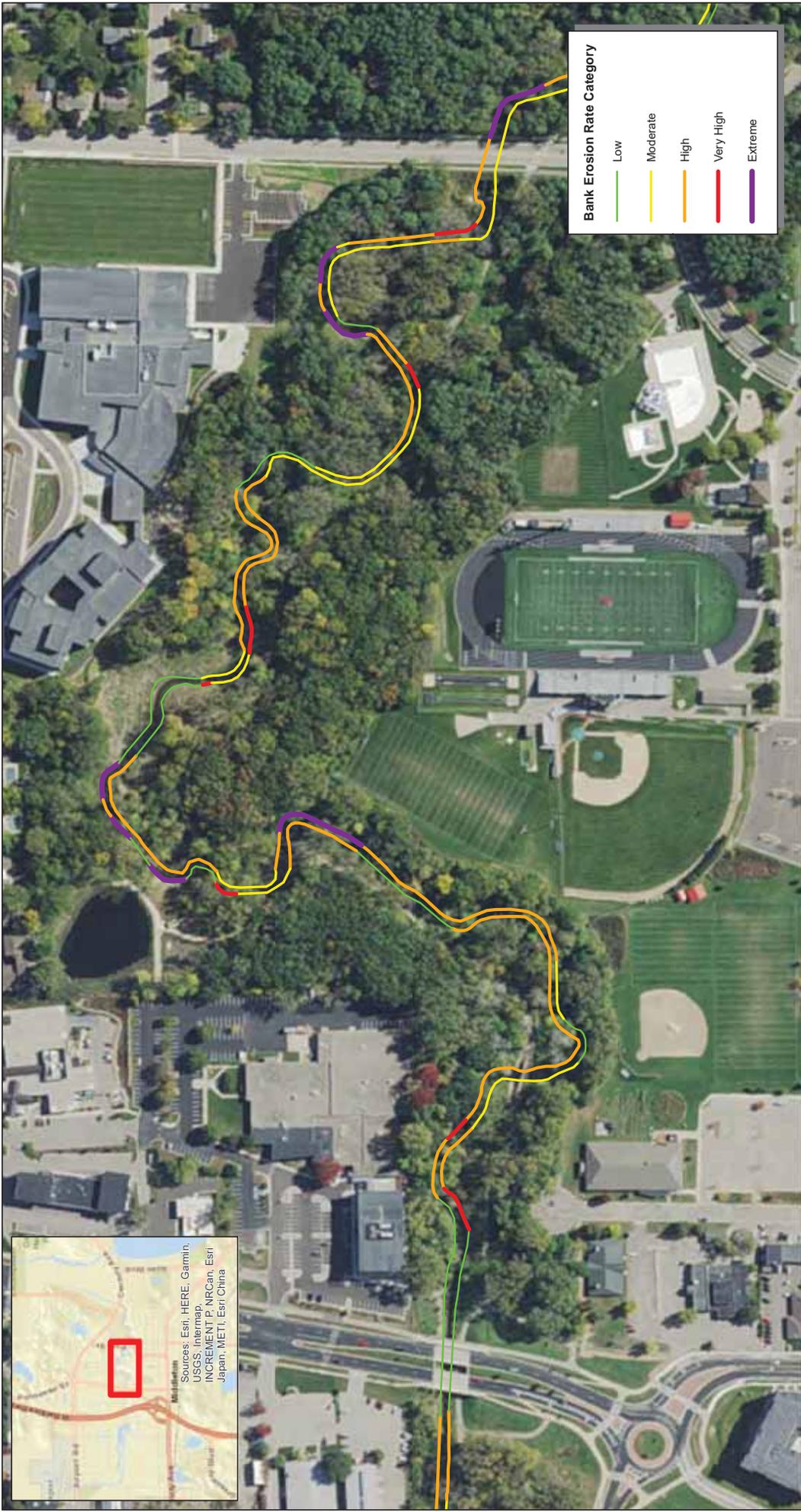
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Sources: Esri, HERE, Garmin,
 USGS, Intermap,
 INCREMENT P, NRCan, Esri
 Japan, METI, Esri, China

Bank Erosion Survey Map - Mainstem of Pheasant Branch from Parmenter to Park Street

Pheasant Branch Bank Assessment
 Dane County, Wisconsin



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Project No. J15V01142

Date: 10/20/2018
 Scale: 1:1000
 Author: [Name]
 Date: 10/20/2018
 Scale: 1:1000
 Author: [Name]



Bank Erosion Rate Category

- Low
- Moderate
- High
- Very High
- Extreme

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China

Bank Erosion Survey Map - Mainstem of Pheasant Branch from Park Street to Century Ave

Pheasant Branch Bank Assessment
Dane County, Wisconsin

0 65 130 260 Feet

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Bank Erosion Rate Category

- Low
- Moderate
- High
- Very High
- Extreme



Sources: Esri, HERE, Garmin,
USGS, Intermap,
INCREMENT P, INRCan, Esri,
Japan, METI, Esri, China

Bank Erosion Survey Map - Mainstem of Pheasant Branch North of Century Ave

Pheasant Branch Bank Assessment
Dane County, Wisconsin



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Pheasant Branch 2018
Flood Damage Assessment
and Five Year Plan

APPENDIX

C

AUGUST 2018 POST-FLOOD PHOTO
ARCHIVE FOR THE NORTH FORK, SOUTH
FORK, AND MAINSTEM OF PHEASANT
BRANCH



Photo 1. Post August 2018 flood photo of the north fork of Pheasant Branch viewing downstream. (October 22, 2018).



Photo 2. Post August 2018 flood photo of the north fork of Pheasant Branch viewing upstream. (October 22, 2018).



Photo 3. Photo of damage to walking path near south fork channel looking downstream (October 16, 2018).



Photo 4. Photo viewing upstream of streambank erosion under a pedestrian bridge abutment caused by August 2018 flood event (January 16, 2019).



Photo 5. Photo of streambank erosion on the south fork of Pheasant Branch viewing upstream (January 16, 2019).



Photo 6. Photo viewing extreme streambank erosion on south fork of Pheasant Branch east of Greenway Boulevard (January 16, 2019).



Photo 7. Photo of collapsing streambank on the south fork of Pheasant Branch viewing upstream (October 16, 2018).

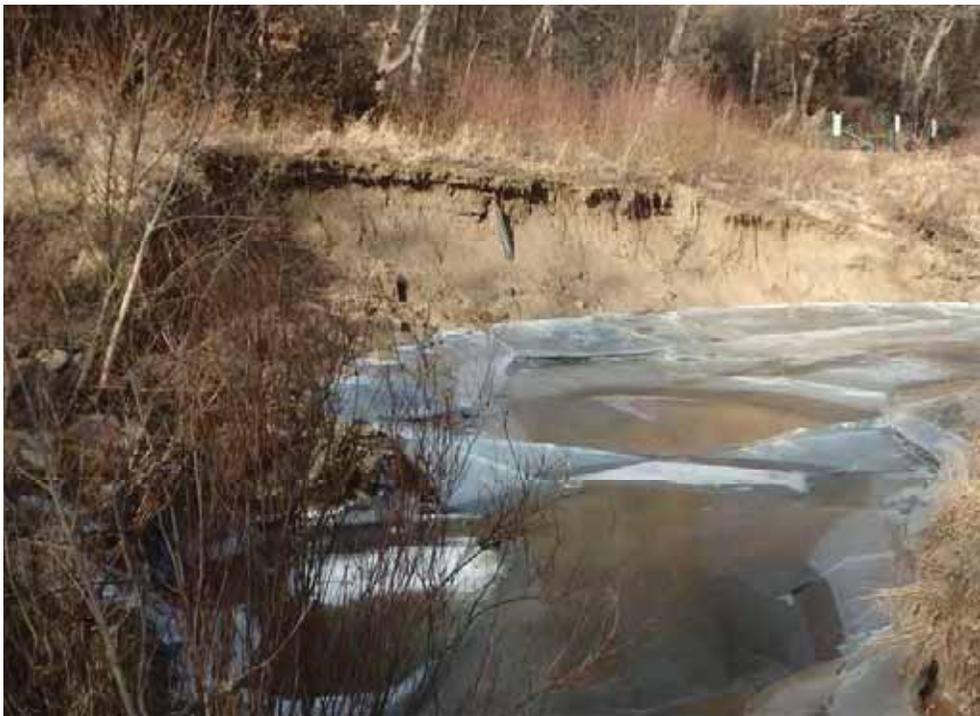


Photo 8. Photo of extreme streambank erosion on south fork of Pheasant Branch viewing downstream (January 16, 2019).



Photo 9. Photo of extreme streambank erosion on the south fork of Pheasant Branch viewing downstream (January 16, 2019).



Photo 10. Photo of extreme streambank erosion on south fork of Pheasant Branch near Market Street viewing downstream (January 16, 2019).



Photo 11. Photo of extreme streambank erosion on the mainstem of Pheasant Branch viewing downstream (January 15, 2019).



Photo 12. Photo of extreme streambank erosion on the mainstem of Pheasant Branch viewing downstream (January 15, 2019).



Photo 13. Photo of erosion near stormwater outlet on mainstem of Pheasant Branch viewing downstream (January 15, 2019).



Photo 14. Photo of very high streambank erosion on the mainstem of Pheasant Branch near Parmenter Street viewing upstream (January 15, 2019).



Photo 15. Photo of damaged bridge near Parmenter Street on the mainstem of Pheasant Branch viewing upstream (August 25, 2018).



Photo 16. Photo of debris jam on the mainstem of Pheasant Branch near Parmenter Street viewing downstream (August 25, 2018).



Photo 17. Photo of damaged stormwater outlet on the mainstem of Pheasant Branch viewing upstream (August 25, 2018).



Photo 18. Photo of debris jam on the mainstem of Pheasant Branch viewing upstream (August 25, 2018).



Photo 19. Photo of damaged bridge and intact rootwad composites on the mainstem of Pheasant Branch viewing downstream (August 25, 2018).



Photo 20. Photo of damaged trail and sediment deposited on trail (August 25, 2018).



Photo 21. Photo of collapsed bank and Donna Drive sedimentation pond failure on mainstem Pheasant Branch (August 25, 2018).



Photo 22. Photo of relatively undamaged area of Kromrey stream relocation project on mainstem of Pheasant Branch (August 25, 2018).



Photo 23. Photo of collapsed bank directly downstream of Donna Drive sedimentation pond failure on mainstem Pheasant Branch viewing upstream (January 15, 2019).



Photo 24. Photo of collapsed bank near Park Street on mainstem of Pheasant Branch viewing downstream (January 15, 2019).



Photo 25. Photo of collapsed bank directly behind sheet-piling mainstem Pheasant Branch near Park Street (January 15, 2019).



Photo 26. Photo of undersized stream crossing and fish passage impediment beneath Park Street. (January 15, 2019).



Photo 27. Photo of collapsed bank directly downstream of Park Street on mainstem Pheasant Branch near Park Street (August 25, 2018).



Photo 28. Photo of streambank erosion near first bridge crossing on mainstem of Pheasant Branch downstream of Park Street. (January 15, 2019).



Photo 29. Photo of bridge damage downstream of Park Street on mainstem Pheasant Branch (August 25, 2018).



Photo 30. Photo of debris dam upstream of damaged bridge near Park Street on mainstem of Pheasant Branch (August 25, 2018).



Photo 31. Photo of trail damage downstream of Park Street (August 25, 2018).



Photo 32. Photo of second damaged bridge and debris jam between Park Street and Century Avenue on mainstem of Pheasant Branch (August 25, 2018).



Photo 33. Photo of debris jam upstream of bridge crossing on mainstem of Pheasant Branch (August 25, 2018).



Photo 34. Photo of debris jam between Park Street and Century Avenue on mainstem of Pheasant Branch (August 25, 2018).



Photo 35. Photo of streambank erosion between Park Street and Century Ave on mainstem of Pheasant Branch (January 15, 2019).



Photo 36. Photo of collapsed slope between Park Street and Century Avenue on mainstem of Pheasant Branch (January 15, 2019).



Photo 37. Photo of damaged stormwater outflow on mainstem of Pheasant Branch near Century Ave (August 25, 2018).



Photo 38. Photo of debris jam near Century Avenue on mainstem of Pheasant Branch (August 25, 2018).



Photo 39. Photo of debris jam on mainstem of Pheasant Branch near Century Ave (August 25, 2018).



Photo 40. Photo of trail damage north of Century Ave (August 25, 2018).



Photo 41. Photo of debris jam north of Century Ave on mainstem of Pheasant Branch (August 25, 2018).



Photo 42. Photo of streambank erosion downstream from Century Ave on mainstem of Pheasant Branch (August 25, 2018).



Photo 43. Photo of debris jam on mainstem of Pheasant Branch (August 25, 2018).



Photo 44. Photo of another debris jam near on mainstem of Pheasant Branch (August 25, 2018).



Photo 45. Photo of debris jam upstream of bridge crossing on mainstem of Pheasant Branch north of Century Ave (August 25, 2018).



Photo 46. Photo of damaged bridge on mainstem of Pheasant Branch north of Century Ave (August 25, 2018).

Pheasant Branch 2018
Flood Damage Assessment
and Five Year Plan

APPENDIX

D

2017 AND 2018 LIDAR DATA SET
COMPARISON FOR THE NORTH FORK,
SOUTH FORK, AND MAINSTEM OF
PHEASANT BRANCH



Legend
VOLUME LOSS (CUBIC YARDS)

- 5-100
- 100-740
- 740+

PROJECT ADDRESS:
 MIDDLETON, WI
 PROJECT PLSS: _____

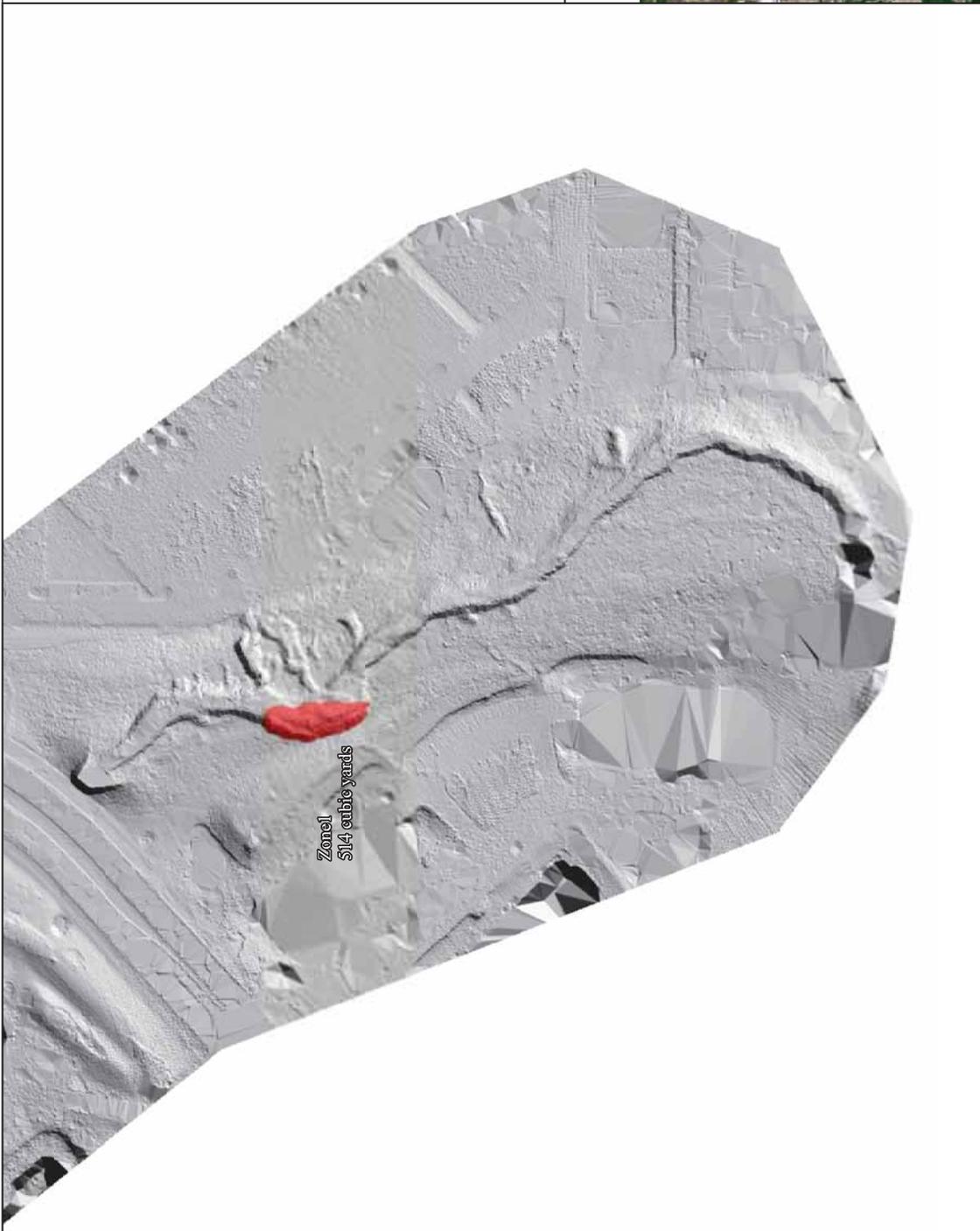


PROJECT NO.
 WER 126,0015.2

DATE:
 1/23/2019



SHEET 1 OF 12
 SCALE (1" x 17'): 1 in = 115 feet
 SOURCE DATA: WER, Ayres Associates
 PROJECTION: Lambert Conformal Conic
 COORDINATE SYSTEM: NAD 1983 HARN WISCRS
 Dane County Feet



CREATED BY:
 NHAUS

MANAGER:
 NHAUS

FIELD DATA COLLECTED BY:
 WER

FIGURE/PHOTO DESCRIPTION:
 SEDIMENT LOSS ESTIMATE
 2018 LIDAR DEM

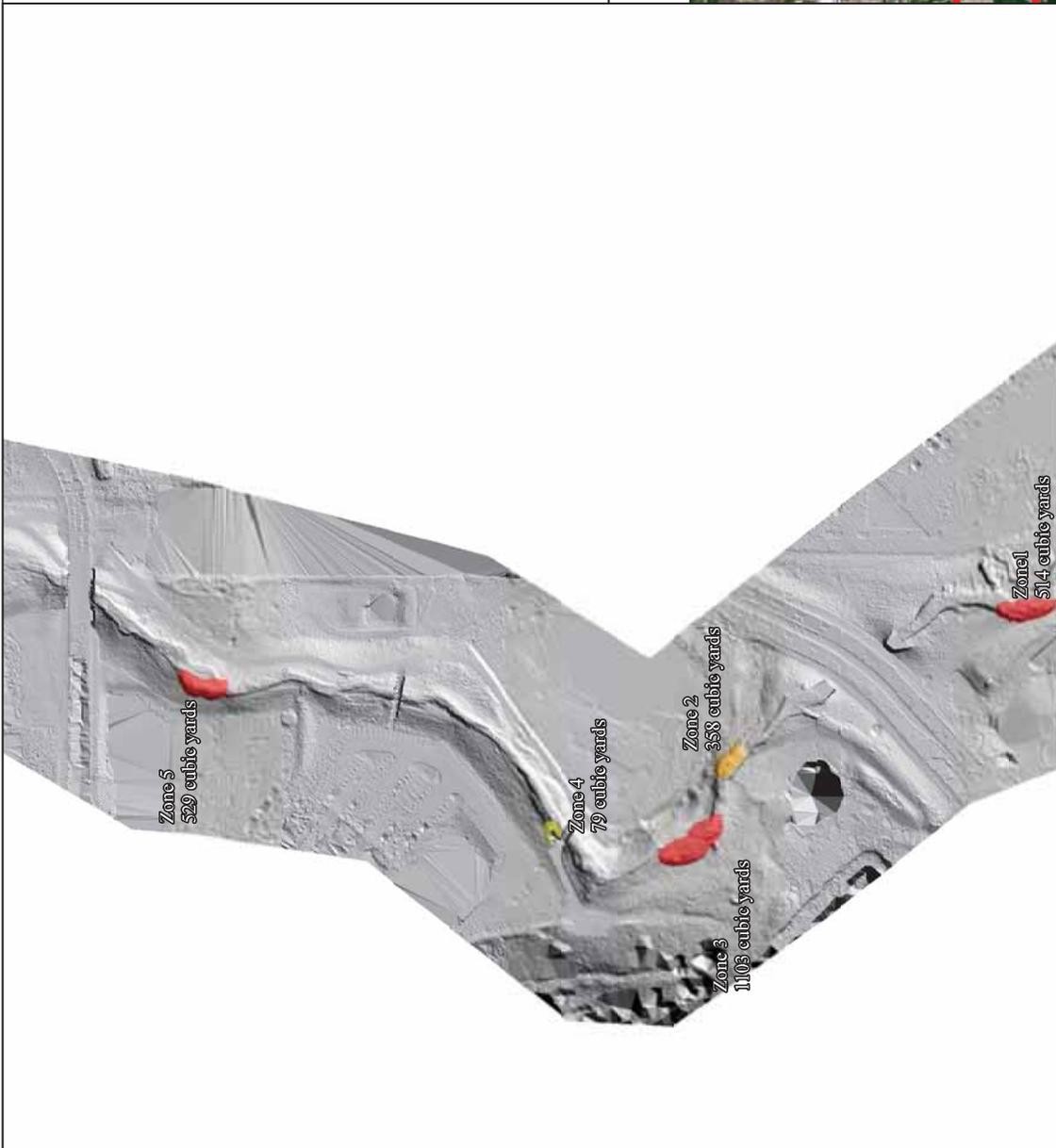
CLIENT/PROJECT:
 CITY OF MIDDLETON

Notes:

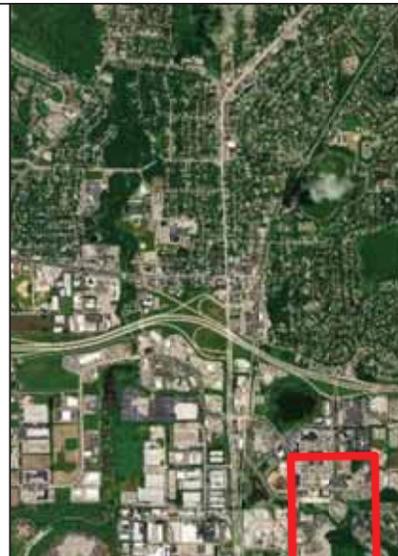
Figure 1
 Wisconsin Environmental Restorations LLC
 PO Box 99
 Strum, WI 54770
 Office (715) 695-3254
 www.wisconsinenvironmental.com



Legend
VOLUME LOSS (CUBIC YARDS)
 5-100
 100-740
 740+



PROJECT ADDRESS:
MIDDLETON, WI
 PROJECT PLSS:



PROJECT NO.
WER 126,0015.2
 DATE:
1/23/2019

SHEET 2 OF 12
 SCALE (1" x 17'): 1 in = 210.83 feet
 SOURCE DATA: WER, Ayres Associates
 PROJECTION: Lambert Conformal Conic
 COORDINATE SYSTEM: NAD 1983 HARN WISCRS
 Dane County Feet



CREATED BY:
NHAUS
 MANAGER:
NHAUS

FIELD DATA COLLECTED BY:
WER

FIGURE/PHOTO DESCRIPTION:
SEDIMENT LOSS ESTIMATE
2018 LIDAR DEM

CLIENT/PROJECT:
CITY OF MIDDLETON

Notes:

Figure 1
 Wisconsin Environmental
 Restorations LLC
 PO Box 99
 Strum, WI 54770
 Office (715) 695-3254
 www.wisconsinenvironmental.com



Legend
VOLUME LOSS (CUBIC YARDS)
 5-100
 100-740
 740+



PROJECT ADDRESS:
MIDDLETON, WI
 PROJECT PLSS:



PROJECT NO.
WER 126,0015.2
 DATE:
1/23/2019

SHEET 3 OF 12
 SCALE (1" x 17"): 1 in = 307.5 feet
 SOURCE DATA: WER, Ayres Associates
 PROJECTION: Lambert Conformal Conic
 COORDINATE SYSTEM: NAD 1983 HARN WISCRS
 Dane County Feet



CREATED BY:
NHAUS
 MANAGER:
NHAUS
 FIELD DATA COLLECTED BY:
WER

FIGUREPHOTO DESCRIPTION:
SEDIMENT LOSS ESTIMATE
2018 LIDAR DEM
 CLIENT/PROJECT:
CITY OF MIDDLETON

Notes:

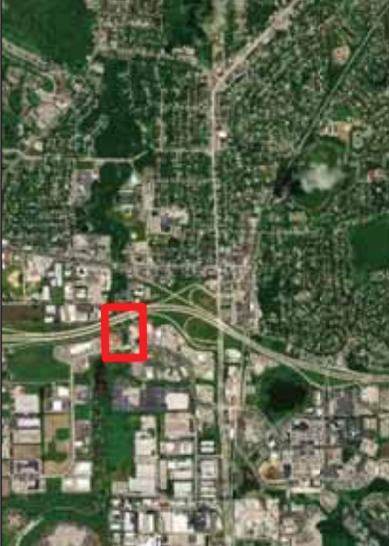
Figure 1
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 Restorations LLC
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 Strum, WI 54770
 Office (715) 695-3254
 www.wisconsinenvironmental.com



Legend
VOLUME LOSS (CUBIC YARDS)
 5-100
 100-740
 740+



PROJECT ADDRESS:
MIDDLETON, WI
 PROJECT PLSS:



PROJECT NO.
WER 126.0015.2

DATE:
1/23/2019



0 25 50 100 150 200 Feet

SHEET 4 OF 12
 SCALE (11 x 17): 1 in = 95.83 feet
 SOURCE DATA: WER, Ayres Associates
 PROJECTION: Lambert Conformal Conic
 COORDINATE SYSTEM: NAD 1983 HARN WISCRS
 Dane County Feet

CREATED BY:
NHAUS

MANAGER:
NHAUS

FIELD DATA COLLECTED BY:
WER

FIGUREPHOTO DESCRIPTION:
SEDIMENT LOSS ESTIMATE
2018 LIDAR DEM

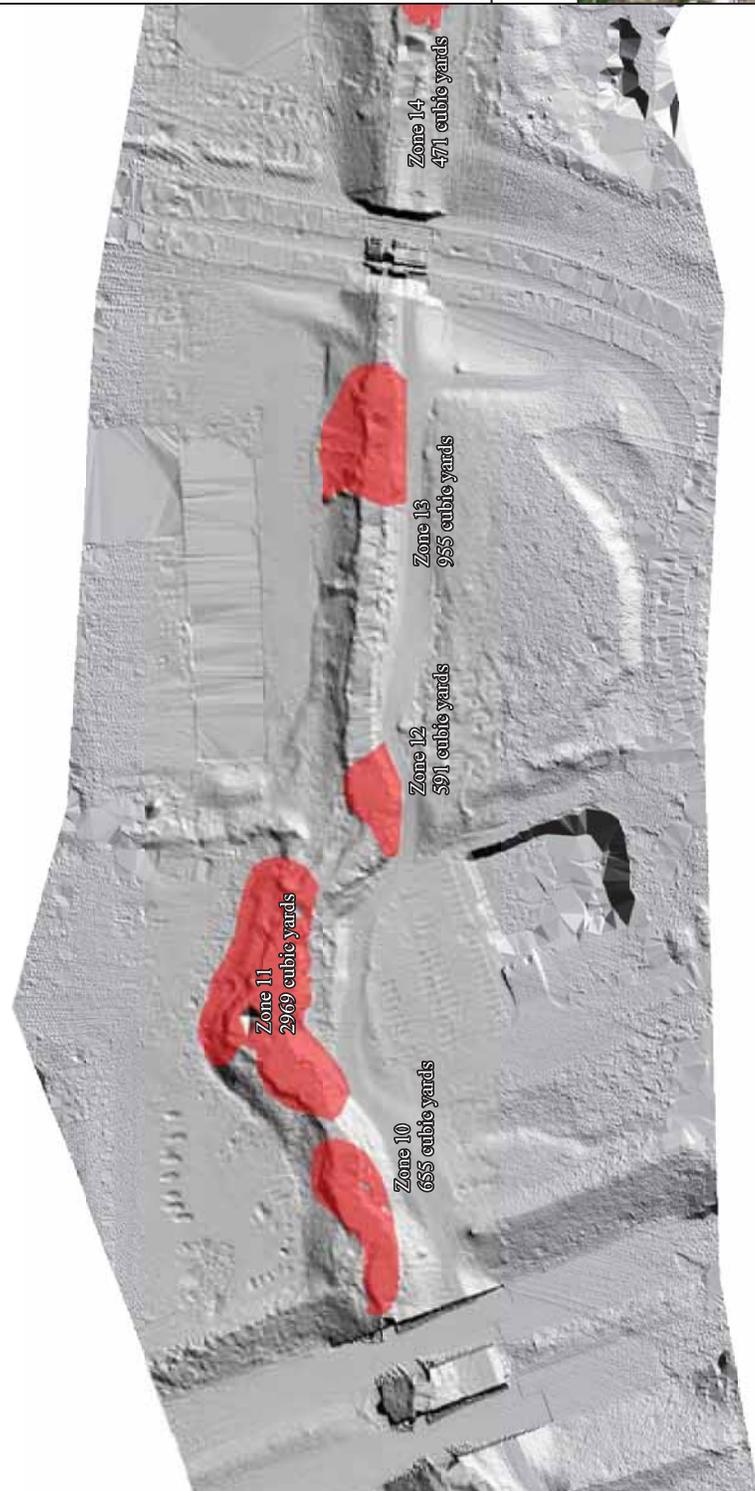
CLIENT/PROJECT:
CITY OF MIDDLETON

Notes:

Figure 1
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 Strum, WI 54770
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Legend
VOLUME LOSS (CUBIC YARDS)
 5-100
 100-740
 740+



PROJECT ADDRESS:
 MIDDLETON, WI
 PROJECT PLSS:



PROJECT NO.
 WER 126,0015.2
 DATE:
 1/23/2019

Scale bar: 0 40 80 160 240 320 Feet

SHEET 5 OF 12
 SCALE (11 x 17): 1 in = 132.5 feet
 SOURCE DATA: WER, Ayres Associates
 PROJECTION: Lambert Conformal Conic
 COORDINATE SYSTEM: NAD 1983 HARN WISCRS
 Dane County Feet

WER

CREATED BY:
 NHAUS
 MANAGER:
 NHAUS
 FIELD DATA COLLECTED BY:
 WER

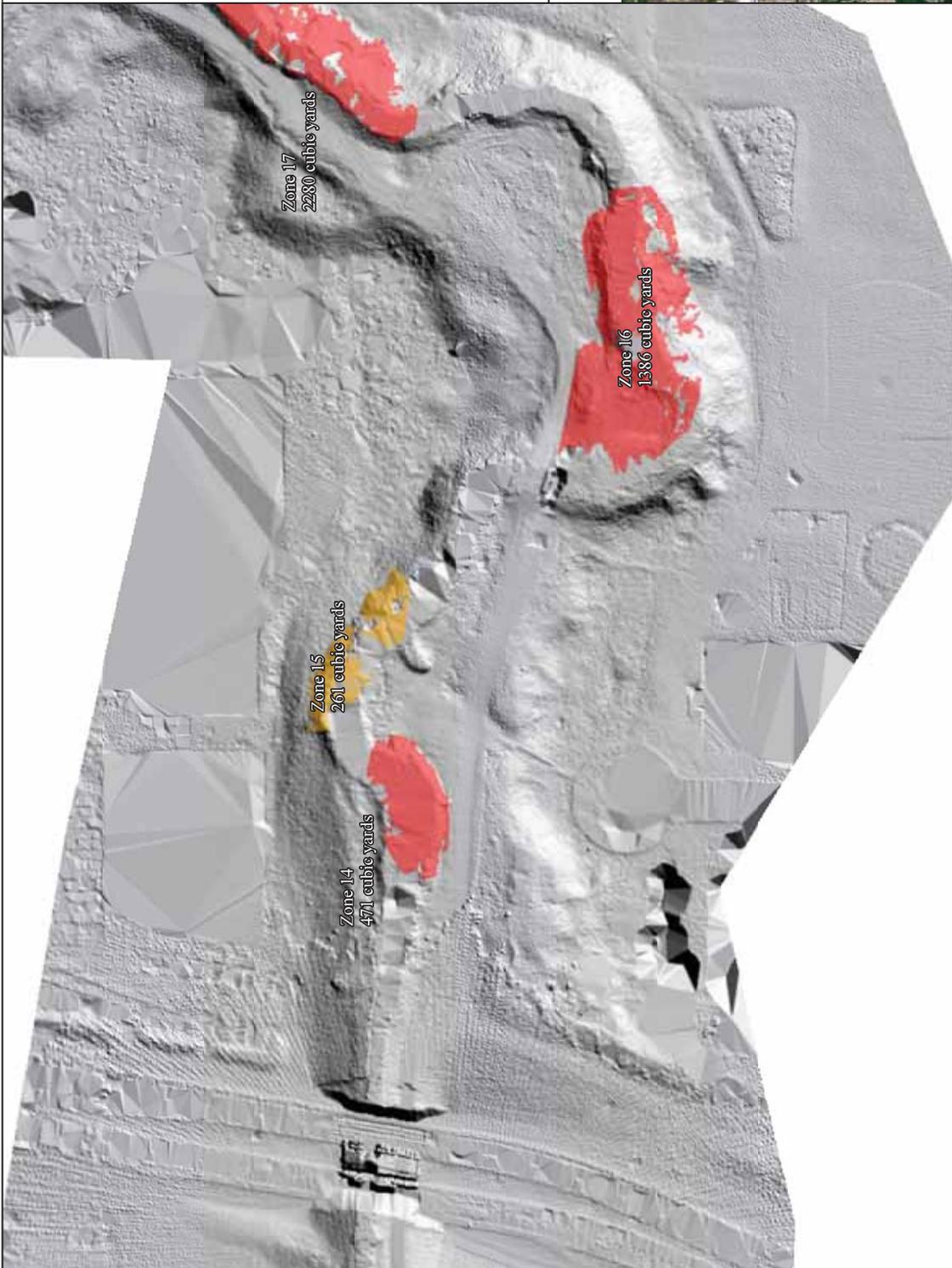
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 SEDIMENT LOSS ESTIMATE
 2018 LIDAR DEM
 CLIENT/PROJECT:
 CITY OF MIDDLETON

Notes:

Figure 1
 Wisconsin Environmental Restorations LLC
 PO Box 99
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Legend
VOLUME LOSS (CUBIC YARDS)
 5-100
 100-740
 740+



PROJECT ADDRESS:
MIDDLETON, WI
 PROJECT PLSS:



PROJECT NO.
WER 126,0015.2
 DATE:
1/23/2019
 SHEET 6 OF 12
 SCALE (11 x 17): 1 in = 89.17 feet
 SOURCE DATA: WER, Ayres Associates
 PROJECTION: Lambert Conformal Conic
 COORDINATE SYSTEM: NAD 1983 HARN WISCRS
 Dane County Feet



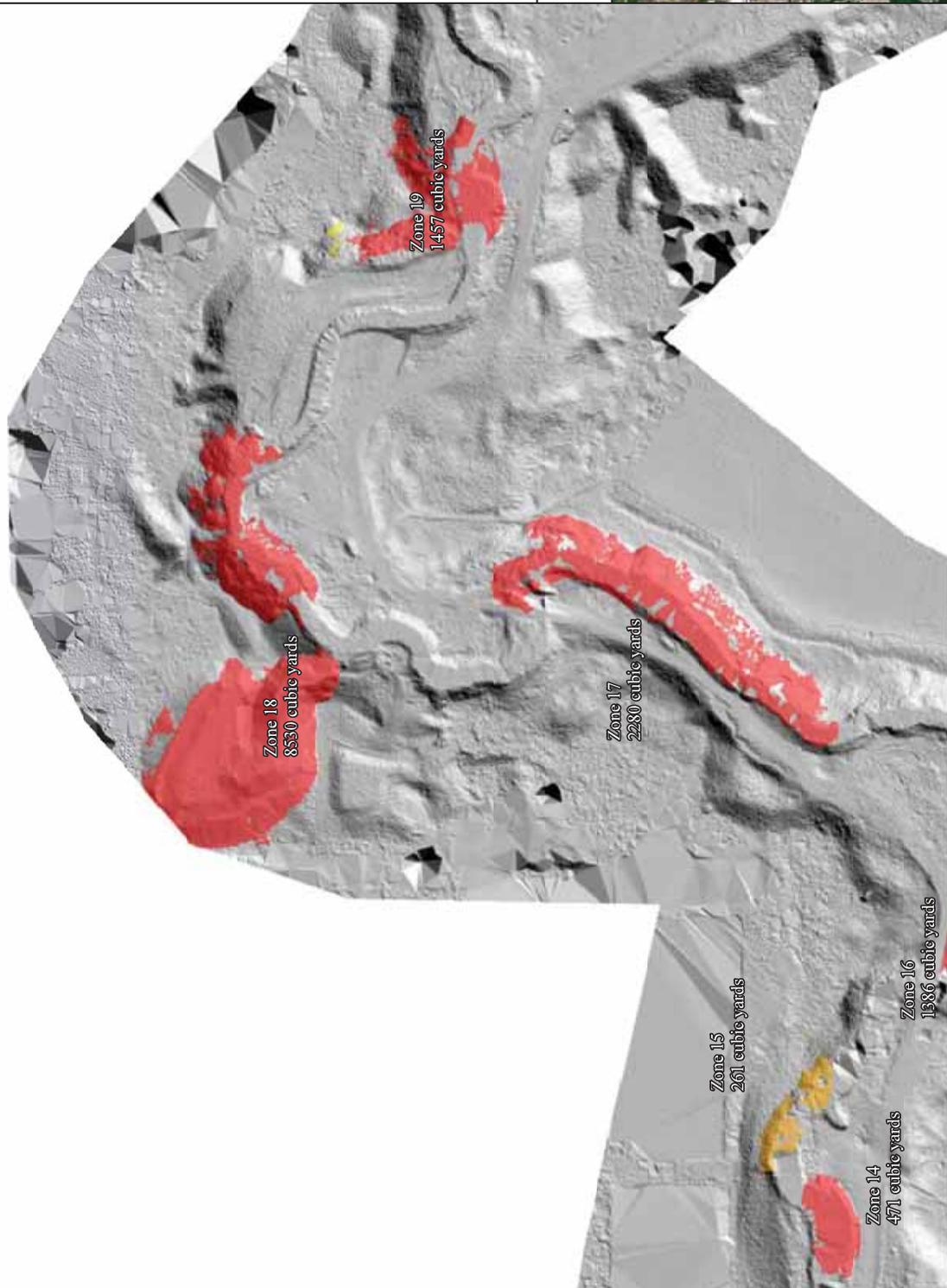
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SEDIMENT LOSS ESTIMATE
2018 LIDAR DEM
 CLIENT/PROJECT:
CITY OF MIDDLETON
 CREATED BY:
NHAUS
 MANAGER:
NHAUS
 FIELD DATA COLLECTED BY:
WER

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Figure 1
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Legend
VOLUME LOSS (CUBIC YARDS)
 5-100
 100-740
 740+



PROJECT ADDRESS:
MIDDLETON, WI
 PROJECT PLSS: _____



PROJECT NO.
WER 126,0015.2
 DATE:
1/23/2019
 SHEET 7 OF 12
 SCALE (11 x 17): 1 in = 125.83 feet
 SOURCE DATA: WER, Ayres Associates
 PROJECTION: Lambert Conformal Conic
 COORDINATE SYSTEM: NAD 1983 HARN WISCONS
 Dane County Feet



CREATED BY:
NHAUS
 MANAGER:
NHAUS
 FIELD DATA COLLECTED BY:
WER

FIGUREPHOTO DESCRIPTION:
SEDIMENT LOSS ESTIMATE
2018 LIDAR DEM
 CLIENT/PROJECT:
CITY OF MIDDLETON

Notes:

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Legend
VOLUME LOSS (CUBIC YARDS)
 5-100
 100-740
 740+

PROJECT ADDRESS:
MIDDLETON, WI
 PROJECT PLSS:



PROJECT NO.
WER 126,0015.2

DATE:
1/23/2019



SHEET 8 OF 12
 SCALE (1" x 17'): 1 in = 55.83 feet
 SOURCE DATA: WER, Ayres Associates
 PROJECTION: Lambert Conformal Conic
 COORDINATE SYSTEM: NAD 1983 HARN WISCRS
 Dane County Feet



CREATED BY:
NHAUS

MANAGER:
NHAUS

FIELD DATA COLLECTED BY:
WER

FIGURE/PHOTO DESCRIPTION:
SEDIMENT LOSS ESTIMATE
2018 LIDAR DEM

CLIENT/PROJECT:
CITY OF MIDDLETON

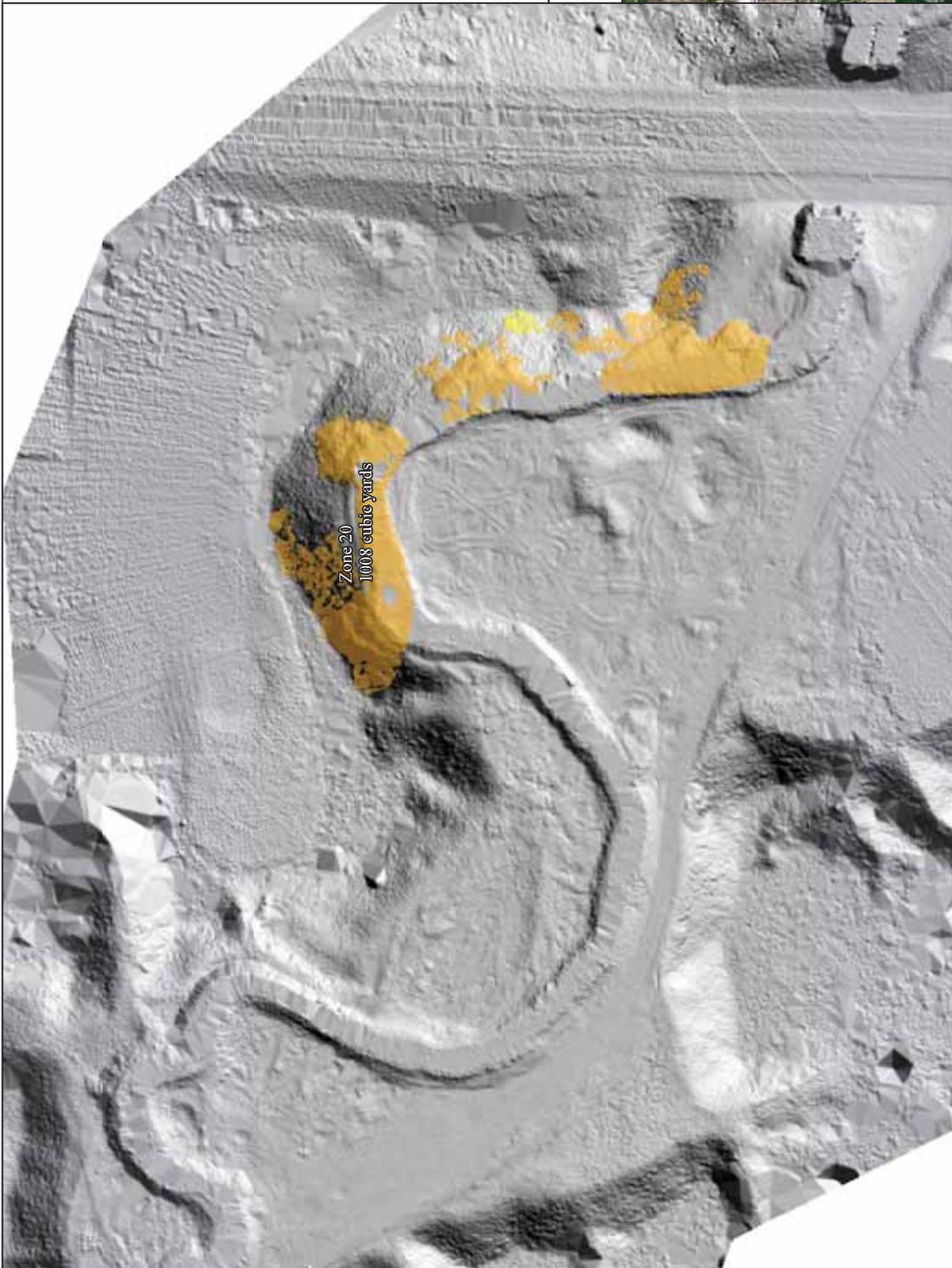
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Figure 1

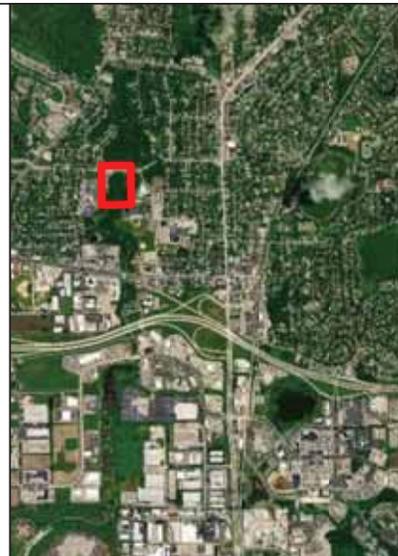
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 Office (715) 695-3254
www.wisconsinenvironmental.com



Legend
VOLUME LOSS (CUBIC YARDS)
 5-100
 100-740
 740+



PROJECT ADDRESS:
 MIDDLETON, WI
 PROJECT PLSS:



PROJECT NO.
 WER 126,0015.2

DATE:
 1/23/2019

SHEET 9 OF 12
 SCALE (11 x 17): 1 in = 74.17 feet
 SOURCE DATA: WER, Ayres Associates
 PROJECTION: Lambert Conformal Conic
 COORDINATE SYSTEM: NAD 1983 HARN WISCRS
 Dane County Feet



CREATED BY:
 NHAUS

MANAGER:
 NHAUS

FIELD DATA COLLECTED BY:
 WER

FIGUREPHOTO DESCRIPTION:
 SEDIMENT LOSS ESTIMATE
 2018 LIDAR DEM

CLIENT/PROJECT:
 CITY OF MIDDLETON

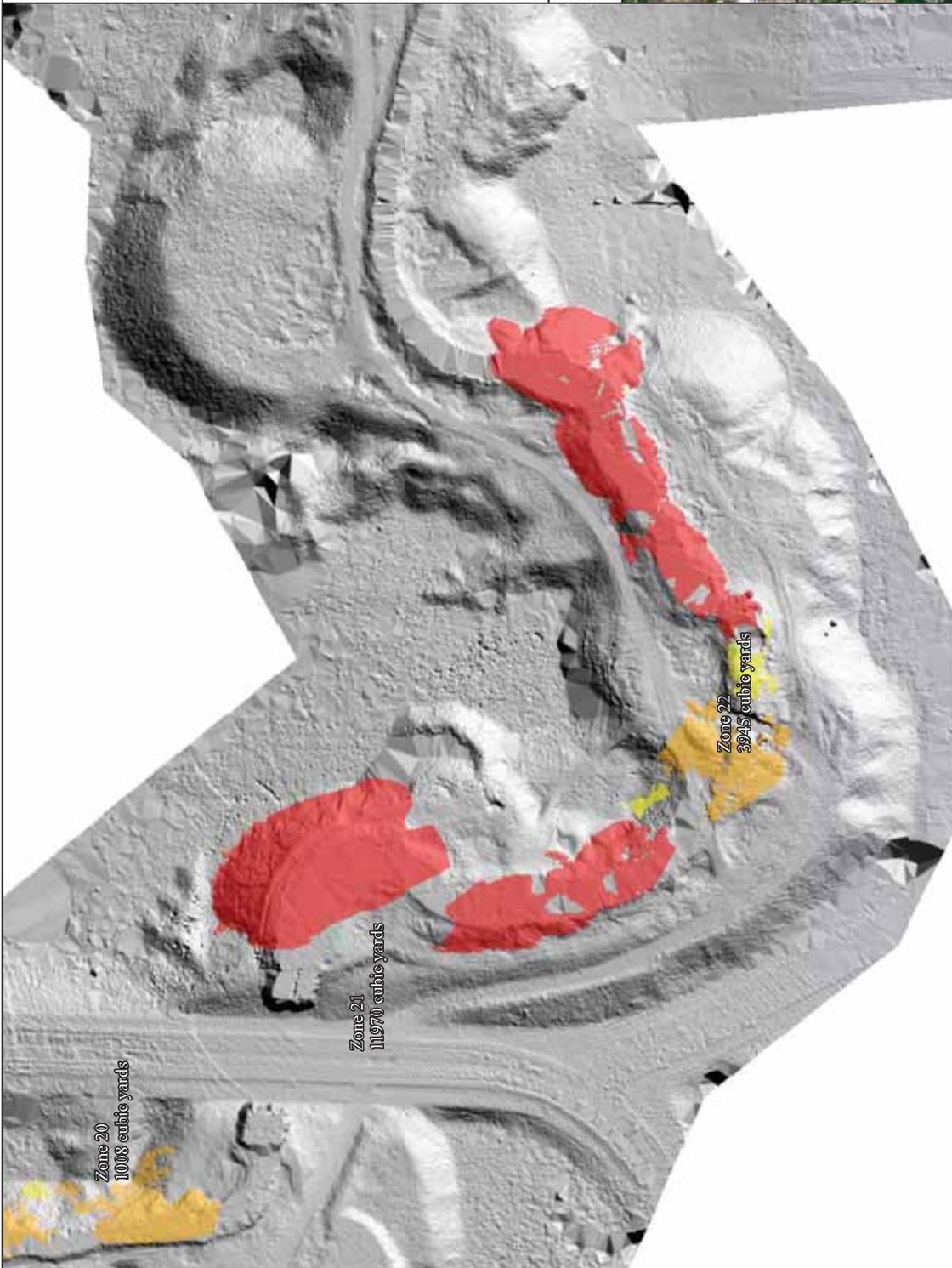
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Figure 1

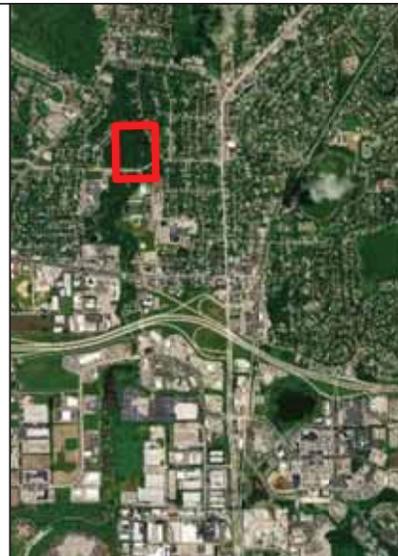
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Legend
VOLUME LOSS (CUBIC YARDS)
 5-100
 100-740
 740+



PROJECT ADDRESS:
 MIDDLETON, WI
 PROJECT PLSS:



PROJECT NO.
 WER 126.0015.2

DATE:
 1/23/2019

SHEET 10 OF 12
 SCALE (1" X 17"): 1 in = 100 feet
 SOURCE DATA: WER, Ayres Associates
 PROJECTION: Lambert Conformal Conic
 COORDINATE SYSTEM: NAD 1983 HARN WISCONS
 Dane County Feet



CREATED BY:
 NHAUS

MANAGER:
 NHAUS

FIELD DATA COLLECTED BY:
 WER

FIGURE/PHOTO DESCRIPTION:
 SEDIMENT LOSS ESTIMATE
 2018 LIDAR DEM

CLIENT/PROJECT:
 CITY OF MIDDLETON

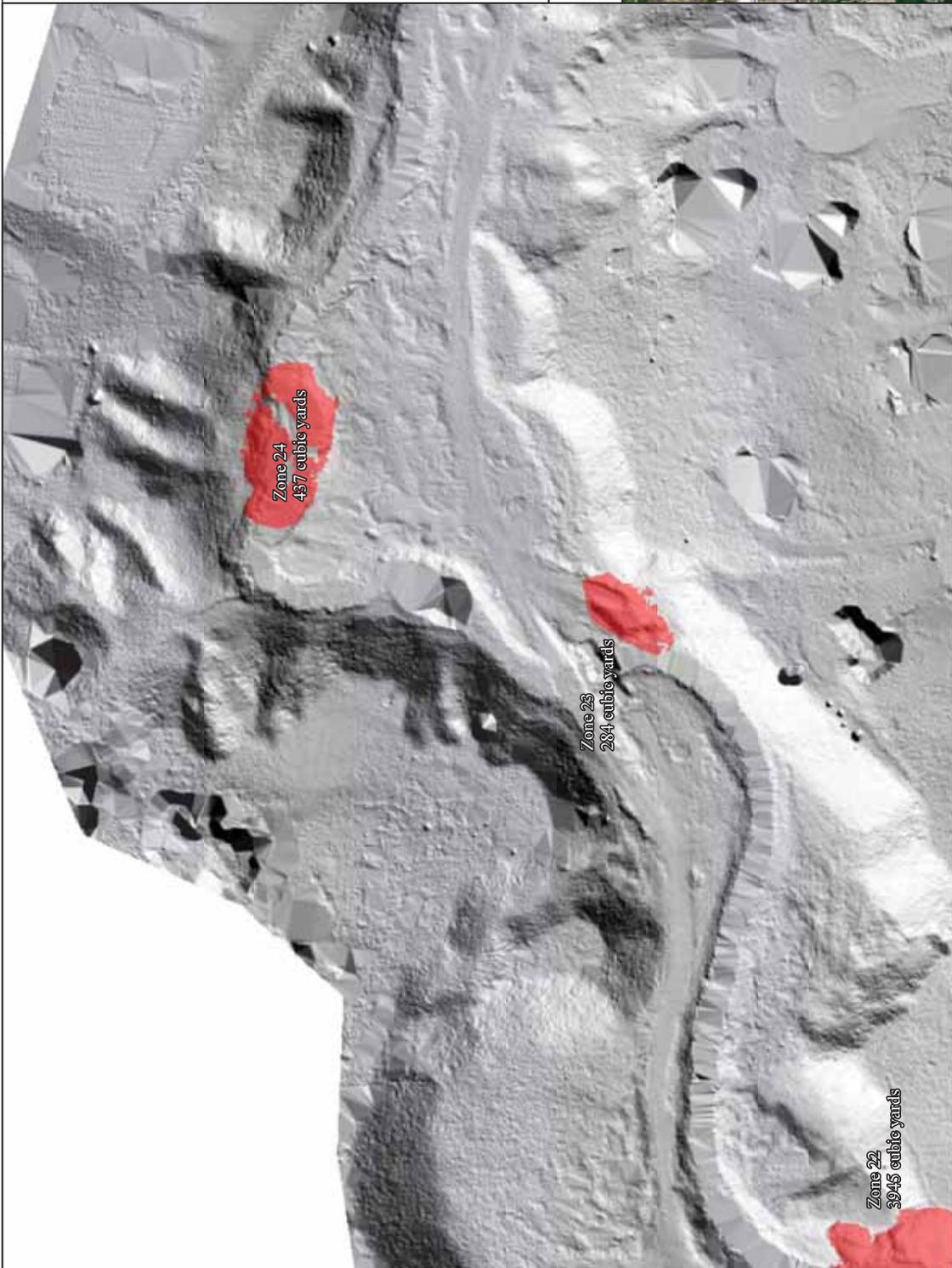
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Figure 1

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Legend
VOLUME LOSS (CUBIC YARDS)
 5-100
 100-740
 740+



PROJECT ADDRESS:
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 PROJECT PLSS:
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PROJECT NO.
WER 126,0015.2

DATE:
1/23/2019



0 25 50 100 150 200 Feet

SHEET 11 OF 12
 SCALE (1" X 17'): 1 in = 81.67 feet
 SOURCE DATA: WER, Ayres Associates
 PROJECTION: Lambert Conformal Conic
 COORDINATE SYSTEM: NAD 1983 HARN WISCONS
 Dane County Feet

CREATED BY:
NHAUS

MANAGER:
NHAUS

FIELD DATA COLLECTED BY:
WER

FIGUREPHOTO DESCRIPTION:
SEDIMENT LOSS ESTIMATE
2018 LIDAR DEM

CLIENT/PROJECT:
CITY OF MIDDLETON

Notes:

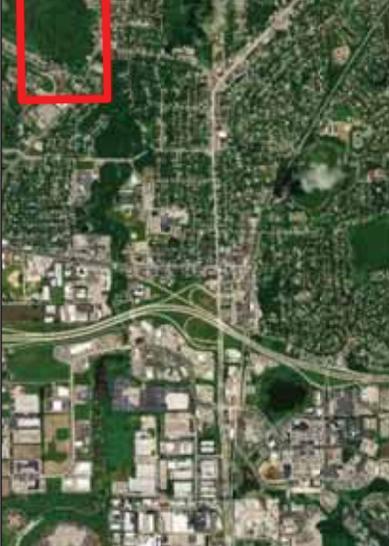
Figure 1

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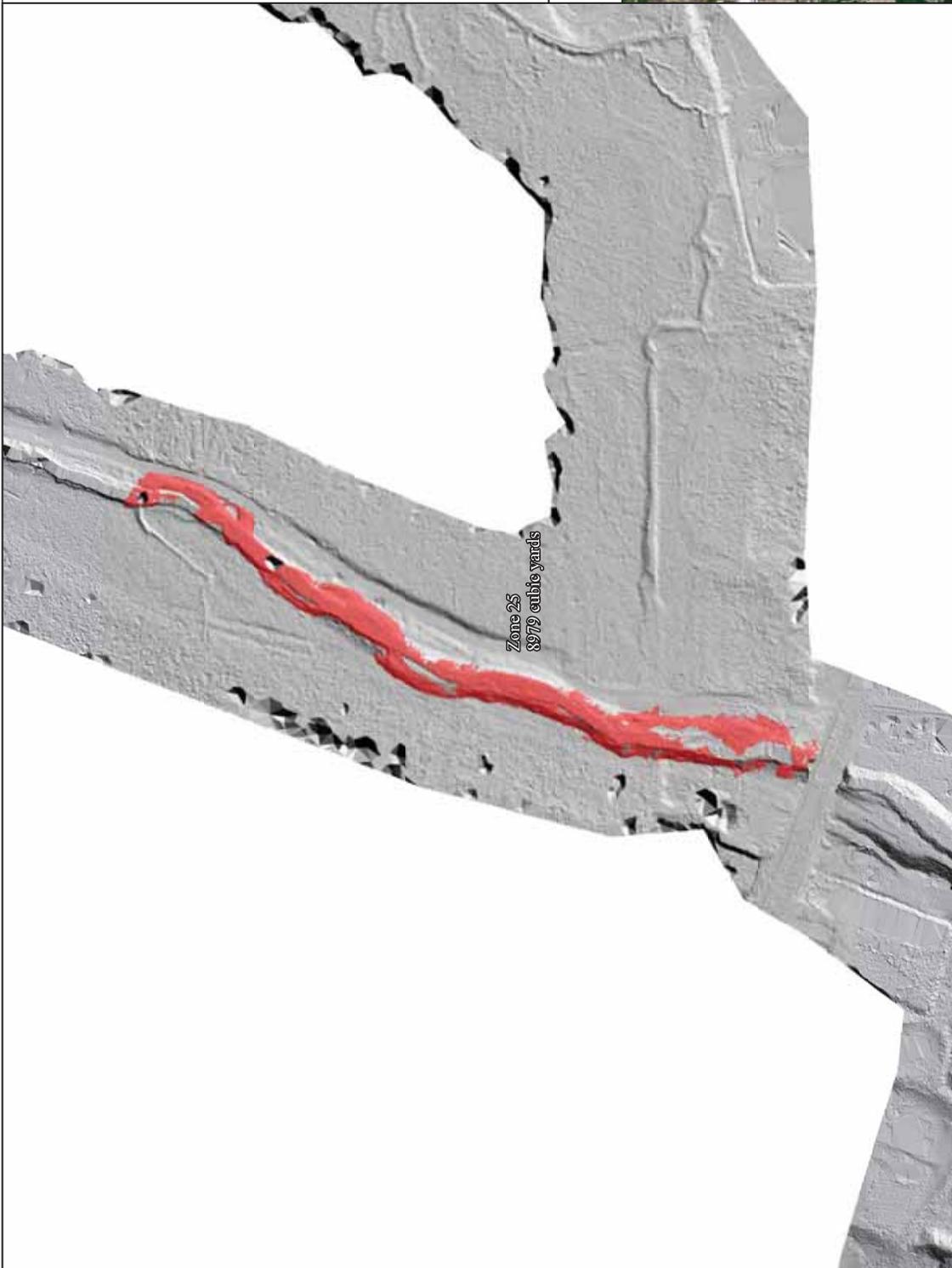
Legend
VOLUME LOSS (CUBIC YARDS)
 5-100
 100-740
 740+

PROJECT ADDRESS:
 MIDDLETON, WI
 PROJECT PLSS:



PROJECT NO.
 WER 126,0015.2
 DATE:
 1/23/2019

SHEET 12 OF 12
 SCALE (1" x 17"): 1 in = 215 feet
 SOURCE DATA: WER, Ayres Associates
 PROJECTION: Lambert Conformal Conic
 COORDINATE SYSTEM: NAD 1983 HARN WISCONS
 Dane County Feet



CREATED BY:
 NHAUS
 MANAGER:
 NHAUS

FIELD DATA COLLECTED BY:
 WER

FIGUREPHOTO DESCRIPTION:
 SEDIMENT LOSS ESTIMATE
 2018 LIDAR DEM

CLIENT/PROJECT:
 CITY OF MIDDLETON

Notes:

Figure 1

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About Cardno

Cardno is an ASX-200 professional infrastructure and environmental services company, with expertise in the development and improvement of physical and social infrastructure for communities around the world. Cardno's team includes leading professionals who plan, design, manage, and deliver sustainable projects and community programs. Cardno is an international company listed on the Australian Securities Exchange [ASX:CDD].

Cardno Zero Harm



At Cardno, our primary concern is to develop and maintain safe and healthy conditions for anyone involved at our project worksites. We require full compliance with our Health and Safety Policy Manual and established work procedures and expect the same protocol from our subcontractors. We are committed to achieving our Zero Harm goal by continually improving our safety systems, education, and vigilance at the workplace and in the field.

Safety is a Cardno core value and through strong leadership and active employee participation, we seek to implement and reinforce these leading actions on every job, every day.